33RD MILLER CONFERENCE

on Radiation Chemistry

5-10 OCTOBER, 2025
DUBROVNIK, CROATIA

PROGRAM AND BOOK OF ABSTRACTS

Edited by:

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Zagreb, September 2025

Miller 2025

33rd Miller Conference on Radiation Chemistry is organized in cooperation with the International Atomic Energy Agency.

IAEA

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The Miller Trust for Radiation Chemistry

The Miller Trust for Radiation Chemistry is an international society registered as a charity in the United Kingdom (registration #802533). It was organized by former colleagues and friends of the late Dr. Nicholas Miller. The objectives of the Trust are the advancement of public education concerning the chemical effects of radiation, particularly through the holding of conferences known as "The Miller Conferences" in the UK and other countries in Europe, in the general subject area of radiation chemistry.

Miller Conferences have been held at two-year intervals since 1959, providing a European equivalent of the past Gordon Research Conferences on Radiation Chemistry, and now the International Conference on Ionizing Processes (ICIP).

All attendees of the most recent Miller Conference are members of the Miller Trust, which is managed by a committee of twelve members elected from the Trust.

List of the Miller Conferences:

1st 1959 - R. Roberts: Portmeirion, Wales
2nd 1961 - F. S. Dainton: Portmeirion, Wales
3rd 1963 - M. Magat: Rocamadour, France
4th 1965 - W. Wild: Portmeirion, Wales
5th 1967 - J. Kroh Kazimierz: Poland
6th 1969 - J. J. Weiss: Portmeirion, Wales
7th 1971 - G. Semerano: Sardinia, Italy
8th 1973 - J. H. Baxendale: Portmeirion, Wales
9th 1975 - T. Gaumann: Biirgenstock, Switzerland
10th 1977 - G. Scholes: Portmeirion, Wales
11th 1979 - N. Th. Rakintzis: Nafplion, Greece
12th 1981 - G. A. Salmon: Windermere, England
13th 1983 - D. Schulte-Frohlinde: Hunfeld, Germany
14th 1985 - A. J. Swallow: Windermere, England
15th 1987 - R. Schiller: Sopron, Hungary
16th 1989 - C. O. Phillips: Windermere, England
17th 1991 - J. Belloni: Giens, France
18th 1993 - P. Wardman: Windermere, England
19th 1995 - Q. G. Mulazzani: Cervia, Italy
20th 1997 - P. O'Neill; A. Johnson: Windermere, England
21st 1999 - J. M. Warman: Doorwerth, The Netherlands
22nd 2001 - N. Green: Windermere, England
23rd 2003 - J. Mayer; J. L. Gebicki: Bialowieza, Poland
24th 2005 - M. Spotheim-Maurizot; C. Houee-Levin: La Londe les Maures, France
25th 2007 - S. M. Pimblott; N. Harridge: Buxton, England
26th 2009 - E. Takacs; L. Wojnarovits: Keszthely, Hungary
27th 2011 - M. Jonsson: Tallberg, Sweden
28th 2013 - I. Zilbermann; S. Goldstein: Dead Sea, Israel
29th 2015 - N. Green: Windermere, England
30th 2017 - C. Dispenza: Castellammare del Golfo, Sicily, Italy
31st 2019 - F. Currell: West Cumbria, England
32nd 2023 - S. Remita; S. Le Caër: Corsica, France (2021 conference postponed due to COVID-19 pandemic
33rd 2025 – T. Jurkin, I. Tartaro Bujak: Dubrovnik, Croatia

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Welcome

Dear participants,

On behalf of the Organizing Committee, it is a great honor to welcome you to the 33rd Miller Conference on Radiation Chemistry, which will take place in Dubrovnik, Croatia, October 5 to 10, 2025.

Since its inception, the Miller Conference has proven to be a leading international forum for the dissemination of cutting-edge research and the exchange of ideas in the field of radiation chemistry. The 33rd edition continues this proud tradition, bringing together 148 participants from 27 countries, including leading scientists, young researchers, and experts from around the world to present their latest findings, discuss new trends, and explore new directions in both the fundamental and applied aspects of radiation chemistry.

Radiation chemistry plays a central role in advancing knowledge and technologies that address some of the most pressing global challenges of our time—from energy and environmental protection to materials science and healthcare. This conference provides an important platform for fostering collaboration and innovation, ensuring that our community continues to deliver solutions to the scientific and societal issues of the future.

The significance of this conference is widely recognized, and this time it has been organized in collaboration with the International Atomic Energy Agency (IAEA), with the support of the IAEA, the International Irradiation Association (iia), and other sponsors. Their support has been particularly important in enabling participation and providing funding opportunities for a greater number of young researchers.

The scientific program of this year's conference will feature a total of 17 invited talks, 7 introductory session talks, 57 oral presentations, and 50 posters, reflecting the diversity and vitality of the research being conducted in our field.

We are particularly pleased to announce that, for the first time in addition to the Miller Conference, a workshop for early career researchers will be organized. This initiative aims to provide a dedicated platform for early career researchers to deepen their expertise, develop professional skills, and engage in constructive dialog with leading experts.

The city of Dubrovnik, renowned for its cultural heritage, historical significance, and inspiring environment, provides an ideal setting for our meeting. We are confident that its unique atmosphere will enrich both the scientific discussions and the personal connections that are at the core of the Miller Conference.

We wish all participants a stimulating and rewarding conference and look forward to the scientific advances and collaborations that will result from our time together in Dubrovnik.

Tanja Jurkin and Ivana Tartaro Bujak,

The Conference Chairs

Full Program

Sunday, October 5th

Workshop for Early Career Investigators

9:00-10:00	**Jay A. LaVerne (US)** Fundamentals of radiation chemistry
10:00-10:30	**Coffee Break**
10:30-11:30	**Mohamad Al-Sheikhly (US)** Ionizing radiation and polymers
12:00-13:00	**Lunch Break**
13:00-14:00	**Radoslaw A. Wach (PL)** Radiation chemistry of polysaccharides
14:00-14:15	**Short Break**
14:15-15:15	**Mehran Mostafavi (FR)** Ionizing radiation and metal, semiconductor and oxide nanoparticles synthesis
15:15-15:45	**Coffee Break**
15:45-16:45	**Matthew Bird (US)** Pulse radiolysis

Registration (17:00 to 19:00)

Opening (19:00-19:15)

Opening speech by the Chairs of the Miller Conference 2025 Tanja Jurkin and Ivana Tartaro Bujak

Welcome speech by the vice mayor of the City of Dubrovnik Mr. Velibor Puzović on behalf of the City

19:15-19:45	**Invited lecture by Taylor J. Woehl (US)** Visualizing and elucidating mechanisms for liquid phase nanomaterial synthesis and self-assembly driven by ultrahigh dose rate electron beams

Welcome Reception Dinner (20:00-…)

Monday, October 6th

Fundamental Processes and Frontiers

Chair: Nicholas Green, Junior Chair: Hanna Hlushko

8:30-8:45	**Introductory lecture by Nicholas Green (UK)**
8:45-9:15	**Invited lecture by Benjamin J. Schwartz (US)** What can quantum simulations tell us about the structure of the hydrated electron?
9:15-9:35	**David Grills (US)** Applying pulse radiolysis to fast proton-coupled electron transfer reactions in acetonitrile
9:35-9:55	**Kristýna Havlinová (CZ)** Determination of radiation chemical yield of hydroxyl radicals for low energy X-rays
9:55-10:15	**Piotr Filipiak (PL)** Exploring hydroxyl radical reactivity in sulfur-containing amino acid models under acidic conditions
10:15-10:35	**Barbora Sedmidubská (FR)** Low-energy electrons-driven processes in the radiosensitization of chemotherapeutic RRx-001: a radiolytic study from picoseconds to products formation
10:35-10:50	**Coffee Break**

Materials and Nanoscale Systems

Chair: Mehran Mostafavi, Junior Chair: Ivan Marić

10:50-11:05	**Introductory Lecture by Mehran Mostafavi (FR)**
11:05-11:35	**Invited lecture by Mingzhang Lin (CN)** Applications of radiation chemistry in nuclear technology
11:35-11:40	**Parallel Session Break**
11:40-12:00	**Jay A. LaVerne (US)** Radiation chemistry of some actinide compounds
12:00-12:20	**Christian Laube (DE)** Electron beam induced modification of nanoparticles
12:20-12:40	**Amel Zorai (FR)** Radiolysis-induced surface functionalization of GaN/InGaN nanowires for photocatalytic hydrogen production

Materials and Nanoscale Systems / Polymers, Parallel Session

Chair: Mark Driscoll

11:40-11:52	**Erwan Martinet-Gerphagnon (FR)** Investigation of l-alpha-alanine radiation chemistry to develop reference dosimetry in innovative radiotherapy methods

11:52-12:04	**Lenka Prouzová Procházková (CZ)** Radiation stability of nanocomposite scintillators
12:04-12:16	**Michael Müller (DE)** Eco-friendly modified fibers from PLA blends via electron-induced reactive melt processing
12:16-12:28	**Aliaksandr Baidak (UK)** Formation of short-chain PFAS in radiolysis of fluoropolymers used in the nuclear industry
12:40-15:35	**Lunch Break + Free Time**
14:00-…	**Miller Trust Committee Meeting** (only for committee members)
	Biological and Biomedical Systems and Applications *Chair: Clelia Dispenza, Junior Chair: Beata Rurarz*
15:35-15:50	**Introductory lecture by Clelia Dispenza (IT)**
15:50-16:20	**Invited lecture by Amitava Adhikary (US)** Radiation chemical mechanisms involved in the FLASH effect of radiation therapy
16:20-16:40	**Tamon Kusumoto (JP)** Changes in yields of radiolytic species in solutions in the presence of GNPs
16:40-17:00	**Emanuela Muscolino (IT)** Radiation-functionalized polyolephinic films for the isolation of rare cells in biological specimens for diagnostic applications
	Poster Session + Aperitif (17:00-19:00)
19:00-20:30	**Dinner**
	Polymers / Biological and Biomedical Systems and Applications *Chair: Wanvimol Pasanphan*
20:30-21:00	**Invited lecture by Piotr Ulanski (PL)** A tribute to prof. Janusz Marian Rosiak (1946 - 2024)
21:00-21:30	**Mohamad Al-Sheikhly (US)** On the mechanisms and kinetic synthesis of poly(vinylpyrrolidone) nanogels by ionizing radiation

Tuesday, October 7th

Polymers

Chair: Xavier Coqueret, Junior Chair: Jordan F. Madrid

8:45-9:00	**Introductory lecture by Xavier Coqueret (FR)**
9:00-9:30	**Invited lecture by Bozena Rokita (PL)** Sonolysis vs. radiolysis of macromolecules in aqueous solution - focusing on crosslinking
9:30-9:50	**Mustapha Kaci (DZ)** Gamma irradiation effect on poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV)/cloisite 30B nanocomposites
9:50-10:10	**Rocco Carcione (IT)** Effects of gamma irradiation on polybutadiene-based materials for solid propulsion applications
10:10-10:40	**Coffee Break**

Fundamental Processes and Frontiers

Chair: Jay A. LaVerne, Junior Chair: Barbora Sedmidubská

10:40-11:10	**Invited lecture by Carine Clavaguera (FR)** Computational modelling the chemical processes in metallic nanoparticles under ionizing radiation
11:10-11:15	**Parallel Session Break**
11:15-11:35	**Vladimir Feldman (RU)** “Top-down” and “bottom-up” processes in solid-state radiation chemistry: the impact of weak interactions
11:35-11:55	**David Bartels (US)** Temperature and pressure dependence of hydrated electron EPR g-factor
11:55-12:15	**Sarra Terfas (FR)** Oxygen and pH dependence on hydrated electron (e^-_{aq}) yield and kinetics: pulsed radiolysis investigation using UHDR alpha and proton beams
12:20-12:40	**Maria Helena Casimiro (IAEA presentation)** From concept to capability: IAEA’s role in radiation technology applications
12:40-13:00	**Martin Comben (iia presentation)** The development, status and future of radiation processing

Fundamental Processes and Frontiers / Biological and Biomedical Systems, Parallel Session

Chair: David Grills

11:15-11:27	**Chaozhong Tian (JP)** Radioprotective mechanisms of positively charged peptides: comprehensive analysis of hydroxyl radical scavenging and chemical repair
11:27-11:39	**Quentin Raffy (FR)** Radiolysis of water and protein biomolecules at high dose rates

11:39-11:51	**Oleg Panfutov (RU)** Ionic intermediates of the radiation-induced transformations of phosphine molecules in cryogenic media: a matrix isolation and computational study
11:51-12:03	**Zhiwen Jiang (CN)** Overlooked activation role of sulfite in accelerating hydrated electron treatment of perfluorosulfonates
12:03-12:15	**Sergey Denisov (FR)** Slow solvation of the solvated electron in LiCl water salt solutions
13:00-15:40	**Lunch Break + Free Time**
15:40-15:50	**Sophie Le Cäer (FR)** Miller Trust lecture

Materials and Nanoscale Systems

Chair: Samy Remita, Junior Chair: Daniel K. Sarfo

15:50-16:20	**Invited lecture by Masanori Koshimizu (JP)** Application of pulse radiolysis to scintillators: observation of excited state dynamics prior to scintillation
16:20-16:25	**Parallel Session Break**
16:25-16:45	**Axel Kahnt (DE)** Mechanistic insights into Fe^{2+} formation in $FeCl_3$/TRITON X-100 systems via pulse radiolysis
16:45-17:05	**Anzhelika Vanina (RU)** Effect of oxide nanoparticles on radical formations under X-ray irradiation of aqueous-organic systems: physical and chemical enhancement

Materials and Nanoscale Systems, Parallel Session

Chair: Sophie Le Cäer

16:25-16:37	**Volkan Yasakci (UK)** Development, isolation, and production of radioisotope-enriched copper nanoparticles
16:37-16:49	**Alžběta Horynová (CZ)** Radiation chemistry of lead iodide at high dose rates
16:49-17:01	**Hanna Hlushko (US)** The impacts of metal oxide surfaces on the chemistry of water radiolysis
17:05-17:30	**Coffee Break**

Biological and Biomedical / Materials / Polymers

Chair: Mustapha Kaci, Junior Chair: Rocco Carcione

17:30-17:50	**Monique Lacroix (CA)** In situ synthesis of silver nanoparticles in pectin matrix using gamma irradiation for the preparation of antibacterial pectin/silver nanoparticles composite films
17:50-18:10	**Julian Murphy (UK)** Assessment of performance through life for new polymer technologies in high radiation environments

18:10-18:30	**Xavier Deschanels (FR)** Compaction of mesoporous silicas by radiation effects
19:00-20:30	**Dinner**

Biological and Biomedical Systems and Applications / Cultural Heritage

Chair: Radoslaw Wach

20:30-21:00	**Invited lecture by Murat Barsbay (TR)** Radiation-induced synthesis as a powerful tool for engineering stable nanogel vectors for RNA delivery: from synthetic control to biological function (Online)
21:00-21:20	**Alexandre Gaspar (FR)** Effect of the lanthanide on the radiolytic stability of Ln-DOTA complexes
21:20-21:40	**Tomasz Pędziński (PL)** How the structure of model disulfides affects reactivity with singlet oxygen
21:40-22:00	**Beatrice D'Orsi (IT)** Ionizing radiation for cultural heritage preservation: material characterization and biocidal efficacy

Wednesday, October 8th

Environmental Applications / Cultural Heritage

Chair: Suresh Pillai, Junior Chair: Joana Madureira

8:30-8:45	**Introductory lecture by Suresh Pillai**
8:45-9:15	**Invited lecture by Shizong Wang (CN)** Enhanced removal of perfluorohexane sulfonate (PFHxS) from water via synergistic electron beam irradiation (EBI)-Induced reactive species
9:15-9:45	**Invited lecture by Krisztina Kovács (HU)** Effect of pH and matrix on the degradation of various pharmaceuticals by high-energy ionizing radiation
9:45-9:57	**Joana Madureira (PT)** Valorization of agri-food wastes using ionizing radiation: the role of extraction conditions on different matrices
9:57-10:09	**Yongxia Sun (PL)** Radiolytic degradation of sulfamethoxazole (SMX) in aqueous solution under electron beam irradiation with H_2O_2 addition
10:09-10:21	**Jordan F. Madrid (PH)** Radiation-induced graft polymerization: tuning macromolecular structure and properties for environmental and other applications
10:25-10:45	**Coffee Break**

Energy Applications

Chair: Mats Jonsson, Junior Chair: Jacy K. Conrad

10:45-11:00	**Introductory lecture by Mats Jonsson**
11:00-11:30	**Invited lecture by James Wishart (US)** Radiation-driven chemistry in molten salts
11:30-11:50	**Suresh Pillai (US)** High energy eBeam technology for the destruction of PFAS in solid matrices
12:00-13:30	**Lunch Break**

Conference Tour (departure at 14:00)

Thursday, October 9th

Environmental and Energy Applications

Chair: Yuta Kumagai, Junior Chair: Renáta Homlok

8:30-9:00	**Invited lecture by Jun Ma (CN)** Advances in radiation catalytic chemistry
9:00-9:20	**Liran Hu (FR)** Radiolytically synthesized 3D graphene-based hydrogels for symmetrical supercapacitor applications
9:20-9:40	**Jacy Conrad (US)** The fundamentals of n-dodecane radiolysis by time-resolved and steady-state methods
9:40-10:00	**Matthew J. Bird (US)** The use of pulse radiolysis in the bio-inspired light-escalated chemistry (BioLEC) Energy Frontiers Research Center
10:00-10:20	**Christophe Jegou (FR)** The contribution of isotopic labeling to better understand the UO_2 oxidative dissolution mechanisms under water radiolysis
10:20-10:50	**Coffee Break**

New Experimental and Computational Tools and Techniques

Chair: Carolyn I. Pearce, Junior Chair: Patricia Huestis

10:50-11:05	**Introductory lecture by Carolyn I. Pearce**
11:05-11:35	**Invited lecture by Marc Simon (FR)** Radiation chemistry with X-ray free electron lasers (XFEL)
11:35-11:55	**Sarina Chand (GB)** Further insights into the discolouration of TATB under ionising radiation

Energy Applications / Environmental / Other

Chair: Carolyn I. Pearce, Junior Chair: Patricia Huestis

11:55-12:15	**Sophie Le Caer (FR)** Radiation-induced insights into vinylene carbonate reduction mechanisms in Li-ion battery solid electrolyte interphase
12:15-12:35	**Kazuhiro Iwamatsu (US)** Effect of radiation and temperature on rhenium ion added molten LiCl-KCl eutectic
12:35-12:55	**Stephanie Castro Baldivieso (US)** Influence of rare earth cations on the chemical behavior of radiolytic transients in molten LiCl-KCl eutectic
13:00-15:50	**Lunch Break + Free Time**

Biological and Biomedical Systems and Applications *Chair: Amitava Adhikary, Junior Chair: Daniel Adjei*	
15:50-16:20	**Invited lecture by Sylwia Ptasinska (US)** Radiation-induced DNA damage as an approach to probing low-temperature plasma chemistry
16:20-16:25	**Parallel Session Break**
16:25-16:45	**Foutina Feghali (FR)** Nanoparticles combined with particle therapy for the treatment of tumors
16:45-17:05	**Bing Xu (NL)** Mechanistic insights into photosensitizer activation by ionizing radiation for enhanced radiotherapy
Biological and Biomedical Systems and Applications, Parallel Session *Chair: Tamon Kusumoto*	
16:25-16:37	**Daniel Adjei (FR)** Dissociative electron attachment mediated nitrogen-centered radical formation
16:37-16:49	**Philip Marinov (BG)** Impact of different doses of ionising radiation on the optical and morphological properties of gold nanoparticles
16:49-17:01	**Severine Chefson (FR)** Radiolytic yields of main water radiolysis products along ion tracks: Experiments and simulations
17:00-17:20	**Coffee Break**
Polymers / Cultural Heritage *Chair: Mohamad Al-Sheikhly, Junior Chair: Jelena Spasojević*	
17:20-17:50	**Invited lecture by Wanvimol Pasanphan (TH)** Electron beam processing of poly(L-lactic acid): Roles of functional multi-branched poly(L-lactide) in associating free radical reaction and bioplastic performance
17:50-18:10	**Luis M. Ferreira (PT)** Improving the long-term structural stability and porosity of PHB biopolymers through radiation processing
18:10-18:30	**Pablo Vasquez (BR)** Development of reversible radio-curable resins for consolidation and restoration of cultural heritage degraded objects
Conference Dinner (20:30) *Including Awards and the Closing Ceremony*	

Friday, October 10th

Next Miller Conference Announcement (9:30-10:00)
Departure

Monday, October 6th

Poster Session

P1	**David Bartels** (US), Laboni Das, Stephen Guerin, Ian Carmichael Unexpected radiation chemistry of borate buffers
P2	**Dalia Gitin** (IL), Tomer Zidki, Stanisław Wacławek, Dan Meyerstein The reaction of $CO_3^{\cdot-}$ radicals with $Co^{II}(HCO_3)_n^{2-n}$
P3	**Jing Peng** (CN), Zhiwen Jiang, Chengli Pan, Jun Ma, Zhirong Liu, Mehran Mostafavi Study on the transient species of N,N,N',N'-tetraoctyldiglycolamide (TODGA) via picosecond pulse radiolysis and DFT calculations
P4	**Karolina Radomska** (PL), Marian Wolszczak Pulse radiolysis studies of water-ethanolic solutions of albumins
P5	**Amel Zorai** (FR), Sergey Denisov, Philippe Moisy, Mireille Benoit, Jacqueline Belloni, Mehran Mostafavi Picosecond time-resolved investigation of nitrate radical NO_3 in tributyl phosphate and water mixtures
P6	Brice Lathuilière, **Nicolas Bérerd** (FR), Julien L. Colaux, Paul-Louis Debarsy, Rachel Gouttebaron, Nathalie Moncoffre Radiolysis at interfaces: characterization by XPS and IBA of the passive film on 316L stainless steel in contact with radiolysis products
P7	Alessia Cemmi, **Rocco Carcione** (IT), **Beatrice D'Orsi** (IT), Ilaria Di Sarcina, Jessica Scifo, Claudia Paoletti, Noemi Fiaschini, Patrizia Nadia Hanieh, Valentina Pinto Gamma irradiation as a tool for tailoring the morphological, structural, and functional properties of nano- and microstructured materials for energy and biomedical applications
P8	**Patricia Huestis** (US) Understanding the radiolysis of pentaerythritol tetranitrate
P9	**Anna Jaros** (PL), Marian Wolszczak Nickel (II) oxide formation and optimization using ionizing radiation
P10	**Maksim Kolesnikov** (IL), Amir Mizrahi, Dan Meyerstein, Tomer Zidki On the reactions of $OH^{\cdot}$, $CO_3^{\cdot-}$ and $CH_2CO_2^{\cdot-}$ radicals with Pt^0-NPs
P11	**Masanori Koshimizu** (JP), Ritsuha Tanaka, Yutaka Fujimoto, Keisuke Asai Development of organic radiophotoluminescence materials for radiation dosimetry
P12	Ivan Marić, Lara Mikac, Goran Dražić, Anđela Pustak, **Ivana Landripet** (HR), Marijan Gotić, Tanja Jurkin Microstructural characterization and potential environmental protection applications of composite iron oxide/Ag nanoparticles

P13	**Edgar Mendes** (PT), Pietro Aprà, Ana Belchior, Federico Picollo, Marta Alves, Rodica Dinica, Maria João Moura, Sofia Sturari, Teresa Pinheiro, Paula Campello Synthesis of gold-coated nanodiamonds via green chemistry and their physicochemical characterization as potential radiosensitizers for proton therapy
P14	**Daniel K. Sarfo** (GH), Juliet Attah, Dennis Kpakpo Adotey, Daniel Adjei, Mehran Mostafavi Gamma radiolysis of DNA bases in the presence and absence of gold nanoparticles
P15	**Amar Boukerrou** (DZ), Noura Hamour Study of the effect of gamma irradiation of alpha fiber reinforced polypropylene composites on mechanical and thermal properties
P16	**Renáta Homlok** (HU), Szabolcs Krizsma, Tamás Igricz, Katalin Bocz, Anna Tegze, Erzsébet Takács, Krisztina Kovács, László Mészáros Ionizing radiation-induced morphological changes in polylactic acid: the role of crystallinity
P17	**Chen Jiafu** (CN), Zhu Chunhua Gamma radiation induced rapid heat and light responsive shape memory polymer with high strain as remote light-controlled actuators
P18	**Ivan Marić** (HR), Anđela Pustak, Iva Džeba, Tanja Jurkin, Miroslav Šimun Irradiation modification of face masks for use in asphalt mixtures
P19	**Michael Müller** (DE), Carsten Zschech, Mathias Pech, Ying Huang, Sven Wießner, Udo Wagenknecht Sustainable electron-induced PLA structure formation in dynamic melts
P20	**Malwina Olejniczak** (PL), Bożena Rokita, Alicja K. Olejnik, Piotr Ulański Comparison of the use of electron beam irradiation and sonochemistry in synthesis of PEGDA hydrogels with bioactive substance for biomedical applications
P21	**Karolina Pietrucha** (PL), Beata Rurarz, Sławomir Kadłubowski, Tatiana Balogh, Radosław Wach, Piotr Ulański, Ademar Lugao Radiation-induced synthesis of carboxymethylcellulose nanogels: synthesis, characterisation and applications
P22	Yaru Zhang, Yishao Li, **Mozhen Wang** (CN), Xuewu Ge Preparation and properties of structural self-regulation crosslinked silicone with excellent radiation resistance
P23	Jie Cen, **Guoying Zhang** (CN), Shiyong Liu Single-component, photoacid-free and high-resolution dual-tone EUV photoresists based on precision self-immolative polycarbamates

P24 **Andreea Simona Baltac** (RO), Raul Augustin Mitran, Daniela Culita, Irina Atkinson, Simona Ionita, Florin Albota, Andreea Serban, Paul Mereuta, Florina Zorila, Daniel Negut, Mioara Alexandru
Radiation-induced synthesis of silver-loaded silica drug delivery systems with antimicrobial properties

P25 **Nelida L Del Mastro** (BR)
Steviol glycosides and their interaction with ionizing radiation

P26 **Marc Benjamin Hahn** (DE), Dorothea C. Hallier, Jyotisha Mishra, Matthias Gross, Elif Tarakci, Iryna Engelmann, Axel Kahnt, Harald Seitz
Radiation damage to DNA and DNA-binding-proteins exposed to various particle sources, dose-rates and oxygen levels

P27 **Ivan Ilakovac** (HR), Ivana Landripet, Ivan Marić, Anđela Pustak, Tanja Jurkin
Enhancing magnetic hyperthermia via phase and morphological control of radiolytically synthesized iron oxide nanoparticles

P28 **Toshitaka Oka** (JP), Hiroko Ishiniwa, Masatoshi Suzuki, Atsushi Takahashi, Taku Sato, Yusuke Mitsuyasu, Yasushi Kino, Kenichi Okutsu, Tsutomu Sekine, Takuma Yamashita, Yoshinaka Shimizu, Mirei Chiba, Toshihiko Suzuki, Ken Osaka, Keiichi Sasaki, Manabu Fukumoto, Hisashi Shinoda
Dose estimation of wild animals captured in the contaminated area of Fukushima Prefectur

P29 **Paula Pryba** (PL), Lidia Chomicz-Mańka
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P30 **Beata Rurarz** (PL), Karolina Pietrucha, Michal Maurin, Urszula Karczmarczyk, Slawomir Kadlubowski, Piotr Ulanski
Nanosolutions to macroproblems - platform for targeted delivery of radioisotopes based on radiation-derived nanocarriers

P31 **Vojtěch Scheinpflug** (CZ), Tomáš Burian, Luděk Vyšín, Jorge J. Rocca, Carmen S. Menoni, Libor Juha
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P32 **Cécile Sicard-Roselli** (FR), Isabelle Billault, Anouchka Gatin
Advanced methodology combining UPLC-MS, isotopic labelling and H/D exchanges reveals new tyrosine-tyrosine cross-links induced by oxidative radicals

P33 **Milica Carević** (RS), Jelena Spasojević, Nadica Abazović, Aleksandra Radosavljević, Vesna Panić, Mirjana Čomor
Modifying g-C_3N_4 with gamma irradiation: toward improved photocatalytic water treatment

P34 **Sofia Fares** (DZ), Mustapha Kaci, Nadjet Dehouche, Amira Zaouak
E-beam irradiation as a sustainable solution for improving the properties of recycled acrylonitrile-butadiene-styrene (ABS) derived from electronic waste

P35	**Elizabeth (Liz) McDaniel** (US), Mark Driscoll, Ileana Pazos, Joey Robertson Molecular weight determination of gamma-irradiated cellulose for solubility in sodium hydroxide
P36	**Anđela Pustak** (HR), Nikolina Juričan, Aleksandra Maršavelski Effect of gamma radiation on thermal and structural properties of polylactid acid – can irradiation assist controlled enzymatic polymer degradation?
P37	**Jelena Spasojević** (RS), Milica Carević, Nadica Abazović, Mirjana Čomor, Vesna Panić, Nikolina Radojković, Aleksandra Radosavljević Cellulose/g-C_3N_4 eco-friendly hydrogel nanocomposites for waste water treatment obtained by gamma irradiation
P38	**Ivana Tartaro Bujak** (HR), Maro Bujak, Anđela Pustak, Ivan Marić, Mirjam Leskovšek, Urška Vrabič Brodnjak Tailoring the structural and mechanical characteristics of bacterial nanocellulose via gamma irradiation and biowaste media
P39	**Dilara Turkel Agacik** (US), Fred B. Bateman, Alexander B. Artyukhin, Mark Driscoll Efficiency of removing emerging contaminants from wastewater using electron beam
P40	Xiang Li, **Shinichi Yamashita** (JP), Atsushi Kimura, Mitsumasa Taguchi Ammonia synthesis utilizing ionizing radiations: Stable product quantification and transient intermediate observation.
P41	**Yuta Kumagai (JP)** Oxalic acid formation by radiation-induced reactions in water under a simple model condition of geological disposal of radioactive wastes
P42	**Mathilde Linger** (FR), Thibault Charpentier, Stéphane Poyet, Sophie Le Caër Radiation-induced degradation of cement hydrates and implications for molecular hydrogen production: Focus on ettringite
P43	Chenxuan Zheng, **Huarong Liu** (CN) Synthesis of functionalized porous resorcinol-formaldehyde resin via high internal phase emulsion for photocatalytic production of hydrogen peroxide
P44	**Laurent Venault** (FR), Jackie Vermeulen, Fanny Moliere, Lilian Berlu, Lionel Jolly, Morgane Michel Alpha-radiolysis of carbon monoxide on plutonium dioxide surface
P45	**Tamon Kusumoto** (JP), Shogo Okada, Koichi Murakami, Takashi Sasaki Underlying mechanisms of sparing effects by ultra-high dose rate irradiation
P46	**Mel O'Leary** (UK), Kay Dewhurst, Jordan Elliot, Aidan Milston, Andy Smith, Fred Currell Spinning wineglass: a novel apparatus for radiation chemistry for ion beam irradiations
P47	**Vincent Fiegel** (FR), Stéphanie Saintignon, Cyrille Le Pennec, Thomas Dalger, Sébastien Faure, Gilles Bourgès Modelling the gas generation of actinide bearing materials in storage containers

P48	**Slobodan Mašić** (RS), Mina Medić Conservation of leather cultural heritage objects by gamma irradiation
P49	**Silvana Vasilca** (RO), Daniel Negut, Irina Petroviciu, Valentin Moise Preserving colour: assessing the impact of gamma irradiation on early synthetic dyes in historical textiles
P50	**Jean-Philippe Larbre** (FR) Picosecond radiolysis facility using electron pump-probe spectroscopy

Invited Lectures

Visualizing and Elucidating Mechanisms for Liquid Phase Nanomaterial Synthesis and Self-Assembly Driven by Ultrahigh Dose Rate Electron Beams

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Liquid phase transmission electron microscopy (LPTEM) enables visualizing nanoscale reactions and materials in the liquid phase with nearly atomic scale spatial resolution. The high energy (100 - 300 keV) imaging electron beam represents a convenient reaction stimulus to stimulate nanoparticle formation, self-assembly, and polymerization reactions. Digital control of the electron beam current, image magnification, and electron beam profile (rastered beam vs. broad beam) enables precise control over the electron dose rate and thus the radiation chemistry. However, the ultrahigh dose rate (MGy/s), continuous irradiation, and sub-micron electron beam size create a distinctly different chemical environment compared to conventional pulsed radiolysis experiments, making modeling radiolysis processes during LPTEM challenging. This talk will describe our group's recent work utilizing LPTEM and radiation chemistry to visualize, quantify, and mechanistically describe the formation mechanisms of aqueous metal nanoparticles. LPTEM is used in conjunction with atomic resolution TEM imaging, mass spectrometry, and radiolysis simulations to elucidate chemical processes during the formation of monometallic, bimetallic, and high entropy alloy nanoparticles. Taken together, this approach allows us to establish molecular scale understanding of the kinetic pathways for nanoparticle formation. The second part of the talk will describe recent efforts to improve our understanding of ultrahigh dose rate radiation chemistry during LPTEM experiments. Experimental observations of electron beam induced polymerization and chain scission of polymers have demonstrated the complex radiolysis environment present during LPTEM experiments using ultrahigh dose rates. Recently developed numerical simulations including the effects of electron beam charging, electromigration, and diffusion on radical concentrations will be presented.

What Can Quantum Simulations Tell Us About the Structure of the Hydrated Electron?

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In addition to its central importance in radiation chemistry, the hydrated electron is of interest to both theorists and experimentalists as a paradigm solution-phase quantum system. Despite all this interest, however, there is still controversy over the molecular structure of the hydrated electron. The general consensus is that the electron occupies a cavity in liquid water, but the arrangement of the water around the cavity and the nature of the fluctuations are still the subject of debate. The question of the local structure is not simply academic: the local structure and motions determine all of the electron's properties, including its chemical reactivity. The fact that the rates of reactions involving hydrated electrons do not follow the Marcus theory of electron transfer [1] indicates that there is something special about the organization of water molecules around the electron that is different from other solutes. In this talk, we examine different simulation models of the hydrated electron, ranging from mixed quantum/classical (MQC) models where the water is treated classically and the electron's behavior is defined by a pseudopotential, and fully quantum mechanical models based on density functional theory (DFT) [2]. We explore the structure and dynamics of these different models, including making direct ties to the following experiments: 1) We predict the results of 2-D electronic spectroscopy experiments on the hydrated electron, and show that different simulation models made starkly different predictions that should be easily distinguished by experiment; 2) We examine the solvation entropy of different models of the hydrated electron, comparing directly to thermodynamic measurements [3]. 3) We examine the spectral shifts induced by ion-pairing of hydrated electrons with different salts, again making ties with recent experiments.[4]. 4) We examine the mechanism of the reaction of two hydrated electrons with water, $e^- + e^- + 2H_2O \rightarrow H_2 + 2OH^-$, showing that the intermediate involves H^- and solvated dielectrons, with predictions for how to observe dielectrons spectroscopically.[5] We find that hydrated electron simulation models with highly structured local environments, such as those produced by DFT, provide generally poor agreement with experiment, while 'softer cavity' MQC models do a better job of reproducing experiment.

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Applications of Radiation Chemistry in Nuclear Technology

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Nuclear technology is always accompanied by ionizing radiation and radioactive materials. The radiation-induced decomposition or damage, resulted from the interaction between ionizing radiation and materials, exist in nuclear reactors, spent fuel reprocessing, and other nuclear facilities. These usually unfavorable radiation effects may be harmful to the safe operation of nuclear energy systems, structural integrity, lifetime management, efficiency and safety of nuclide separation, and radioactive waste management. A careful investigation on the radiation effects and their mechanisms, especially on the countermeasures to reduce those negative effects, is imperative for the improvement in nuclear energy safety and stable operation of nuclear systems. Thus, my presentation will be focused on some of our research practices in recent years related to 1) experimental and modelling studies on the radiolysis of new type of reactor coolants, especially those containing ammonia or hydrazine[1]; 2) investigation of the radiation stability of some new extractants such as phenanthroline diamide and its derivatives[2]; 3) studies on the radiation stability of various polymer nanocomposites doped with boron nitride powders or nanosheets[3, 4].

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Radiation Chemical Mechanisms Involved in the FLASH Effect of Radiation Therapy

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The most important cause of radiation-induced cell death, mutation and transformations is damage to nuclear DNA. The type of DNA-aberration (simple, e.g., base damage or single strand break, versus complex, e.g., clustered lesionstandem lesions including crosslinks) and its extent, active repair pathways, and type of cell death (apoptotic versus necrotic, etc.) are affected by dose-rate. Recent ultrahigh dose-rate preclinical radiation (UHDR, ≥ 40 Gy/s) caused significantly reduced normal tissue damage compared to that following a conventional treatment (<<1 Gy/min to 10 Gy/min), termed the "FLASH effect". For the same overall dose (UHDR vs. conventional), the number of ionizations were the same; however, UHDR generated a higher concentration of free radicals within a short time interval compared to conventional because of the altered rate of ionizations. Time-resolved studies have established that both irradiated normal cells, and hypoxic cells involve fast free radical reactions as the key component, and the concentration of oxygen in cells at the instant of irradiation matters. The microenvironment (concentration of macromolecules including cellular redox status, pH, metabolic status, nature of the membrane, reactive oxygen species nature and concentrations, cell-to-cell contact, etc.) of the tissues with normal vs. hypoxic tumor cells influence these processes. Thus, we have undertaken an international collaboration to elucidate how these initial events may ultimately lead to a differential radiosensitivity between normal vs. hypoxic cells and hence illuminate the FLASH effect. We will investigate the differential radiosensitivity using assays based on biological responses of radiation damage with the goal of identifying the optimal parameters for the clinical translation of the FLASH effect. Our *in vitro* modeling experiments using aqueous solutions of plasmid pUC19 DNA under UHDR vs. conventional dose rates showed that the strand break and clustered damage including densely accumulated lesions yields decreased by factors of 1.3-3.5 after UHDR. Moreover, our experimental results showed that the inter-track reactions did not contribute to the observed dose-rate effects on DNA damage agreeing with predictions based on Monte-Carlo calculations. We plan to employ yeast spores to closely mimic the tissues. The current and planned Monte-Carlo and experimental studies will be summarized.

A Tribute to Professor Janusz Marian Rosiak (1946 - 2024)

Piotr Ulański[1], Renata Czechowska-Biskup[1], Sławomir Kadłubowski[1], Alicja K. Olejnik[1], Bożena Rokita[1], Beata Rurarz[1], Tomasz Szreder[1], Radosław A. Wach[1]

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In May 2024, Professor Janusz Marian Rosiak, an outstanding scientist, well known to our community, passed away. He worked continuously at the Faculty of Chemistry of the Lodz University of Technology for 45 years, heading a research team at the Institute of Applied Radiation Chemistry.

His scientific interests focused on radiation chemistry of polymers, and especially the use of radiation for the synthesis and modification of biomaterials. He published over 150 papers, many chapters in monographs and over 30 patents. His publications have been cited over 5500 times. In 2020, he was included in the "World's Top 2% Scientists" database.

Professor Rosiak has made major developments in the theory of radiation cross-linking of polymers. His experimental work greatly contributed to the understanding of radiation-initiated reactions in synthetic and natural polymers. These works are among the foundations of the current radiation chemistry of polymers.

He gained worldwide recognition for his work on polymeric biomaterials. The innovative technology he developed for the production of hydrogel dressings was patented and implemented for production in many countries. He is also one of the pioneers of nanotechnology, including research on radiation synthesis of nanogels.

Since 1991, as an IAEA expert, he has completed over 30 technical missions in many countries around the world. He led the implementation of many projects of EU, IAEA, and NATO. He has been a scientific consultant to numerous companies and institutions.

He was frequently invited to deliver lectures at the most important conferences in the field of radiation chemistry and technology. For his achievements, Professor Rosiak received many awards. On the occasion of his retirement in 2016, he was honored with a special session at the Ionizing Radiation and Polymers conference.

Professor Rosiak made a lasting and important contribution to science, developed inventions that save health and life. He earned the gratitude and memory of many people in Poland and abroad. As members of the Team he created, we strive to continue his work, remembering him as our master and friend. His memory will always accompany us in our actions as a model to follow and a source of inspiration.

Figure 1. A photograph of Professor Janusz Marian Rosiak

Single-Molecule Biodosimetry with DNA for Precision Radiotherapy

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Radiotherapy operates with many modalities, sources, dose rates, etc., that initiate cascading chemical reactions and lead to complex biological effects, ultimately culminating in cell death. Despite clinical success, a critical component remains missing from the precision medicine toolkit: accurate and actionable biological dosimetry. Direct measurement and modeling of the fast chemical reactions and downstream cellular effects are prohibitively difficult. However, these processes are connected through DNA damage. We are developing methods via nanopore sensing to rapidly and quantitatively measure DNA lesions. In this talk, I will present a proposal to use such measurement of DNA lesions to reimagine how we quantify radiation dosimetry. Such efforts will support the development of a mechanistic framework to characterize otherwise stochastic biological outcomes, like cell death and cancer risk. This approach will enhance our understanding of radiation-induced DNA damage and has applications in emergency response, medical radiology, radiation protection, space research, and radiation processing.

Sonolysis vs. Radiolysis of Macromolecules in Aqueous Solution - Focusing on Crosslinking

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Crosslinking of macromolecules in aqueous solutions can be effectively achieved using sonochemical and radiation-based methods, both of which enable the formation of stable polymer networks without the need for chemical initiators - often toxic and difficult to remove from the system.

High-frequency ultrasound induces acoustic cavitation, where the implosion of cavitation bubbles generates extreme local conditions (temperatures of several thousand K, pressures up to hundreds of atm.). These lead to the formation of free radicals (e.g., OH and H in water), as well as pyrolysis and mechanochemical effects that can break or initiate formation of covalent bonds. Although ultrasound was historically associated mainly with polymer degradation, our studies shown that it can also induce effective crosslinking and hydrogel formation in optimized conditions. The dominant mechanism - degradation vs. crosslinking - depends strongly on ultrasound frequency and intensity, and on the other system parameters.

Radiation-induced crosslinking of polymers (e.g., with gamma rays or EB) in aqueous solution involves typically hydrogen abstraction from C atoms, thus formation of macroradicals, which recombine to form a crosslinked network. This method enables precise control of the crosslinking degree and mechanical properties and has been widely applied in biomedicine - notably in hydrogel dressings, drug delivery systems, and smart materials responsive to pH, temperature or enzymes.

A comparative study of sonochemical vs. radiation crosslinking was conducted using polyethylene glycol diacrylate, poly(ethylene glycol), Pluronic F-127 and albumin. Evaluated parameters included gelation dose, gel fraction, swelling degree, mechanical properties, and molecular weights via static light scattering or particle sizes via dynamic light scattering. Selected systems were also tested for cytotoxicity using endothelial cells to assess their potential for biomedical applications.

The use of well-characterized mechanisms of radiation-induced processes provides a valuable reference for analyzing the more complex and less predictable sonochemical processing. Comparing both techniques may allow for a comprehensive evaluation of their efficiency, selectivity, operational conditions, as well as the identification of technological limitations and application potential, particularly in biomedical contexts. Such analysis may be valuable in selection of appropriate processing method with respect to the polymer type, the desired structure and function of the resulting material.

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Computational Modeling of Chemical Processes in Metallic Nanoparticles under Ionizing Radiation

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Metallic nanoparticles have been demonstrated to be highly promising nanomaterials due to their tunable chemical, physical, and optical properties. However, a comprehensive understanding of their properties remains challenging, partly due to the dynamic interactions that are present at the interface with the surface ligands and the surrounding solvent. In addition to experimental approaches, computational modeling has been proved to be a powerful method for providing essential atomistic insights. Over the last few years, we have developed a multi-scale simulation strategy with the aim of deepening the understanding of the nanoparticle properties in diverse chemical environments. The presentation will outline the various levels of computational modeling that are employed in the study of gold and silver nanoparticles, as well as Bi-Pt bimetallic systems, all of which are closely related to radiolysis experiments performed in ICP at Paris-Saclay University.

First, the adsorption of various organic molecules, including several aromatic compounds and radical species, on gold nanoparticles was investigated at the density functional theory level. Topological analyses were conducted to identify the formation of several non-covalent interactions. Energy decomposition analyses revealed that electrostatic and dispersion interactions were the main contributors to these interactions [1]. Vibrational and electronic spectra were calculated to understand how adsorption on the nanoparticle affects the spectroscopy signatures of the organic compounds.

Recently, real-time electron dynamics approaches have been implemented to calculate the electronic stopping power of water molecules irradiated with fast ions, a first step toward modeling the complex interface between water and metallic nanoparticles [2].

Finally, we will present recent work on the structural characterization of Bi-Pt nanoparticles using machine learned interatomic potentials that are trained on quantum chemistry data to maintain accuracy, while significantly reducing computational costs. The model has been paired with a global optimization algorithm for an efficient simulation of the system's structural space [3].

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Application of Pulse Radiolysis to Scintillators: Observation of Excited State Dynamics Prior to Scintillation

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Scintillators are phosphor materials based on inorganic, organic, and organic-inorganic hybrid materials. They are key materials in radiation detection, and many researchers are developing novel materials. Ionizations and electronic excitations by ionizing radiations in scintillators undergo complex dynamics including recombination, charge transfer, excitation energy transfer, quenching, and radiative transition. To obtain high scintillation light yield, suppression of quenching and promotion of excitation energy transfer and radiative transition are necessary. However, factors influencing the quenching and energy transfer are unclear: hence, the design principle of scintillators is not established.

Under the circumstance, we aim to elucidate the dynamics of ionizations and excitations in scintillators using pulse radiolysis. Up to now, we have analyzed the dynamics of excited states in various inorganic scintillators based on oxides, fluorides, and iodides. In some scintillators based on inorganic compounds, fast decay of transient absorption within several ns was observed and attributed to fast quenching of excited states. Also, decay component of transient absorption signal significantly longer than the scintillation decay was observed in some compounds, and it was attributed to the trapped electrons and holes at different sites. In organic scintillators, transient absorption of triplet excited states was observed over long time. Also, upon addition of triethylamine, cation radicals of organic molecules are observed in liquid scintillators. As a conclusion, we have observed the dynamics of excited states in various kinds of scintillators and found some novel phenomena in the scintillation process.

Radiation-Induced Synthesis as a Powerful Tool for Engineering Stable Nanogel Vectors for RNA Delivery: From Synthetic Control to Biological Function

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The development of safe, efficient, and structurally versatile delivery systems remains a critical challenge in advancing nucleic acid therapeutics. While viral vectors offer high transfection efficiency, their clinical application is hindered by immunogenicity and production-related challenges, underscoring the need for robust non-viral alternatives [1,2]. Lipid nanoparticles, currently the most widely used non-viral carriers, are valued for their high transfection efficiency and clinically validated performance, particularly in mRNA delivery. However, they still face significant challenges including limited structural stability, narrow cargo compatibility, and sensitivity to formulation conditions, highlighting the need for more tunable and robust polymeric alternatives. In this context, radiation-induced nanostructuring offers a clean, scalable, and crosslinker-free route to synthesize three-dimensional polymeric nanogels with high stability and functional flexibility [3-5]. Recent studies have shown that nanogels synthesized via gamma irradiation from partially hydrolyzed poly(N-vinylformamide) (PNVF) precursors can yield polyvinylamine (PVAm)-based networks with adjustable amine content and enhanced colloidal behavior. These nanogels demonstrated superior dispersion stability, narrower size distributions, and improved nucleic acid binding and transfection efficiency compared to their homopolymer counterparts. While PVAm homopolymers are inherently flexible and modifiable, their nanogel derivatives displayed better performance in transfection settings due to the added benefits of network crosslinking, colloidal integrity, and enhanced surface characteristics. Compared to polyethylenimine (PEI), the current polymeric gold standard, PVAm-based nanogels offered improved RNA complexation and comparable cytoplasmic delivery, with reduced cytotoxicity and greater structural adaptability.

While DNA transfection was limited, likely due to restricted nuclear entry, RNA delivery to the cytoplasm was comparable in efficiency to that of other polymer-based carriers. In a disease-relevant application, these nanogels were tested in the treatment of myotonic dystrophy type 1 (DM1). Although not yet matching the performance of commercial reagents, the nanogels showed encouraging potential as low-toxicity, customizable carriers with long-term stability.

These findings underscore the broader utility of nanogel platforms formed via radiation-induced crosslinking in non-viral nucleic acid delivery and highlight the untapped potential of irradiation-based fabrication strategies in the design of next-generation transfection agents.

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Enhanced Removal of Perfluorohexane Sulfonate (PFHxS) from Water via Synergistic Electron Beam Irradiation (EBI)-Induced Reactive Species

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The removal of perfluoroalkyl sulfonic acids (PFSAs) from water is highly challenging due to the strength of C–F bonds and the stability of sulfonate groups. In this work, two ionizing radiation (IR)-based systems, IR/formate ($HCOO^-$) and IR/sulfite (SO_3^{2-}), were developed to decompose perfluorohexanesulfonic acid (PFHxS). Both systems achieved effective defluorination, with 80.3% for IR/$HCOO^-$ and 95.1% for IR/SO_3^{2-} at 100 kGy (10 mM additives, 5 mg/L PFHxS). Given its superior performance, the IR/SO_3^{2-} system was further investigated in detail. Mechanistic investigations revealed that $SO_3^{\bullet-}$, though unable to directly cleave C-F bonds, forms transient complexes with PFHxS or its intermediates, thereby lowering the energy barrier for C-F cleavage by e_{aq}^-. This synergistic interaction among e_{aq}^-, $SO_3^{\bullet-}$, and $HO^\bullet$ significantly accelerates PFHxS degradation. The system also exhibited strong resistance to coexisting ions, broad applicability to real wastewater, and high energy efficiency, surpassing UV and electrochemical methods. Overall, while both systems are effective, the IR/SO_3^{2-} pathway demonstrates superior efficiency and unveils a novel radical-assisted defluorination mechanism for PFAS remediation.

Effect of pH And Matrix on the Degradation of Various Pharmaceuticals by High-Energy Ionizing Radiation

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Pharmaceutical contaminants in water bodies pose a significant environmental risk due to their persistence and potential toxic effects. Among them, trimethoprim (TMP) and tramadol (TRA) are frequently detected in several water resources [1−2] due to their widespread use as an antibiotic and analgesic, respectively, raising concerns about their bioaccumulation, antimicrobial resistance, and potential ecotoxicological effects [3−4]. Conventional wastewater treatment processes often fail to completely remove these compounds, necessitating the development of alternative degradation methods. High-energy ionizing radiation has emerged as a promising technique for the efficient removal of pharmaceuticals, yet its effectiveness depends on various factors, including pH and matrix composition.

In this study, the radiolytic degradation of trimethoprim and tramadol (Fig. 1.) was investigated under various pH conditions and in different aqueous matrices (pure water, tap water, synthetic wastewater and purified wastewater). The pH dependence of hydroxyl (•OH) radical-induced reactions shows that the rate constants increase with rising pH for both compounds. This is due to the electrophilic nature of •OH, which reacts more rapidly with the neutral molecule than with its protonated form. Comparing the different matrices, the highest removal efficiency is observed in high-purity water for both oxidation and mineralization processes. Initially, high-energy ionizing radiation leads to the formation of products that are more toxic than the parent molecules; however, at sufficiently high doses, the degradation progresses to the formation of non-toxic, biologically degradable products. The organic and inorganic components that make up the matrices may retard degradation processes. By acting as radical scavengers, these constituents can transform into less reactive species, thereby reducing overall removal efficiency.

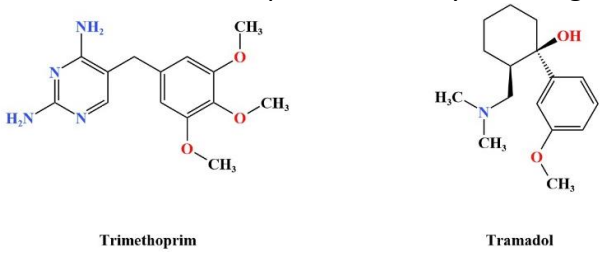

Figure 1. The chemical structure of Trimethoprim and Tramadol

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Radiation-Driven Chemistry in Molten Salts

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Molten salts are proposed as liquid fuels or coolants in a new fleet of nuclear reactors. The salt will be exposed to high radiation levels under those conditions, thus understanding the chemical effects of radiolysis on the molten salt fuel is essential to reliable reactor operation. Building this understanding begins with characterizing the speciation of primary salt radiolysis products (solvated electrons (e_{solv}^-) and Cl_2^-) in different molten salt compositions and measuring their reaction kinetics with metal ions,[1,2] which depend strongly on the composition of the salt. We do this by performing high-temperature pulse radiolysis transient absorption spectroscopy at the BNL Laser-Electron Accelerator Facility,[3] aided by insights from *ab initio* molecular dynamics simulations.[4] Salt mixtures containing monovalent and divalent cations are of particular interest because of their tunable Lewis acidity-basicity that can be used to control the solubility of dissolved metal ions in the reactor. Changing the $MgCl_2$:KCl mixing ratio alters the absorption spectra of radiolytically-produced excess electrons, producing strong blue shifts indicating significant changes in the electron's energetics and reactivity that we have now probed by measuring reaction kinetics with metal ion electron acceptors. We observe that reaction rates of the solvated electron depend strongly on the composition of the salt. Reactivity trends among first-row transition metals will also be discussed.

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Advances in Radiation Catalytic Chemistry

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The efficient use of renewable X/γ-rays or accelerated electrons for chemical transformation of CO_2 and water to value-added chemicals or materials holds promise for a carbon-neutral economy; however, such processes are challenging to implement and require the assistance of catalysts capable of sensitizing secondary electron scattering and providing active metal sites to bind intermediates. Therefore, we would like to introduce our recent advances in radiation catalytic chemistry. This include several radiolytic strategies, the basic principle, and the attempts in large-scale processes.

Radiation Chemistry with X-ray Free Electron Lasers (XFEL)

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X-ray Free-Electron Lasers (XFELs) are last-generation radiation sources that deliver, in a pulse lasting only a few femtoseconds (or even a few hundred attoseconds), as many X-ray photons as a synchrotron beamline does in one second. These pulses are extremely intense, highly focused, ultra-short in duration, and fully coherent (>95%), which explains the uniqueness of these machines and the fact that they have simultaneously revolutionized several scientific fields.

It is not only the intensity of the pulses — enabling high spatial resolution — but also their ultra-short duration — maximizing temporal resolution — that makes XFELs unique in their ability to probe matter. Elementary processes associated with ionization of liquid water provide a framework for understanding radiation-matter interactions in chemistry and biology.

Tunable femtosecond soft x-ray pulses have been used to reveal the dynamics of the valence hole created by strong-field ionization and to track the primary proton transfer reaction giving rise to the formation of OH radical [1]. The isolated resonance associated with the valence hole (H_2O^+/OH) enabled straightforward detection. Molecular dynamics simulations revealed that the x-ray spectra are sensitive to structural dynamics at the ionization site.

Time-resolved X-ray absorption spectra of ionized liquid water demonstrate that OH radicals, H_3O^+ ions, and solvated electrons all leave distinct X-ray spectroscopic signatures [2]. This allows to characterize the electron solvation process through a tool that focuses on the electronic response of oxygen atoms in the immediate vicinity of a solvated electron. The experimental results, supported by ab initio calculations, confirm the formation of a cavity in which the solvated electron is trapped. It shows that solvation dynamics are governed by the magnitude of the random structural fluctuations present in water. As a consequence, the solvation time is highly sensitive to temperature and to the specific way the electron is injected into water.

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Radiation-Induced DNA Damage as an Approach to Probing Low-Temperature Plasma Chemistry

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A low-temperature plasma (LTP) is being advanced as an alternative radiation source that offers unique chemical properties owned by a variety of reactive plasma species (RPS), such as radicals [1], electrons [2], and excited species, delivered and formed in targets upon exposure. Our recent research explored the possibility of implementing DNA and its damage as a probe for specific plasma diagnostics such as RPS formation and transient local heating [3]. Both LTP characteristics have been analysed based on the detection of two types of DNA damage: strand breaks and DNA denaturation. We implemented a physics-guided neural network model to predict the formation of both types of damage and their yields for a given combination of LTP parameters. Based on our findings we suggested that denaturation of DNA can be attributed to transient local heating of the aqueous DNA. Moreover, our results showed that DNA can be utilized as a probe for RPS, particularly for reactive oxygen and nitrogen species that cause strand breaks in aqueous DNA. A similar approach which explores the experimental data-driven predictive modelling of DNA damage, was utilized by us to determine a dose rate of LTP radiation [4].

In addition to the fundamental aspect of our work, the outcomes of these studies have potential for further breakthroughs in plasma applications ranging from industrial to medical areas. Since many chemical processes are involved during plasma interaction with the target that can be varied by process parameters, choosing the ideal parameter combinations for obtaining the desired chemical effects is often challenging. The knowledge of RPS dynamics for specific plasma conditions is an invaluable key to overcoming this challenge.

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Electron Beam Processing of Poly(L-lactic acid): Roles of Functional Multi-branched Poly(L-lactide) in Associating Free Radical Reaction and Bioplastic Performance

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Poly(L-lactic acid) (PLLA), an aliphatic polyester derived from bio-based monomers, is one of the sustainable polymers or bioplastics for many applications (e.g., food packagings, textiles, 3D-printed objects, medical devices). A paradigm shift of radiation chemistry and electron beam (EB) processing for reinventing PLA bioplastics and other bio-based polymers is a foreseen science and technology towards more sustainable materials. In this presentation, EB processing of PLLA in the presence of different functional multi-branched poly(L-lactide) (mPLLA) additives are proposed. Alteration of the PLLA morphology by functional and multi-branched structures in association with EB irradiation (0-100 kGy) brings about change in crystallinity, thermal stability, and mechanical property. After modification, the PLLA performance including microwave resistance, radiation resistance, antioxidant, and antimicrobial have been studied. The mPLLA and mPLLA-*co*-poly(e-caprolactone) (PCL) functionalized with glycidyl methacrylate (GMA) promoted partial cross-linking of PLLA via free radical mechanism induced by EB irradiation [1, 2]. The methacrylate function and PCL copolymer segment play an estential role for EB-induced cross-linking. The PLLA films and the fabricated bowl exhibited microwave resistance property. Polyphenol and cyclic amine functional groups from gallic acid (GA) and piperidine (PPD) were also anchored onto mPLLA and compounded with PLLA films [3-5]. Free radicals of PLLA created by EB irradiation were scavenged by mPLLA-GA and mPLLA-PPD. The kinetics free radical residue of PLLA were investigated by electron spin resonance (ESR) spectroscopy. The GA and PPD functions play a crucial role for free radical scavenging ability as well as chain scission retardance. The GA and PPD on mPLLA endowed their antioxidant and antimicrobial functions which capable for i) radiation resistance under irradiation sterilization doses, ii) oxygen trapping in packaging, iii) free radical scavenging in PLLA matrix and in packaging atmosphere, and iv) microbial growth inhibition for prolonging the shelf life of food. The studies demonstrate that different functional groups (i.e., acrylate, phenolic, amine) of mPLLA play different roles as radiation cross-linker, free radical scavenger, or microbial inhibitor to accomplish different functional bioplastics. The current studies show that turning morphology of PLLA with functional compounding in associating with EB modification is a promising process for enhancing bioplastics performance.

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Oral Lectures

Applying Pulse Radiolysis to Fast Proton-Coupled Electron Transfer Reactions in Acetonitrile

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In our group, we use pulse radiolysis (PR) as a tool to investigate reaction mechanisms, particularly those of redox catalysis associated with solar energy conversion, such as CO_2 and proton reduction, where PR can rapidly generate the reduced forms of catalysts for subsequent interrogation by time-resolved spectroscopy. Acetonitrile (CH_3CN) is a commonly employed solvent in the field of electro- and photo-catalysis due to its high polarity, aprotic nature, and excellent solubilizing properties. For clean mechanistic PR studies in CH_3CN, we have developed radiolytic radical scavenging strategies, including the use of formate[1] or triethylamine[2] as scavengers. We have also quantified the combined radiation yield and spectroscopic properties of the two forms of solvated electron, $e_{solv}^{\bullet -}$ in CH_3CN (cavity electrons and solvent dimer radical anions).[3]

Using PR coupled with time-resolved infrared spectroscopy (PR-TRIR), we have probed key intermediates in the catalytic cycles of a variety of CO_2 reduction catalysts. However, it has proved challenging to investigate critical proton-coupled electron transfer (PCET) steps, which involve the protonation of reduced catalytic intermediates, and which are arguably the most important fundamental steps in the catalytic cycle. The difficulty lies in the fact that in CH_3CN, $e_{solv}^{\bullet -}$ is rapidly scavenged by most Brønsted acids that are added to the solution, such as alcohols and carboxylic acids, thus preventing the initial reduction of the catalyst. Here, we discuss recently developed strategies for overcoming this challenge, which involve: (1) leveraging acid/base homoconjugation; (2) using dissolved CO_2 as an efficient scavenger of electrons in the presence of an acid; and (3) radiolytically producing a Brønsted acid. These strategies are demonstrated with the efficient production of the protonated benzophenone ketyl racidal, BP-$H^{\bullet}$ (see Figure). This new development opens many new opportunities to probe PCET reactivity in CH_3CN by PR, which will allow catalytic mechanisms to be fully deciphered.

Determination of Radiation Chemical Yield of Hydroxyl Radicals for Low Energy X-rays

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Hydroxyl radicals (•OH) are highly reactive species that play a central role in chemical and biological processes initiated by ionizing radiation, particularly in aqueous environments. This makes the ability to quantify them crucial, especially for understanding and optimizing various applications of ionizing radiation. In this study, we investigated the radiation chemical yields of hydroxyl radicals generated in aqueous solutions irradiated with low-energy X-rays, with tube voltages ranging from 25 to 300 kV. To achieve this, we employed two established fluorescence-based chemical dosimetry methods that rely on specific reactions between •OH and probe molecules. Terephthalic acid (TA) reacts selectively with hydroxyl radicals, predominantly yielding a fluorescent product, 2-hydroxyterephthalic acid (TA-OH) [1]. Similarly, coumarin-3-carboxylic acid (C3CA) undergoes hydroxylation, producing, among other products, the fluorescent 7-hydroxycoumarin-3-carboxylic acid (7OH-C3CA) [2]. The fluorescence intensity of these products serves as an indirect but sensitive indicator of hydroxyl radical presence and concentration.

Both methods provide simple and sensitive means of hydroxyl radical determination, offering similar perspectives and mutual confirmation of hydroxyl radical formation in water under low energy X-ray irradiation. Quantification of the fluorescent products of hydroxylation allowed the determination of radiation chemical yields of hydroxyl radicals. These findings provide a bridge over an existing gap in literature where data on •OH yields at lower photon energies remain scarce.

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Exploring Hydroxyl Radical Reactivity in Sulfur-Containing Amino Acid Models under Acidic Conditions

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Methionine (Met) residues in proteins and peptides are particularly susceptible to one-electron oxidation. The presence of nearby amide groups plays a key role in facilitating this process, enabling Met to participate in long-range electron transfer mechanisms. Hydroxyl radicals ($HO^{\bullet}$), produced both endogenously via cellular metabolism and exogenously by ionizing radiation, are highly reactive species that can oxidize Met.

The $HO^{\bullet}$ reaction with Met primarily proceeds through two consecutive steps: addition of $HO^{\bullet}$ to the sulfur atom, followed by elimination of HO^{-}, leading to one-electron oxidation of the thioether group. We previously studied this reaction at pH 7 using model peptides that mimic methionine and its cysteine-methylated analog: $CH_3C(O)NHCHXC(O)NHCH_3$, where X = $CH_2CH_2SCH_3$ or CH_2SCH_3 [1]. The mechanism was found to depend on the distance between the sulfur atom and the peptide backbone.

However, to better understand the equilibria involved particularly proton transfers, we extended our study to acidic pH. In the present work, we investigated the reactivity of $HO^{\bullet}$ with these model systems at pH 4 using pulse radiolysis with both conductivity and time-resolved optical detection, alongside product analysis via LC-MS and high-resolution MS/MS following γ-radiolysis.

This comprehensive approach allowed us to monitor transient species and proton fluxes with high sensitivity. Comparison of the data collected at neutral and acidic pH clarified how the proximity of amide groups influences both the kinetics and pathways of Met oxidation. The results further support the role of local environment in modulating radical-driven transformations of sulfur-containing amino acid residues and contribute to a deeper mechanistic understanding relevant to protein oxidation under physiological and stress conditions.

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Low-Energy Electrons-driven Processes in the Radiosensitization of Chemotherapeutic RRx-001: A Radiolytic Study from Picoseconds to Products Formation

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The primary benefit of concomitant chemo-radiotherapy lies in its synergistic effect -enhanced therapeutic from the interplay between chemotherapy and radiotherapy. Although the precise mechanism remains unclear, it was shown that electron-affine radiosensitizers contribute to this synergy through interactions with secondary low-energy electrons (LEEs) (1). Radiosensitizer is a chemical agent that can make tumour cells more sensitive to irradiation after its insertion into the tumour. LEEs arise as highly reactive particles in irradiated tissue in large quantities during the early stages of radiolysis.

This study centres on the molecule RRx-001 (2), a chemotherapeutic with low toxicity and notable efficacy in hypoxic tumour environments. These characteristics, combined with its radiosensitizing properties followed by validated synergy with radiotherapy, underscore its therapeutic uniqueness. Structurally, RRx-001 incorporates three electron-affine functional groups serving as potential targets for LEEs in electron attachment. This interaction facilitates the generation of free radicals and enhances tumour perfusion, further contributing to its radiosensitizing potential (3).

The objective of this study is to elucidate the mechanistic role of LEEs in the radiosensitizing action of RRx-001. For the first time, a multi-methodological approach is employed to investigate the radiolytic behaviour of the molecule focusing on LEE-induced processes across phases from picoseconds to product formation. Gas-phase experiments examine LEE attachment to microsolvated RRx-001 in detail on the femtosecond timescale (4); while picosecond pulsed radiolysis in ethanol provides insight into its interactions with quasi-free and fully solvated electrons under the intermediates formation up to microseconds (5). Stable radiolytic products in solution are identified using nuclear magnetic resonance (NMR) spectroscopy following irradiation with high-energy electrons from a microtron accelerator. Complementary theoretical calculations mainly characterize anionic intermediates forming and detected in solution during pulse radiolysis experiments.

Our results confirm that RRx-001 undergoes strong and specific interactions with LEEs, supporting its role in electron-mediated radiosensitization. We suggest a radiolytic mechanism of RRx-001 focused on LEEs. This mechanistic insight contributes to the groundwork for rationally designing next-generation radiosensitizers, aimed at enhancing cancer treatment with reduced side effects.

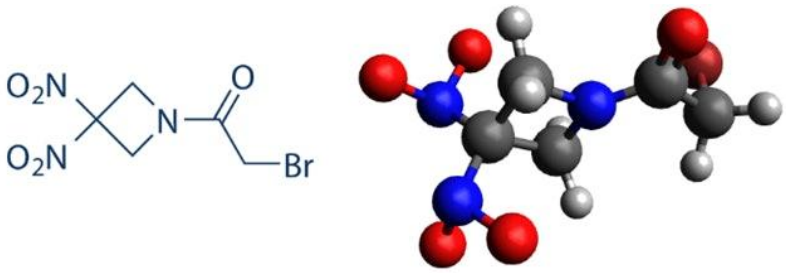

Figure 1. Structural formula of RRX-001 and its 3D model.

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Radiation Chemistry of Some Actinide Compounds

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Actinide chemistry has long been studied because of the interesting fundamental aspects of f-element compounds and for the more practical applications in the nuclear industry, medicine, and forensics. However, surprisingly little is known about the radiation stability of these compounds due to self-radiolysis or from the intense radiation environments they often experience. Even less is known about the basic radiation chemistry mechanisms involved in their decomposition and subsequent reactions. We have begun to apply classical radiation chemistry methodology to systematically probe radiation induced processes of actinides at the atomic level. Most of the discussion will focus on uranyl compounds that vary from nanometer clusters to metal organic frameworks, MOFs. Many of these compounds can survive extreme doses of radiation, but we are now gaining some insight into their radiolytic decomposition and subsequent reactions.

Electron Beam Induced Modification of Nanoparticles

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Nanoparticles are of great importance for multiple applications in catalysis, medicine, biotechnology, data technology, and communications. The combination of nanoparticle- and defect-based quantum sensing has particularly high potential in this regard. Control over the production of the nanoparticles, their shape, surface functionality, and even their crystallinity with respect to defects concentration exhibit a crucial role in their applicability. At the Hertz Electron Laboratory of the Leibniz Institute of Surface Engineering, electron beam technologies are being probed for the mechanistic understanding of relevant parameters for nanoparticle synthesis, modification, and application, with the ultimate aim of applying optimized nanoparticles. Here, the approaches are summarized using selected examples. In particular, we will illustrate our results on the mechanistic understanding of the growing and etching process of gold and semiconductor nanoparticles using pulse radiolysis as a complementary tool to liquid cell TEM experiments. The successful electron beam-based surface modification of nanoparticles will be illustrated by the modification of fluorescent nanodiamonds were our focus lies on the immobilization of drugs and sensor molecules such as doxorubicin and dimethylanthracence on the diamond surface aiming for innovative applications in cancer diagnostics and treatment. Finally, we will target the controlled defect generation inside diamond material aiming optimized fluorescence properties. These investigations are crucial for multiple quantum sensing application. Furthermore, we were able to demonstrate that defects in diamond can be applied for long term data storage devices.

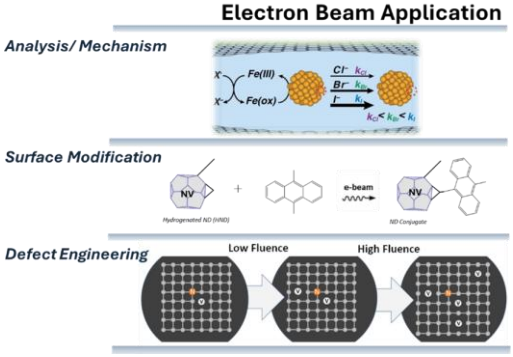

Figure 1. Application of the electron beam technology for analysis and reaction mechanisms investigations of nanoparticles related reactions, surface modification of nanoparticles and defect generation inside nanoparticles.

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Radiolysis-Induced Surface Functionalization of GaN/InGaN Nanowires for Photocatalytic Hydrogen Production

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Green hydrogen (H_2), produced from water through photocatalysis, represents a promising pathway toward a carbon-neutral energy future by 2050. This research focuses on the development of advanced photocatalysts based on gallium nitride (GaN) nanowires (NWs), epitaxially grown on silicon substrates. To enhance photocatalytic efficiency, these nanostructures are functionalized with platinum nanoparticles, induced via radiolysis. GaN and its related III-nitride materials possess a direct bandgap and, due to their compositional tunability, enable full coverage of the visible spectral range—from 3.4 eV for GaN to 1.5 eV for $In_{0.8}GaN$. This makes them highly effective for broad-spectrum photon absorption and efficient generation of electron-hole pairs. This work bridges epitaxial synthesis, radiolytic surface modification, and photocatalytic application for hydrogen production. Preliminary results demonstrate promising H_2 evolution using both platinum-functionalized GaN NWs and bare InGaN NWs, highlighting the potential of III-nitride nanostructures as versatile and efficient photocatalysts.

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Investigation of L-alpha-Alanine Radiation Chemistry to Develop Reference Dosimetry in Innovative Radiotherapy Methods

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Radiotherapy remains today a cornerstone of cancer treatment, using ionizing radiation to control and eradicate tumors while preserving healthy tissues. Its effectiveness is nonetheless limited by precise dose measurement to ensure optimal treatment. Recent advancements in the field have complemented the traditional photon-based external beam radiotherapy with innovative modalities such as FLASH radiotherapy and proton therapy, both of which bring distinct tissue sparing advantages.

FLASH radiotherapy delivers ultra-high dose rates (>40 Gy/s) over short durations, producing a biological response characterized by reduced damage to normal tissues—the so-called FLASH effect [1]. Meanwhile, proton therapy leverages the Bragg peak to achieve localized deposition, minimizing dose to surrounding healthy tissue.

These modalities induce new complex radiation chemistry, particularly in regions of high linear energy transfer (LET) such as the Bragg peak, therefore introducing new challenges for solid dosimeters readings and comprehension.

In this work, we explore the potential use of L-alpha-alanine as reference solid dosimeters for the new modalities of proton and FLASH radiotherapy. Alanine is known to have a dose-rate independent [2], linear and precise (<3%) response, which makes it a well-suited candidate for FLASH applications. Its use in high LET conditions is nonetheless rare and LET correction factors are still not well established. Radio-induced stable radicals generated in alanine have been studied extensively in the past 30 years using electron paramagnetic resonance (EPR) techniques [3]. Using EPR, we aim to study the variation of the relative contribution of each radical with LET to evaluate its usability as basis for correction.

We utilize the EasySpin simulation toolbox to deconvolute EPR spectra of alanine, extracting each contribution of radio-induced radicals. This allows us to assess the effects of LET and ultra-high dose rates on the radical quantities and proportions.

Preliminary studies have indicated that the high LET regimes induce an underestimation of alanine dosimeters response as large as 10%, furthermore indicating the significant difference with conventional irradiations. EPR at low temperatures have allowed the study of radical generation and provided insights on the underlying radiation chemistry of alanine. We aim to use this knowledge to develop dosimetric techniques suitable for next-generation clinical protocols.

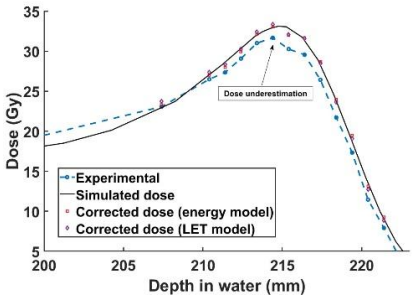

Figure 1. Alanine dose response in a 180MeV proton beam Bragg Peak at conventional dose rate

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Acknowledgments. TROMPIER François, DE MARZI Ludovic.

Radiation Stability of Nanocomposite Scintillators

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Physical, chemical and mechanical stability in the field of ionizing radiation are key parameters of all materials that are exposed to irradiation. The investigation of different types of radiation is also important from the perspective of high-energy physics (HEP), as materials used in calorimetry will be exposed to a combination of different types of ionizing radiation. Very different dose rates must also be considered from the perspective of using materials in different applications, as well as different environment (vacuum/air). Currently, polymer and/or nanocomposite scintillating materials (composed of inorganic nanoparticles or quantum dots embedded in polymer matrices) are being considered for new generation of detectors in HEP or in medical imaging devices. While inorganic scintillators, usually bulk single crystals or ceramics, tend to be considered advantageous for their radiation hardness, the main advantages of their polymer counterparts are low cost, simplicity of processing, machining and shaping, as well as an ease of replacement. However, organic scintillators feature relatively low radiation stability. Due to the advent of new nanocomposite scintillators developed for advanced applications, the radiation stability of these new inorganic/organic materials became one of serious concerns. Nanocomposites typically consist of scintillating nanoparticles embedded into the organic optical matrix. Nanoparticles of ZnO:Ga or $CsPbBr_3$ (CPB) were identified as promising materials for time-of-flight applications in medical imaging as well as high energy physics [1] because of their superior timing performances [2,3]. Nanocomposite scintillators combine the properties of polymer matrix and inorganic crystals and, so far, their behavior and change in parameters under irradiation has not been sufficiently mapped.

In our preliminary work, we studied irradiation of ZnO:Ga PS and YSO:Ce-PS nanocomposites. Bright burn effect, so far typically observed in bulk inorganic crystals, was observed for press-compacted pellets of scintillating powders as well as for nanocomposite materials. Moreover, the distribution of radiant energy in a nanocomposite will be very different from homogeneous inorganic or organic materials. As recent work suggests [4], modelling the distribution of absorbed energy in a nanocomposite and comparison with experimental data can yield interesting results.

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Changes in Yields of Radiolytic Species in Solutions in the Presence of GNPs

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Gold Nanoparticles (GNPs) are known as a radiosensitizer. The increase of the biological effectiveness due to GNPs has been reported, but the mechanisms are not satisfactory understood. To unveil the enhancement mechanisms, we evaluate changes in yields of water radiolysis species (hydrogen peroxide and OH radicals) under X-rays, protons and heavy ions.
One of the enhancement mechanisms has been considered as the increase of reactive oxygen species formed by water radiolysis. Previously, using plasmid DNA, it was reported that the decomposition of hydrogen peroxide in the persence of GNPs led to the increase of OH radicals. To verify the relation between hydrogen peroxide decomposition and OH radical increase, we evaluate yields of hydrogen peroxide formed by water radiolysis in the presence and in the absence of GNPs. Hydrogen peroxide is quantified using Ghomley technique and OH radicals are measured by Amplex Red solutions.
Hydrogen peroxide formed by water radiolysis species is completely decomposed in the presence of GNPs. In the case of X-rays, hydrogen peroxide formed increase with dose above 25 Gy. As the decomposition of hydrogen peroxide, yields of OH radicals increase significantly in the presence of GNPs, compared to that in the absence of them. Similar trends are seen under protons and heavy ions. Indeed, GNPs have been inactivated above certain doses under the irradiation. Thus, hydrogen peroxide could be decomposed by redox reactions in the presnce of GNPs, leading to the increase of OH radicals. In the presentation, we will present our recent advances of biological experiments using living cells.

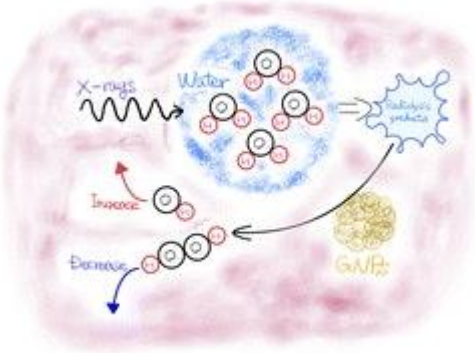

Figure 1. Three pathways to form OH radicals by water radiolysis in the presence of GNPs.

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Radiation-Functionalized Polyolephinic Films for the Isolation of Rare Cells in Biological Specimens for Diagnostic Applications

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Early detection and effective treatment significantly impact survival rates in disease management. In prenatal diagnostics, micromanipulation is a dependable method for manually isolating rare fetal cells from maternal fluids for molecular or cytogenetic analysis. While effective, this approach is costly and time-consuming due to the need for skilled personnel and specialized equipment[1].

This study aims to enhance the efficiency and affordability of prenatal diagnosis in hospital settings by developing a device for semi-automated selection of rare cells from biological samples. The device utilizes polyolephinic films functionalized to obtain carboxyl groups on the surface via electron-beam radiation. These functional groups can be then used to decorate the films with antibodies to selectively capture target cells based on surface antigens.

Bioconjugation methods employing EDC/NHS chemistry were developed to impart cell-capture capabilities to the films, exploiting the streptavidin or avidin with biotin lock and key bound. Fluorescently labelled antibodies enabled assessment of conjugation success via fluorimetry and spectrofluorimetry.

Cell capture tests were conducted using mesenchymal stem cells (MSC) on antibody-decorated films, with observations made using optical and confocal microscopy to evaluate capture efficacy. Release after capture mechanism of the streptavidin or avidin with biotin lock and key bound was also tested using fluorescent biotinylated probes. The electron-beam functionalized polyolephinic films resulted successfully decorated with the target cells, holding promise to develop a device for cell selection.

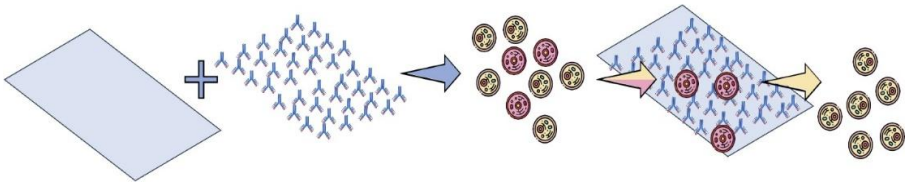

Figure 1. Schematic representation of film antibody decoration and specific cells selection.

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Fragmentation Dynamics of Polymers Under Varied Intensities of Extreme Ultraviolet Radiation

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Participation cancelled.

Gamma Irradiation Effect on Poly(3-Hydroxybutyrate-Co-3-Hydroxyvalerate) (PHBV)/ Cloisite 30B Nanocomposites

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The effect of ɣ-irradiation on Cast poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) and PHBV/Cloisite 30B (C30B) filled at 3 wt.% nanocomposite prepared by melt compounding, was evaluated at various doses, i.e., 5, 15, 20, 50 and 100 kGy at room temperature in air. Changes in molecular weight, morphology and physical properties of the irradiated materials were investigated. The study showed that the main degradation mechanism occurring in ɣ-irradiation in both Cast PHBV and C-PHBV/3C30B nanocomposite is chain scission, responsible for the decrease of molecular weight. Differential scanning calorimetry (DSC) data indicated a regular decrease in crystallization temperature, melting temperature and crystallinity index for all irradiated samples with increasing the dose. Further, DSC thermograms of both Cast PHBV and PHBV nanocomposite sample exhibited double melting peaks due probably to changes in the PHBV crystal structure. Tensile and dynamic mechanical analysis (DMA) data showed a reduction in Young's modulus, strength, elongation at break and storage modulus with the radiation dose; the decrease was however more pronounced for Cast PHBV. The morphological damages were much less pronounced for the PHBV nanocomposite sample compared to Cast PHBV, for which some irregularities and defects were observed at 100 kGy. This study highlighted the ability of C30B organoclay to counterbalance the detrimental effect of radiolytic degradation on the functional properties of PHBV up to 100 kGy, thus acting as a potential anti-rad.

Effects of Gamma Irradiation on Polybutadiene-Based Materials for Solid Propulsion Applications

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Solid propulsion is considered as a fundamental technology for space exploration, offering high energy density, reliability, and operational simplicity compared to liquid propulsion systems [1]. Traditional solid propellants rely on hydroxyl-terminated polybutadiene (HTPB) cured through polyaddition with isocyanates, a well-established approach that ensures mechanical stability and long-term storability. In the last years, emerging manufacturing techniques, such as UV-induced photopolymerization, have introduced a novel route for polybutadiene (PB) curing, enabling improved process control, reduced energy consumption, and greater compatibility with additive manufacturing technologies.

Despite these advantages, the response of photopolymerized PB binders to ionizing radiation—a major requirement in the space environment—is currently not sufficiently explored. In particular, recent studies outline that gamma irradiation of such materials can produce a combination of effects, such as chain scission, radical formation, and oxidation processes that may alter the chemical and mechanical properties of propellant binders, ultimately impacting their stability and performance [2]. In this context, the present contribution is focused on the systematic investigation of the effects produced by gamma irradiation on PB-based materials synthesized via different polymerization routes, including conventional chemical curing and UV-induced photopolymerization with varying degrees of crosslinking.

PB samples were fabricated at the Space Propulsion Laboratory (SPLab) at Politecnico di Milano. The irradiation tests at 25, 50 and 130 kGy were performed at the Calliope Co-60 facility at ENEA Casaccia Research Center (Rome) [3]. The radiation-induced modifications are studied through a comprehensive characterization by combining Micro-Raman, FTIR, and EPR spectroscopies with colorimetry analyses. The results disclosed that the chemical formulation and the polymerization technique are crucial to tailor the oxidation levels, degradation mechanisms, radical formation and recombination after gamma irradiation. Notably, photopolymerized PB samples exhibit distinct spectral modifications compared to chemically cured ones, suggesting different pathways for radiation-induced transformations. Additionally, uncured photopolymerizable mixture are exposed to gamma irradiation to assess whether this approach may influence the polymerization process.

The obtained results provide essential insights into the radiation resistance of PB-based materials, paving the way to the development of next-generation solid propellants with improved radiation tolerance, promising for future deep-space missions and long-duration operations.

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Eco-Friendly Modified Fibers from PLA Blends via Electron-Induced Reactive Melt Processing

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The modification of semi-crystalline thermoplastic fibers through electron irradiation poses a significant challenge due to the high degree of crystallinity inherent in these polymer structures. Primary electrons are preferentially captured within crystalline regions of the fibers, generating radicals that can induce chain scission. This phenomenon is attributed to the limited chain mobility in these domains, which ultimately leads to a deterioration of the mechanical properties, such as tensile strength and elastic modulus. To overcome this issue, we present a novel approach introduces accelerated electrons into a crystallite-free polymer melt. Electron-induced reactive melt processing (EIReP) can establish covalent bonds between polymer phases, enhancing PLA/PCL interphase compatibility during compounding, without the need for additives. For comparison, we also investigate the feasibility of performing the compatibilization process during fiber melt spinning by introducing the electron beam into the fiber draw zone. The results indicating that electron irradiation, both before and during the fiber formation process, not only mitigates the challenges associated with crystallinity but also enhances the mechanical properties of the resulting fibers.

Formation of Short-Chain PFAS in Radiolysis of Fluoropolymers Used in the Nuclear Industry

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Fluoropolymers such as polyvinylidene fluoride (PVDF) are widely employed in radiation-intensive nuclear environments due to their thermal and radiolytic stability. However, with increasing scrutiny of per- and polyfluoroalkyl substances (PFAS), including proposed EU ban [1], the environmental and health consequences of fluoropolymer degradation products are of growing concern. While PVDF degradation has traditionally been assessed via HF release and bulk property changes [2], less attention has been paid to the potential formation of toxic, short-chain PFAS during its radiolysis.

In our study, PVDF powders, pellets, and films were irradiated under Co-60 gamma radiation (dose range 10- 250 kGy) in aqueous solutions with variable pH levels. Fluoride release was quantified using an ion-selective electrode, while the aqueous phase was analysed using LC-MS for short-chain perfluorinated acids. Gas-phase products were identified by GC-MS, and structural changes in the polymer matrix were probed via IR and UV-Vis spectroscopy.

As expected, dehydrofluorination was found to be the dominant radiolytic pathway, yielding fluoride at rates consistent with literature (2-3 molecules/100 eV), [3]. However, even at relatively low doses, the headspace contained volatile fluorinated hydrocarbons - notably short-chain fluoropropanes, including hydrogenated and unsaturated species. Concurrently, LC-MS analyses of the supernatant identified low but detectable levels of short-chain perfluorinated acids, confirming scission pathways beyond simple HF elimination. Infrared spectroscopy revealed dose-dependent signatures associated with unsaturation (C=C) and hydroxylation, further supporting a fragmentation-based mechanism.

These findings highlight that chain scission and secondary reactions during PVDF radiolysis can yield trace quantities of PFAS compounds. While yields remain low, their potential persistence and toxicity render them significant from a regulatory and operational perspective. As PFAS regulations tighten globally, understanding the molecular pathways leading to such degradation products is critical. This work provides the first integrated experimental evidence for low-dose PFAS formation from PVDF under realistic nuclear-relevant conditions, underscoring the need for detailed radiolytic product speciation in materials deployed across the nuclear sector.

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"Top-down" and "Bottom-up" Processes in Solid-state Radiation Chemistry: the Impact of Weak Interactions

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The early stages of the radiation-induced transformations of molecules in condensed phases basically involve formation of weakly bound metastable species (intermolecular and radical-molecule complexes), which are often elusive in the common radiation chemistry of liquids due to fast molecular dynamics and diffusion. Meanwhile, these intermediate states are clearly detectable and crucially significant in rigid solids, particularly, in the cryogenic media widely occurring in the physical chemistry of the Universe. Their role may be also significant in the radiation chemistry of polymers, mesoporous and nanoporous systems. On the other hand, the weakly bound complexes may act as building blocks for production of new molecules, including complex and biologically relevant species under the action of ionizing radiation in a rigid environment. In this report, the "top-down" and "bottom-up" radiation-induced processes in cold media involving intermolecular complexes will be discussed on the basis of extensive studies performed in our laboratory and illustrated with recent examples [1 - 5]. Furthermore, the common role of weak interactions in different fields of radiation chemistry will be outlined.

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Temperature and Pressure Dependence of Hydrated Electron EPR g-factor

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The EPR g-factor of the hydrated electron has been measured using pulse radiolysis and time-resolved pulsed EPR up to 350°C, at pressures up to 240 bar. We find a maximum shift of the g-factor g_e away from (below) the free-electron g-factor g_{fe} near 200°C. There is a small but measurable pressure effect, giving greater g-factor shift $\Delta=g_e-g_{fe}$ at higher pressure. When the g-factor shift is divided by the water density ρ at given temperature and pressure, the normalized g-factor shifts collapse to a straight line vs. temperature. That is, the water density effect on g_e is cleanly separable from the temperature effect. The result can be reported in ppm (T in °C) as

$\Delta(ppm) = (-1798 -3.022\ T) \times \rho(g/cc)$

The g-factor shift results directly from spin-orbit coupling in the $(e^-)_{aq}$ wavefunction, and this is completely dominated by spin density at the oxygen atoms in the hydrated electron solvation shell. We analyze DFT calculations of model hydrated electron cluster configurations to show that the density effect relates directly to the "size" of the hydrated electron solvation cavity, with less spin density at oxygen as the water density decreases. The temperature effect is related to disorder of the OH bond directionality. For fixed density, as temperature increases, the electron becomes less tightly localized in the central void. This means that more spin density leaks outward to the water oxygens, and g-factor shift increases. A second effect is that average water coordination number increases with temperature, and this can also increase the g-factor shift as more oxygen is in close contact with the electron center.

Figure 1. High Pressure/Temperature EPR apparatus at Notre Dame Radiation laboratory 3MeV van de Graaff accelerator.

Oxygen and pH Dependence on Hydrated Electron (e^-_{aq}) Yield and Kinetics: Pulsed Radiolysis Investigation Using UHDR Alpha and Proton Beams

Sarra Terfas[1], Guillaume Blain[1], Emeline Craff[2], Charbel Koumeir[1, 2], Ferid Haddad[1, 2], Freddy Poirier[2], Johan Vandenborre[1, 3]

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The hydrated electron (e^-_{aq}) is one of the primary species generated during water radiolysis, playing a crucial role in radiation chemistry by influencing both chemical[1] and biological[2] processes, particularly in the context of innovative FLASH radiation therapy[3]. However, direct experimental data on e^-_{aq} under ultra-high dose rate (UHDR) and charged particle beams remain scarce. Understanding its generation and reactivity under various conditions is essential for advancing radiation therapy and refining computational models.

In this study, we investigate the effects of pH and dissolved oxygen concentration on the yield and kinetics of e^-_{aq} using pulsed radiolysis with 66.9 MeV protons and 54.9 MeV alpha beams at UHDR. These experiments provide new insights into an LET range below 40 keV/µm and explore oxygen concentration and pH conditions that have been rarely explored. Our measurements focus on the microsecond time scale, a critical phase for homogeneous chemical stage, which remains inaccessible to traditional scavenging techniques.

Time-resolved UV-Visible spectroscopy, combined with pulsed particle beams, enabled us to directly measure the radiolytic yield and decay of e^-_{aq} at 2 µs post-radiation. Results from proton beam experiments exploring the plateau region of the Bragg curve show a strong dependence on oxygen concentration: as oxygen levels increase from 0.04% to 21%, the e^-_{aq} yield decrease significantly (from 0.96 to 0.13 molecules/100eV), while its half-time shortens from 8.8µs to below 2.5µs. Similarly, pH influences both yield and lifetime, with near complete suppression of e^-_{aq} at pH 2.6, while at alkaline pH (9-11), its half-life extends up to 24 µs. Additional results from alpha beam experiments, exploring both the plateau region and the entire Bragg curve, will also be presented and discussed in detail during the conference.

Conducted at the ARRONAX cyclotron facility, these experiments using two different beams particles provide valuable insights into radiation-induced processes in aqueous systems, particularly under UHDR conditions relevant to FLASH radiotherapy. These findings will also contribute to the validation of Monte Carlo models, such as Geant4-DNA and TOPAS-nBio. By shedding light on the fundamental chemical effects of UHDR radiation, this study advances both biological applications and fundamental research in radiation chemistry.

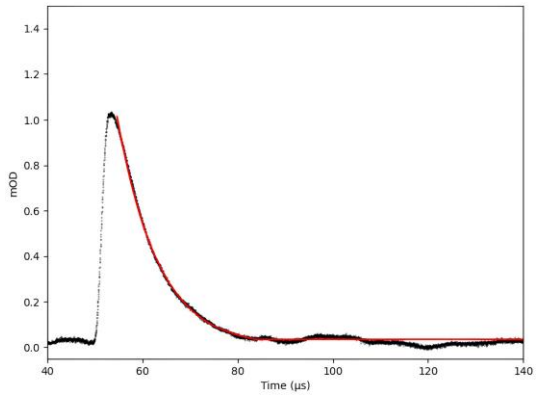

Figure 1. Kinetics of e-aq recorded at 633 nm in the plateau region, measured by irradiating pure water under deaerated condition (0.04% O_2) using proton beam.

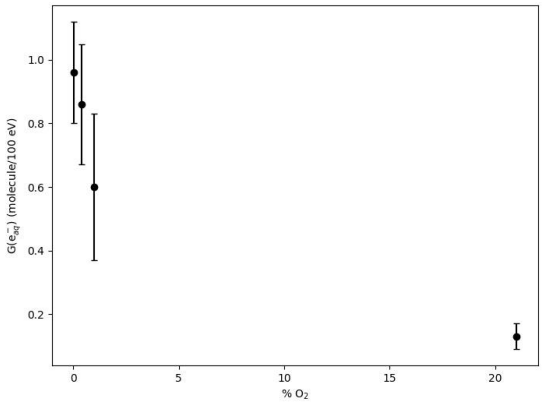

Figure 2. Effect of oxygen percentage on the hydrated electron yield using proton beam.

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From Concept to Capability: IAEA's Role in Radiation Technology Applications

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The International Atomic Energy Agency (IAEA) plays a critical role in transforming innovative concepts in radiation technology into practical capabilities within its Member States. Through a combination of technical cooperation projects, coordinated research initiatives, training workshops, and knowledge-sharing platforms, the IAEA facilitates the development, adaptation, and safe application of radiation technologies in key areas such as healthcare, industry, agriculture, and environmental protection.

The Agency's efforts encompass both foundational support − such as education and infrastructure development − and advanced initiatives, including the deployment of a mobile electron beam facility for on-site training and demonstration, and the launch of a comprehensive e-learning platform to expand access to technical knowledge. These tools strengthen national capacities, particularly in developing countries, and enable broader implementation of proven technologies like sterilization, pollution treatment, materials modification, and cultural heritage preservation.

This presentation will explore how the IAEA bridges the gap between research and real-world implementation, highlighting recent successes and emerging trends in areas such as plastic recycling and value-added material production. The lecture will also reflect on the importance of multidisciplinary collaboration and international cooperation in driving innovation and building sustainable radiation technology capabilities globally.

The Development, Status and Future of Radiation Processing

Martin Comben[1]
[1]*International Irradiation Association*

The history of radiation processing dates back to the 1950's with the first commercial production of cobalt-60 and linear accelerators. Since these early steps, the science, technologies and applications of irradiation have grown enormously. Today, radiation processing is a global industry that helps to keep us safe and healthy, supports our economies and helps to protect the global environment.

The business of irradiation has evolved as radiation processing has moved from an age of pioneers to that of multinational businesses. Today, radiation processing is a complex, dynamic and competitive market place. Organisations and technologies are evolving, new science is being introduced and current challenges are being addressed. Additionally, there is a greater focus on sustainable operating practices and this is changing the way that organisations operate.

Radiation processing has a bright future as demand continues to grow and new applications are introduced. This presentation summarises the important issues of the irradiation market, highlights the important technology developments, and looks at the prospects and focus for the future.

Radioprotective Mechanisms of Positively Charged Peptides: Comprehensive Analysis of Hydroxyl Radical Scavenging and Chemical Repair

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Radiation therapy has been widely applied as one of the most effective modalities in cancer treatment. Despite its clinical benefits, severe side effects arising from radiation-induced damage to normal tissues remain a major challenge. Therefore, developing radioprotective agents that can alleviate such adverse effects has attracted continuous attention. Among various candidates, positively charged peptides (PCPs) have recently gained interest due to their favorable properties, including biocompatibility, cell-penetrating ability, and strong affinity toward negatively charged DNA. In this study, a series of PCPs, including His-Tyr-His, Lys-Tyr-Lys, Arg-Tyr-Arg, His-Cys-His, and Arg-Cys-Arg, were synthesized by solid-phase peptide synthesis and characterized to investigate their radioprotective properties.

The hydroxyl radical (•OH) scavenging rates and chemical repair capabilities towards deoxyguanosine monophosphate (dGMP) radicals were determined by pulse radiolysis as a part of collaborative research project at Nuclear Professional School, the University of Tokyo. The results revealed that both the radical scavenging and chemical repair capabilities of PCPs were strongly dependent on their amino acid sequences. Among the Tyr-containing PCPs, Arg-Tyr-Arg exhibited the highest chemical repair rate, whereas His-Tyr-His exhibited the highest radical scavenging capacity; however, its chemical repair ability was the lowest, which may be attributed to the shielding effect of the His residues on the Tyr residue.

Since Cys has been widely recognized as an effective radical scavenger and radioprotective agent, the Cys-containing PCPs (His-Cys-His and Arg-Cys-Arg) were further examined. Although they exhibited •OH scavenging abilities comparable to those of Tyr-containing PCPs, their chemical repair activities were significantly inferior. This unexpected result suggests that Tyr may play a more crucial role than Cys in DNA radioprotection through efficient chemical repair, providing novel insights that challenge the conventional understanding of amino acid-based radioprotectors.

In addition, DNA protection experiments utilizing agarose gel electrophoresis combined with base excision repair enzyme treatment demonstrated that all PCPs effectively suppressed radiation-induced single- and double-strand breaks, whereas their protective effects on base damage showed distinct sequence-dependent tendencies. These differences may originate from the interactions between each PCP and DNA. Such variation may further serve as a basis for the development of PCP-based radioprotectors with targeting abilities toward specific DNA structures.

Radiolysis of Water and Protein Biomolecules at High Dose Rates

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FLASH radiotherapy, using high-dose-rate radiation, is a very promising modality. Healthy tissues seem to be better preserved at high dose rates, while the therapeutic effect on tumors remains intact. The mechanisms behind the so-called "FLASH effect" are still widely debated. Water radiolysis is the first chemical step in the indirect effects of ionizing radiations on cells, and is likely to play a role in the FLASH effect. It is therefore interesting to assess the influence of dose rate on water radiolysis species. The next step, considering *indirect effects* of ionizing radiation, is the reaction of water radiolysis reactive species, HO• in particular, with biomolecules. Proteins being the most abundant biomolecules in the cell, IPHC Radiochimie team studies their radiolysis mechanisms, as well as that of their building blocks, amino acids and peptides.

Hydroxyl radical and hydrated electron e^-_{aq} yields were measured under 24 MeV H^+ irradiation with several molecular probes at various dose-rates, from conventional one, up to 200 Gy/s, higher than what is generally considered as FLASH dose-rate (40 Gy/s).

For both species, measured at scavenging times of 74 and 296 ns, no dose-rate effect was observed under these experimental conditions.

Radiolysis of phenylalanine, an aromatic amino acid, and aspartame, a small peptide containing phenylalanine, were studied under the very same conditions as water radiolysis measurements, at a scavenging time of 74 ns. We have shown that radiolysis of phenylalanine included in a peptide follows the same mechanism as with the free amino-acid, with tyrosine ortho, meta and para isomers as the main products, along with dihydroxy phenylalanine isomers (DOPA). At conventional dose-rate, dimers form specifically under ion irradiation, as well as 2,5-DOPA specifically.

In conditions were no dose-rate was observed with water radiolysis species e^-_{aq} and HO•, we could identify a dose-rate effect on the radiolysis of both biomolecules, with an increasing formation of 2,5-DOPA with increasing dose-rate. This was also observed with electrons, and at much higher dose-rate, with C and He ions (cf. figure). Radiolysis mechanisms of the increased formation of 2,5-DOPA will be discussed.

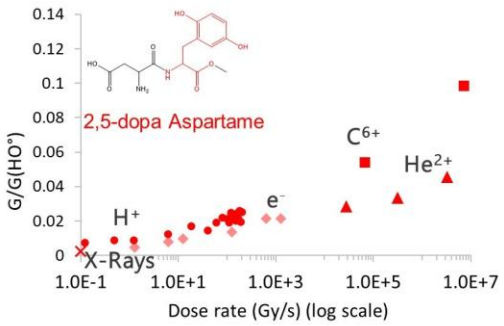

Figure 1. Radiolytic yields of formation of 2,5-DOPA Aspartame, normalized by G(HO•), under irradiation by various ionizing radiations, as a function of dose-rate. x, X-rays; dots 24 MeV H, diamonds 1 MeV e-, trangles He ions, squares C ions.

Ionic Intermediates of the Radiation-induced Transformations of Phosphine Molecules in Cryogenic Media: a Matrix Isolation and Computational Study

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Phosphine (PH_3) is considered as a biosignature molecule in interstellar icy media and planetary atmospheres, where it can be subjected to UV and ionizing radiation. Previously, we investigated the spectroscopic characteristics and formation mechanism of neutral species ($PH_2^{\bullet}$ and PH) resulting from isolated phosphine molecules under VUV and X-ray irradiation in cryogenic media [1]. This research focuses on identification of ionic intermediates produced by X-ray irradiation of solid PH_3/Ng matrices (Ng = Ne, Ar, or Kr) at 4.5 K using a combination of EPR and FTIR spectroscopy, complemented with ab initio computations. It was shown that both cationic and anionic species are stabilized in irradiated PH_3/Ng films, and the effect of electron scavenger (SF_6 or $CFCl_3$) allowed us to unambiguously distinguish between cationic and anionic intermediates. In the absence of scavengers, we have identified PH_2^- and $PH^{-\bullet}$ anions using FTIR spectroscopy and comparison with quantum-chemical calculations [2]. Based on analysis of matrix effects, we have proposed two possible mechanisms of $PH^{-\bullet}$ formation. The cationic species are also formed in the PH_3/Ng matrices, whereas their yield dramatically increases in the presence of electron scavengers. The formation of $PH_3^{+\bullet}$ as a primary product of PH_3 radiation-induced transformations was clearly revealed by both EPR and FTIR spectroscopy. In addition, the dimeric cationic form – $P_2H_6^{+\bullet}$ was detected in the samples with higher PH_3 concentration. The assignment was confirmed by deuteration (using PD_3 instead of PH_3). The experimental and computational results show that the P-H stretching frequencies in anionic species are red-shifted in respect to those in the corresponding neutrals indicating weakening of the P−H bonds. On the contrary, the P-H stretching vibrations in $PH_3^{+\bullet}$ are blue-shifted in respect to PH_3, which implies strengthening of the P−H bonds. Remarkably, the most intense IR absorption in $P_2H_6^{+\bullet}$ corresponds to the deformational mode, while the P-H stretching are very weak in this symmetric structure. The vibrational spectra of $PH^{-\bullet}$, $PH_3^{+\bullet}$ and $P_2H_6^{+\bullet}$ were experimentally obtained and assigned for the first time. We believe that the obtained results may be useful for molecular astrophysics and basic radiation chemistry of phosphorus containing molecules.

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Overlooked Activation Role of Sulfite in Accelerating Hydrated Electron Treatment of Perfluorosulfonates

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Photoexcitation of sulfite (SO_3^{2-}) is frequently employed to produce hydrated electrons (e_{aq}^-) for degrading per- and polyfluoroalkyl substances (PFAS)[1]. It is generally acknowledged in existing studies that effective defluorination should avoid SO_3^{2-} concentrations higher than 10 mM[2]. Consequently, this limitation has impeded a deeper understanding of sulfite chemistry beyond its function as an electron source through photolytic processes. By contrast, this study employs radiation chemistry, directly generating e_{aq}^- via water radiolysis, revealing a previously unrecognized activating role for SO_3^{2-} in defluorination reactions[3]. Quantitative experiments utilizing ^{60}Co gamma irradiation demonstrated that elevating SO_3^{2-} concentration from 0.1 M to 1 M substantially improved the defluorination rate by approximately 15 times, particularly evident for short-chain perfluoroalkyl sulfonates (PFSA). Additionally, when treating long-chain PFSA (C_8F_{17}-SO_3^-) at higher SO_3^{2-} concentrations, previously unobserved intermediate species, namely C_8H_{17}-SO_3^- and C_3F_7-COO^-, were detected, which were absent in reactions without SO_3^{2-}. These experimental findings underscore that increased SO_3^{2-} concentration promotes both primary reaction pathways: carbon-chain shortening and hydrogen-fluorine exchange. Pulse radiolysis measurements further confirmed that high concentrations of SO_3^{2-} accelerated the bimolecular reaction rate between e_{aq}^- and PFSA by two orders of magnitude. Moreover, ^{19}F NMR spectroscopy and theoretical simulations provided insights into the non-covalent interactions between SO_3^{2-} and fluorine atoms, significantly lowering the carbon-fluorine bond dissociation energy by nearly 60%. Consequently, this research presents a more efficient approach to the degradation of highly persistent PFSA contaminants.

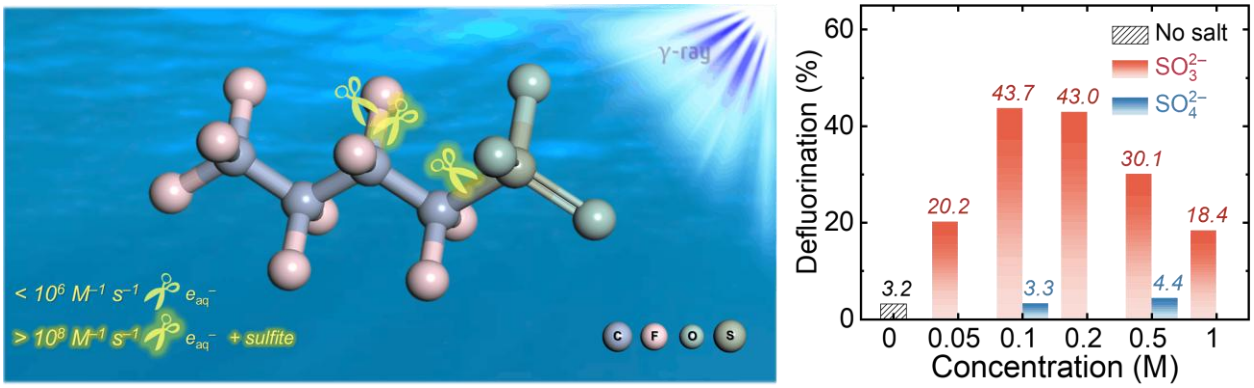

Figure 1. Scheme of the acceleration treatment of PFBS by eaq- in the presence of sulfite.

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Slow Solvation of the Solvated Electron in LiCl Water Salt Solutions

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Since the discovery of the solvated electron, it has been widely reported that dissolved cations and anions significantly influence its absorption maximum. An increase in salt concentration typically induces a blue shift in the solvated electron's (e_s^-) absorption spectrum. Early work by Kreitus et al. systematically studied these shifts in aqueous LiCl solutions (up to 15 M) and highlighted the unique role of Li+ in altering the electron's local environment. Mostafavi et al. extended this research to various chloride and perchlorate salts, finding that both cation size and the salt's dissociation degree affect the extent of the observed spectral shift. However, despite these efforts, the dynamics underlying electron-cation pairing and subsequent solvation have remained experimentally uncharted.

Here, we present a picosecond pulse radiolysis study on electron solvation dynamics in LiCl solutions over a broad concentration range (2-14.6 M). We observe a clear, concentration-dependent increase in the electron solvation time, from about 10.6 ps at 3.5 M LiCl to 17.3 ps at 14.6 M, indicating progressively stronger interactions between the excess electron and Li+ hydration shells. These findings shed new light on ion-specific solvation phenomena and, for the first time, reveal the temporal evolution of electron-cation pair formation in LiCl solutions.

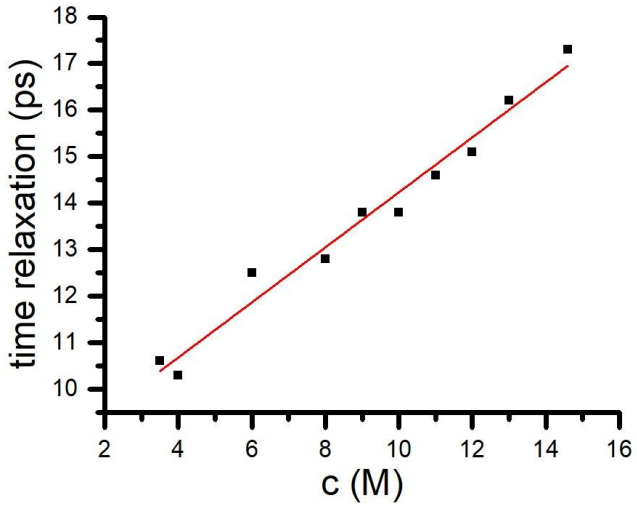

Figure 1. Time of solvation of Li-cation solvated electron pairs in water at different LiCl concentration.

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Mechanistic Insights into Fe^{2+} Formation in $FeCl_3$/TRITON X-100 Systems via Pulse Radiolysis

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Superparamagnetic magnetite/maghemite iron oxide nanoparticles have recently been synthesized via electron beam radiolysis of $FeCl_3$/TRITON X-100 microemulsions.[1] To optimize radiolysis conditions, a deeper mechanistic and kinetic understanding of nanoparticle formation in these emulsions is required. Thus, pulse radiolysis studies were conducted to complement electron beam radiolysis investigations.

In this study, we employed pulse radiolysis to examine the interactions of water radiolysis products, particularly solvated electrons (e_{aq}^-) and hydroxyl radicals ($^\bullet$OH), with $FeCl_3$, TRITON X-100, and their mixtures. While Fe^{3+} reduction by e_{aq}^- proceeded as expected and aligned with literature reports, we identified an additional Fe^{2+} formation pathway. The reaction of TRITON X-100 with $^\bullet$OH generated cyclohexadienyl radicals, which, in the presence of Fe^{3+}, underwent oxidation with a rate constant of 4×10^7 L mol^{-1} s^{-1}, yielding Fe^{2+} and hydroxy-substituted TRITON X-100 derivatives.

This secondary reduction pathway explains the enhanced Fe^{2+} yield observed during electron beam-induced nanoparticle synthesis. These findings provide valuable insights for optimizing radiolytic iron-based nanoparticle synthesis by leveraging both direct and indirect Fe^{3+} reduction mechanisms.

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Effect of Oxide Nanoparticles on Radical Formations under X-ray Irradiation of Aqueous-organic Systems: Physical and Chemical Enhancement

Anzhelika Vanina[1], Ekaterina Shiryaeva[1], Elizaveta Sanochkina[1], Irina Baranova[1], Vladimir Feldman[1]

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Radiotherapy remains one of the most effective cancer treatments, yet its efficiency can be further improved by combining it with nanoradiosensitizers. Now metal oxide nanoparticles (NPs) containing elements with high atomic number (Z) have been widely used for these purposes. These NPs enhance the effects of X-ray irradiation through both physical mechanisms (increased photon absorption due to high-Z atoms) and chemical mechanisms (redox reactions involving solvated electrons). This study aims to establish the enhancement mechanisms in oxygen-free aqueous-organic systems under X-ray irradiation (20-45 keV) in the presence of metal oxide nanoparticles.

Metal oxide NPs (HfO_2, WO_3, SnO_2) with varying sizes were synthesized via hydrothermal, sol-gel methods or spray pyrolysis in flame, respectively. Radical yields were quantified using spin-trapping technique (C-phenyl-N-tert-butylnitrone, PBN) with EPR spectroscopic detection. Hydroxyl radicals, primarily generated in the water-CH_3OH-PBN-NPs systems, quantitatively reacted with methanol to form $^{\bullet}CH_2OH$ radicals, which were trapped as stable CH_2OH-$PBN^{\bullet}$ adducts. The ratio between absorbed dose in the Fricke dosimeter and in the investigated samples was determined by the Monte Carlo simulation (Geant4 code).

The main findings revealed that HfO_2 NPs (diameters 18 and 84 nm) exhibited only physical enhancement regardless of NP size, which is consistent with dose absorption calculations [1]. For WO_3 NPs with an average diameter of 40 nm, physical enhancement was dominant, while smaller NPs (d = 2 nm) showed additional chemical enhancement attributed to the redox activity of W^{VI}, and this effect increased in homogeneous Na_2WO_4 solutions [2]. In contrast, the low-Z SnO_2 NPs (d = 5 nm) showed solely chemical enhancement via Sn^{IV} redox reactions, which was absent for larger NPs, highlighting the critical role of surface area in radical generation.

These results establish two criteria for chemical enhancement (observed even for low-Z elements) in the oxygen-free systems: 1) the presence of metastable oxidation state of metal enabling redox reactions, and 2) large NP surface. These findings provide a common basis for the optimal selection of metal oxide NPs as radiosensitizers in the X-ray medical treatments (e.g., targeting hypoxic tumors) and material chemistry.

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Development, Isolation, and Production of Radioisotope-Enriched Copper Nanoparticles

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The rising global cancer burden has accelerated advancements in diagnostic and therapeutic agents. In this context, radionuclides are synthesised using medical cyclotrons or nuclear reactors, ideally serving both imaging and therapy with suitable half-lives. Target materials must also be affordable, available, and yield high-quality products [1-3]. Theragnostic applications have recently expanded rapidly. This study is part of the 'Optimised Production of Theragnostic Isotopes of Copper and Scandium (OPTICS)' project, funded by the Department for Energy Security and Net Zero (DESNZ, MRIP-08), which aims to develop an automated, modular system spanning transmutation to synthesis. This report focuses on blended copper isotopes (nat/61Cu, nat/64Cu). Transmutations are carried out at the Dalton Cumbrian Facility, where copper-based nanoradiopharmaceuticals are produced via a fully automated process involving dissolution, separation, nanoparticle synthesis, and antibody labelling.

For copper radioisotope production, natural nickel (natNi) and enriched 61Ni were used as target materials. The solid targets were dissolved in concentrated HCl with a few drops of 30% H_2O_2. The solution's pH was adjusted to 9 with ammonia, diluted with deionized water, and electrodeposited at 4.5 V and 50 µA. Transmutations were performed using protons (up to 10 MeV) and alpha particles (up to 15 MeV) for 1-2 hours. For separation, a Dowex 1x8 chloride resin was employed. The column was preconditioned with 9 M HCl; nickel was eluted with the same, and copper was subsequently eluted using 0.1 M HCl. Copper nanoparticles were then synthesised using catechin at 30°C for one hour under nitrogen flow. All steps were carried out in a fully automated, computer-controlled system, including a Target/Dissolution unit, a Separation Board, and a Vortex Mixer, the latter two installed in a hot cell for remote and safe operation.

The gamma counter results obtained indicate that the transmutation of 61/64Cu was successfully achieved. Furthermore, based on the size measurements and electron microscopy findings, the Cu nanoparticles range from 1 to 50 nm in diameter. Later, functional nanoparticles will be PEGylated and conjugated to PSMA-617, a prostate-specific membrane antigen ligand; their efficacy against prostate cancer will be evaluated in vitro.

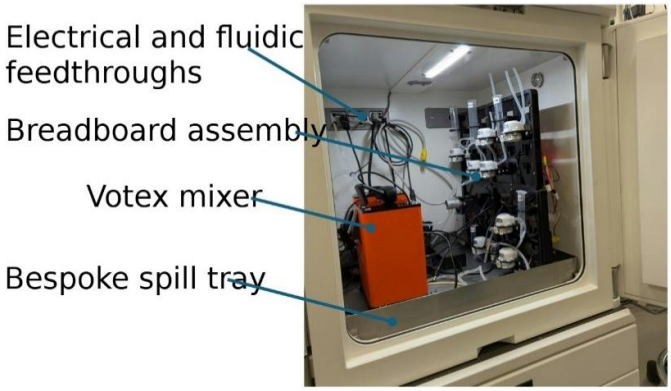

Figure 1. Automation system in the hot cell.

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Radiation Chemistry of Lead Iodide at High Dose Rates

Alžběta Horynová[1, 2], Věra Hájková[1], Šimon Jelínek[1, 3, 4], Jaromír Chalupský[1], Vojtěch Vozda[1], Luděk Vyšín[1], Jakub Bulička[1, 4], Tomáš Burian[1], Roman Dudžák[1, 3], Michal Krupka[1, 2, 3], Zuzana Valdová[1, 4], Josef Krása[1], Michal Šmíd[5], Nikita Medvedev[1, 3], Ladislav Fekete[1], Robert Král[6]

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Modern pulsed sources of intense x-ray and extreme ultraviolet (XUV) radiation, such as free-electron lasers (FELs) and capillary-discharge lasers (CDLs), pave the way towards understanding the radiation damage processes occurring in solids at extreme energy densities and dose rates. Lead iodide PbI_2, a wide band gap semiconductor with a polytypic layered crystalline structure, is frequently used for ablation imprinting of focused x-ray FEL beams, benefiting from its high density and effective atomic number. The method makes it possible to characterize the beam and determine its interaction parameters (e.g., lateral distribution of intensity, focal spot diameter, energy and fluence) and at the same time offers insight into the mechanisms of x-ray laser-induced decomposition reactions and phase transitions occurring in the irradiated material. At very high dose rates, a key question arises whether the character of the damage process in lead iodide is either thermal or non-thermal, and special attention should be paid to a possible interplay between thermal and non-thermal effects. Irreversible changes induced in PbI_2 samples by radiation pulses have been indicated *in situ* (ion mass spectrometry) and *ex situ* (Raman spectroscopy, atomic force microscopy, Nomarski microscopy, scanning electron microscopy, etc.). Both thermal and non-thermal processes have also been investigated using computer simulations, and solely thermal effects have been studied by various techniques of thermal analysis, e.g., thermogravimetry (TG) and differential thermal analysis (DTA). Experimental results obtained with x-ray FEL and XUV CDL sources will be compared to the thermal decomposition and the behavior of lead iodide crystals under irradiation with conventional radiation sources.

The Impacts of Metal Oxide Surfaces on the Chemistry of Water Radiolysis

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Molecular hydrogen (H_2) is in high demand as an energy storage, and as a feedstock for steel and ammonia production. Consequently, studying the various pathways for efficient H_2 generation is important for meeting the growing demand for affordable H_2. The use of ionizing radiation to generate H_2 through water radiolysis is an underutilized method. Tangentially, this same process also poses a major safety concern for the storage of used nuclear fuel and radioactive waste. Therefore, understanding the mechanisms of H_2 generation under ionizing radiation is crucial. While bulk water radiolysis can yield 0.45 molecules of H_2 per 100 eV of deposited radiation, certain metal oxides, such as zirconium oxide (ZrO_2), can enhance H_2 production by several orders of magnitude when the reaction occurs at the interface between the oxide surface and adsorbed water.[1] In bulk water, H_2-precursors can be scavenged by oxygen-centered radicals, such as hydroxyl radicals. On irradiated metal oxides, oxygen-centered radicals have been shown to live longer than hydrogen radicals.[2] Differences in radical mobility between H_2-precursors and H_2-scavengers at the surface leads to phase separation resulting in: H_2-precursors efficiently recombining and rapidly transferring to the gas phase; and the incorporation of the oxygen-centered radicals into the crystal lattice of the metal oxide materials. This phase separation may be the key factor responsible for the enhanced yields of H_2 in irradiated hydrated metal oxide systems. This work investigates the accumulation and identification of long-living oxygen-centered radicals on the surface of various oxides, including ZrO_2, which are relevant to nuclear energy applications. The radicals were generated by irradiating hydrated oxide powders up to 10 MGy with cobalt-60 gamma rays or accelerated 5 MeV helium ions. Irradiated materials were analyzed using X-ray photoelectron spectroscopy, electron paramagnetic resonance, and diffuse-reflectance infrared spectroscopy. The knowledge gained was then used to develop engineered ZrO_2-nanomaterials for efficient radiolytic H_2 generation. The impacts of dopant ions on H_2-generating capacity of these novel electrospun materials were also examined.

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In Situ Synthesis of Silver Nanoparticles in Pectin Matrix Using Gamma Irradiation for the Preparation of Antibacterial Pectin/Silver Nanoparticles Composite Films

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I*n situ* synthesis of silver nanoparticles (AgNPs) in pectin matrix using γ-irradiation at 2.5 and 5 kGy and preparation of antibacterial pectin-based nanocomposite films. The FE-SEM micrographs showed that the neat pectin film was smooth but became a little rough after forming AgNPs in the pectin films. The UV-visible spectroscopy analysis exhibited a surface plasmon resonance (SPR) band about 430 nm confirming the formation of AgNPs in the pectin films. The Hunter color values of nanocomposite film changed after the formation of AgNPs. FTIR and thermogravemetric analysis results revealed no structural and thermal stability changes in the pectin films after the synthesis of AgNPs by γ-irradiation. However, mechanical properties and water vapor permeability of the composite films improved after AgNPs synthesis. The pectin-AgNPs nanocomposite films exhibited potent antibacterial activity against *Escherichia coli* and *Salmonella* Typhimurium. The developed antibacterial pectin-based nanocomposite films incorporated with AgNPs using γ-irradiation have a potential to increase the shelf life of packaged food.

Assessment of Performance Through Life for New Polymer Technologies in High Radiation Environments.

Julian Murphy[1], Philip Cobb[1]
[1]*AWE*

To enable the development and eventual deployment of new technologies in environments, where they are exposed to high levels of ionising radiation, the maturity of the technology must be assessed at critical decision points. Polymeric materials undergo changes due to the accumulation of a significant radiation dose, through an extended service life, which poses particular challenges. The presentation will detail Technology Readiness Levels (TRLs), which are applicable to component technologies where both the materials and production process are linked to ultimate performance. Also discussed will be the associated assessment of performance and the impact of the accumulated radiation dose through an extended service life.

Compaction of Mesoporous Silicas by Radiation Effects

Jun Lin[1], Clara Grygiel[2], Sandrine Dourdain[1], Yannick Guari[3], Cyrielle Rey[1], Sophie Le Caer[4], Guillaume Zante[4], Jérémy Causse[1], Olaf Walter[5], Denis Menut[6], Xavier Deschanels[1]

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In recent years, mesoporous silicas (SBA15, MCM41) discovered in the 1990s [1] have been the subject of numerous studies for various applications in the field of catalysis, CO_2 encapsulation, or treatment of radioactive effluents [2]. More precisely, a new strategy for this treatment is based on the use of a mesoporous silica functionalized by an organic ligand selective of the RadioNuclides (RN). This hybrid material would allow at the same time the separation of the RN and their encapsulation after collapsing the porosity. Several ways are being considered to close the mesoporosity: chemical reactions (sol-gel in particular), thermomechanical treatments, and irradiation effects. The collapse of silica mesoporosity by external irradiation (ion and electron) has been demonstrated in several works [3]. More recently, the possibility of closing the porosity of a mesoporous silica through self-irradiation damage produced by the presence of the short-lived actinide ^{238}Pu has been studied in our laboratory. The results of this work will be presented in the talk.

^{239}Pu and ^{238}Pu sorption experiments have shown that hybrid silicas grafted with phosphonate ligands (Ac-Phos and Prop-Phos) [4] have a loading capacity of around 10% by weight. Small-angle X-ray scattering (SAXS), which is accessible on the SOLEIL synchrotron's MARS beamline, was employed for characterization of these Pu-doped materials. After 27 months of ageing, these measurements show a decrease in the interplanar (100) distance of the hexagonal pore network of mesoporous silica, indicating a densification of around 10% of the pore volume (Figure 1). Results relating to the radiolysis of the phosphonate ligands will also be discussed [5].

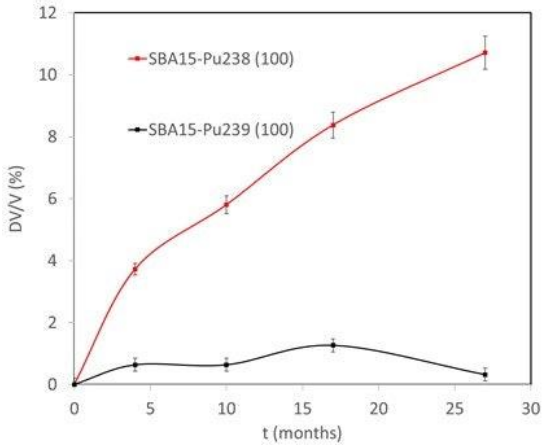

Figure 1. Comparison of the evolution of the volume of the hexagonal cell of SBA15-Prop-phos ^{238}Pu and SBA15-Prop-phos ^{239}Pu, versus ageing duration. The volume is calculated on the basis of the (100) plane of the porous network. SBA15 sample doped with ^{239}Pu is used as a reference because this short-lived isotope induces very low level of damage in the mesoporous silica.

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Effect of the Lanthanide on the Radiolytic Stability of Ln-DOTA Complexes

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For the past decade, radionuclides have been increasingly used in nuclear medicine, for both diagnostic and therapeutic applications. The introduction of these radionuclides into a biological environment is generally achieved through a radiopharmaceutical composed of three elements:

- a radionuclide, source of radiation;
- a chelating agent, which can bind stably to the radionuclide to avoid any release into the body ;
- a targeting vector, which transports the radiopharmaceutical to the target cells.

Targeted radionuclide therapy, using β^- emitters (such as ^{177}Lu) or α emitters (such as ^{225}Ac) encapsulated in a radiopharmaceutical, appears very promising for cancer treatment.[1] When in contact with the radionuclide, the chelating agent as well as the targeting vector can be affected by radiation which can lead to the degradation of the chelating agent or the vector and therefore an alteration of the radiopharmaceutical's properties, or even to the release of the radionuclide in the body.
Among the radionuclides most promising for radiotherapy are ^{177}Lu, ^{225}Ac, and ^{149}Tb.[2] One of the most widely studied chelating agents in nuclear medicine for these radioisotopes is DOTA (1,4,7,10-tetraazacyclododecane-1,4,7,10-tetraacetic acid). Previous studies[3] identified degradation products of the DOTA ligand formed under gamma irradiation both in the absence and presence of Zirconium(IV). The study revealed that complexing DOTA with Zr increases its radiolytic stability and changes degradation mecanisms.
The aim of this study is to investigate the radiolytic stability of Ln-DOTA complexes in aqueous solution after γ irradiation (Ln = Lu, La, Tb). The degradation products obtained were identified by Electrospray Ionization Mass Spectrometry (LC-ESI-MS). Quantification of the Ln-DOTA degradation was made by ^{1}H NMR (Figure 1). Quantum chemistry calculations by DFT were also performed to determine bond dissociation energies (BDE) and Fukui functions. Fukui indices indicate chemical reactivity of a particular atom towards radical attack whereas BDEs evaluate bond strength. Based on these results, degradation pathways will be presented. The degradation of the Ln(III)-DOTA complex will be discussed and compared to those of the Zr(IV)-DOTA complex and the protonated DOTA.[3]

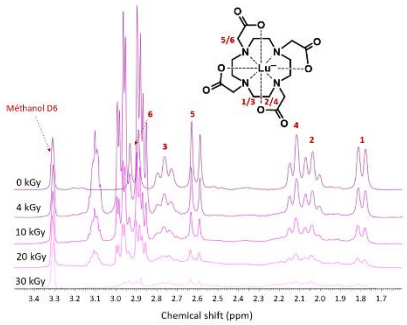

Figure 1. 1H NMR spectra of irradiated Lu-DOTA solution. Conditions: 5 mM in pure water (pH 6.5). MethanolD4 is used as an external lock solvent. From top to bottom: 0, 4, 10, 20 and 30 kGy.

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How the Structure of Model Disulfides Affects Reactivity with Singlet Oxygen

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Disulfide bonds are critical structural elements in some biologically relevant peptides and proteins as they stabilize folded structures. Oxidative modifications of these linkages may be associated with a loss of structure and function. In this work we investigated the oxidation of a series of model disulfides with singlet oxygen ($^1O_2$), a key intermediate in photo-oxidation reactions. The kinetics of disulfide-mediated $^1O_2$ removal were monitored using the time-resolved 1270 nm phosphorescence of $^1O_2$. The experiments were carried out using a home-made, time-resolved emission spectrophotometer based on TCSPC/MCS method. Stern-Volmer plots of these data showed a large variation in the quenching rate constants k_q (from 2×10^7 for α-lipoic acid to 3.6×10^4 $M^{-1}s^{-1}$ for cystamine). It was found that 5-membered ring disulfides (lipoic acid, lipoamide) react more rapid than linear disulfides. LC-MS analyses show formation of mono- (thiosulfinate) and di-oxygenated (thiosulfonate) products. The variation in quenching rates and product formation are ascribed to zwitterion stabilization by neighboring, or remote, lone pairs of electrons. These data suggest that some disulfides, including some present within or attached to proteins (e.g., α-lipoic acid), may be selectively modified, and undergo subsequent cleavage, with adverse effects on protein structure and function.

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Ionizing Radiation for Cultural Heritage Preservation: Material Characterization and Biocidal Efficacy

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Ionizing radiation is increasingly recognized internationally as a valuable tool for the preservation of Cultural Heritage (CH), offering effective disinfection of artworks composed of various organic and inorganic materials, such as paper, parchment, wood, and stone. While widely adopted in several countries, this technique remains underutilized in Italy, where concerns about possible radiation-induced physico-chemical modifications still limit its broader acceptance among CH professionals. There is therefore a strong need to disseminate reliable scientific data to encourage the responsible and evidence-based adoption of this technique in Italy. Compared to conventional conservation methods, which often involve toxic chemicals that pose health risks to operators, radiation treatment is rapid, sustainable (leaving no chemical residues), and fully compatible with restoration techniques. It represents a non-invasive and scalable solution for the long-term preservation of fragile and biodeteriorated artifacts.

This study presents recent research carried out at the Calliope gamma irradiation facility (1) of the ENEA Casaccia Research Center (Rome, Italy), employing gamma radiation from a ^{60}Co source. Different experimental techniques, such as FTIR, Raman, and EPR spectroscopy, along with colorimetric analysis, were applied to investigate the molecular and structural modifications induced by irradiation in CH materials (2,3). Complementary microbiological evaluations were performed to assess the biocidal efficacy of the treatments against biodeteriogenic agents.

The results contribute to a deeper understanding of the secondary effects induced by ionizing radiation and support its safe and effective application for the conservation of cultural artifacts. Selected case studies involving various materials, including ancient paper, parchment, synthetic leather, and textile fabric, are discussed, providing evidence of the potential of this technology for Cultural Heritage preservation.

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Valorization of Agri-Food Wastes Using Ionizing Radiation: the Role of Extraction Conditions on Different Matrices

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The increasing generation of agri-food wastes raises environmental and economic impacts. Nevertheless, these wastes are rich in valuable bioactive compounds with potential health benefits and their sustainable recovery offers a promising opportunity for industries to develop cost-effective strategies aligned with circular economy principles.

In this work, ionizing radiation (2 and 4 kGy) were applied to pineapple and avocado wastes (core, pulp and peel) to evaluate its feasibility in improving the extractability of bioactive compounds, as well as the bioactivities of the obtained extracts. Furthermore, the extraction conditions to recover these compounds were optimized in order to select the most efficient methodology to maximize the bioactivity of the obtained extracts, using ethanol (50 and 80%, v/v) and water as solvents at different temperatures (25, 50, and 90 ºC).

For pineapple wastes, the best conditions to extract bioactive compounds from the pulp and core were achieved at 25 ºC using water as solvent, while for the peel, the optimal conditions were at 90 ºC using 80% ethanol. Furthermore, ethanolic peel extracts seemed to present higher bioactive content and bioactivity than aqueous core and pulp extracts. Regarding the effect of gamma radiation, 4 kGy appeared to preserve the total phenolic content, antioxidant activity, and antidiabetic activity of the ethanolic peel extracts. The results also indicated that pineapple gamma irradiation preserved the bioactive content, antioxidant activity, and antidiabetic activity of aqueous pulp extracts, especially at 2 kGy.

For avocado wastes, the optimal extraction conditions were 90 °C with 50% ethanol for the pulp and peel, and 25 °C with 80% ethanol for the core. In comparison with peel and core extracts, pulp extracts presented the lowest content of total phenolic compounds as well as lowest antioxidant activity. Electron beam irradiation at 2 kGy of avocado seemed to enhance the phenolic content and antioxidant activity of peel and core extracts and to preserve the bioactivities of pulp extracts.

The outcomes of this work may help promoting the use of ionizing radiation as a sustainable process, while offering valuable insights to develop new ingredients for food and pharmaceutical industries and supporting the implementation of the circular economy practices.

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Radiolytic Degradation of Sulfamethoxazole (SMX) in Aqueous Solution under Electron Beam Irradiation with H_2O_2 Addition

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The radiolytic degradation of sulfamethoxazole (SMX), a widely used antibiotic and persistent water contaminant, was investigated under electron beam irradiation in the presence of hydrogen peroxide (H_2O_2). The study focused on elucidating the underlying degradation mechanisms and identifying the reactive species responsible for SMX decomposition. The individual effects of hydroxyl radicals ($^{\bullet}OH$), hydrogen atoms ($H^{\bullet}$), and hydrated electrons (e^-_{aq}) were examined by varying the aqueous medium conditions. It was found that the degradation efficiency followed the order: N_2O-saturated water > deionized water > Ar-saturated water with *tert*-butanol at pH 2 > Ar-saturated water with *tert*-butanol (Figure 1), confirming that $^{\bullet}OH$ radicals play the dominant role in SMX degradation.

The addition of H_2O_2 significantly enhanced $^{\bullet}OH$ formation, thereby accelerating SMX degradation via oxidative pathways (Figure 2). At an absorbed dose of 0.5 kGy and an initial SMX concentration of 10 mg/L, the addition of 10 mg/L H_2O_2 increased the degradation efficiency by approximately 10%. A further increase in H_2O_2 concentration to 20 mg/L led to an additional 3.2% removal of SMX.

LC-MS analysis of degradation products revealed key transformation pathways, including hydroxylation, aromatic ring opening, and sulfonamide bond cleavage. These findings provide mechanistic insight into the $^{\bullet}OH$-driven degradation pathways and demonstrate the potential of electron beam irradiation, enhanced by H_2O_2, as an effective advanced oxidation process for removing pharmaceutical micropollutants from water.

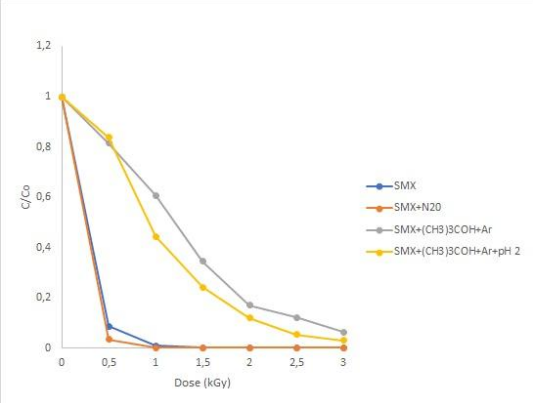

Figure 1. Reactive species responsible for SMX decomposition in aqueous solution under electron beam irradiation.

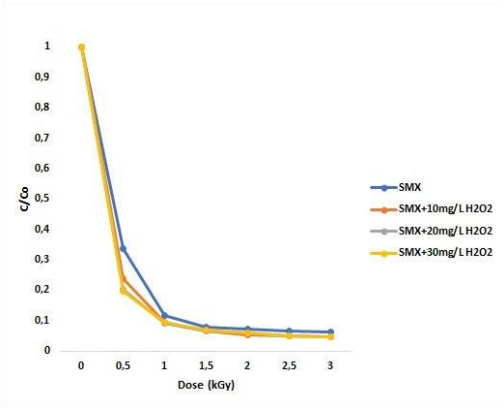

Figure 2. Influence of H_2O_2 addition on SMX degradation in aqueous solution under electron beam irradiation.

Acknowledgments. This work is financed by the National Center for Research and Development, Poland-China Cooperation Program, acronym TAPEB "Advanced treatment of typical antibiotic pharmaceuti-cal wastewater using electron beam irradiation" under contract number (WPC3/2022/68/TAPEB/2024) and the Key Program for Intergovernmental S&T Innovative Co-operation Project of China (2024YFE0101700).

Radiation-Induced Graft Polymerization: Tuning Macromolecular Structure and Properties for Environmental and Other Applications

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Radiation-induced graft polymerization (RIGP) is an effective technique for producing materials that can be customized for specific applications, utilizing either gamma irradiation or electron beam irradiation, each presenting distinct advantages. This work presents the use of RIGP with various monomers to synthesize polypropylene and pineapple fiber-based adsorbents for chromium and gold ions from aqueous media. The effect of various grafting and functionalization parameters was systematically varied to evaluate their effect to the grafting and adsorbent development. The FTIR and XPS spectra, as well as the results from other characterization methods, of the pristine and modified trunk materials showed the changes on the surface of the fabric brought about by the grafting and subsequent functionalization. The adsorption performance of the fabrics was evaluated at varying conditions. The findings demonstrate the potential of using the adsorbents for removing pollutant metal ions and recovering precious metals in aqueous solutions. These accomplishments strengthen the assets of radiation processing to help address existing and emerging challenges and promote a sustainable future.

Radiation-Induced Insights into Vinylene Carbonate Reduction Mechanisms in Li-Ion Battery Solid Electrolyte Interphase

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In lithium-ion batteries, the incorporation of electrolyte additives such as vinylene carbonate (VC) is essential for forming a stable and protective solid electrolyte interphase (SEI) on the negative electrode. This study investigates the complex reduction behavior of VC using picosecond pulsed radiolysis combined with quantum chemistry calculations. Upon reduction, VC forms the anion radical $VC^{\bullet-}$, which rapidly undergoes ring opening within nanoseconds. This transformation yields transient species, including a ring-opened anion $C_3H_2O_3^{\bullet-}$ and a dimeric radical $(VC)_2^{\bullet-}$. Within 100 ns, these species evolve into $(VC)(C_3H_2O_3^{\bullet-})$, a key intermediate that initiates the oligomerization process leading to polymer formation.

The resulting polymer predominantly comprises poly(VC) units; however, the presence of additional alkyl groups indicates that even trace amounts of water significantly influence the reaction pathway and product composition. Moreover, the study reveals that the behavior of VC under ionizing radiation varies with dose rate. Low-dose-rate gamma irradiation promotes complete polymerization, while high-dose-rate electron irradiation leads predominantly to oligomerization. Radiolytic yield measurements of H_2, CO, and CO_2 further support the observation that different irradiation conditions influence the kinetic chain lengths and the overall nature of the reaction products.

Comprehensive solid-state NMR confirmed the heterogeneous nature of the polymeric SEI, which deviates from a simple poly(VC) composition. The proposed reaction mechanism elucidates the sequential transformation of VC—from its initial reduction to the formation of diverse intermediate radicals and, ultimately, to a complex polymer network at the SEI.[1] These findings enhance our understanding of VC's reduction behavior and underscore the intricate chemical processes that underpin SEI formation in lithium-ion batteries.

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Radiolytically Synthesized 3D Graphene-Based Hydrogels for Symmetrical Supercapacitor Applications

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Three-dimensional graphene-based gels (3D GBGs) have garnered increasing interest in energy storage due to their exceptional properties, including increased active material per projected area, excellent electrical conductivity, porosity, and robust electrochemical and structural stability [1]. However, conventional synthesis methods such as the hydrothermal approach, rely heavily on high-temperature processing and external reducing agents, which introduce scalability challenges and post-synthesis contamination.

To address these limitations, based on our previous research works [2, 3], we developed an alternative approach for synthesizing reduced graphene oxide hydrogels via gamma-ray irradiation, eliminating the need for chemical reductants or energy-intensive thermal treatments. During irradiation, noble metal nanoparticles can be simultaneously synthesized and stably incorporated into hydrogel structures. Electrochemical analysis using the synthesized hydrogels as electrode materials in symmetric supercapacitor demonstrated their excellent performance in energy storage, including remarkable specific capacitance, power density and stability, as well as the synergic effects of the incorporated metal nanoparticles. This work establishes a novel, facile and industrially viable pathway for designing 3D GBG composites, bridging the gap between sustainable synthesis and high-performance energy storage technologies.

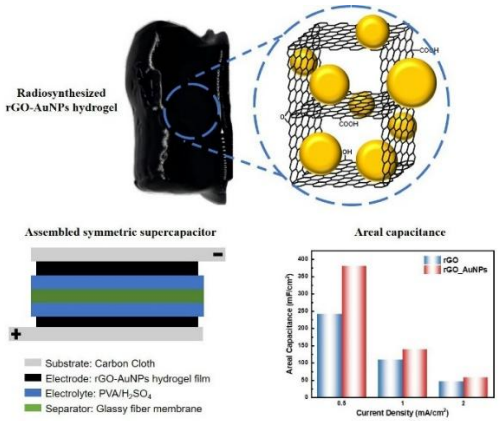

Figure 1. Radiolytically synthesized rGO-AuNPs hydrogel and areal capacitance of assembled symmetric supercapacitor

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The Fundamentals of n-Dodecane Radiolysis by Time-Resolved and Steady-State Methods

Jacy Conrad[1], Kash Anderson[1], Joseph Wilbanks[1], Andrew Cook[2], Hanna Hlushko[1], John Klaehn[1], Bobby Layne[2], Stephen Mezyk[3]

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Liquid organic molecules serve as solvents, complexing ligands, and additives in nuclear fuel reprocessing and in subsequent waste streams. These organic molecules are continuously exposed to ionizing radiation, resulting in the formation of short-lived, highly energetic radical species. The chemical reactivity of these radicals leads to the degradation of solvents and organic solutes, forming various degradation products that negatively impact process performance. Our understanding of the fundamental chemistry of these short-lived organic radicals is limited, hindering our ability to predict and control organic liquid radiolysis under process conditions.

To address this gap, this project explores the radiolytic behavior of *n*-dodecane ($C_{12}H_{26}$), a long chain, liquid, aliphatic hydrocarbon that is a prototypical nuclear fuel cycle solvent. The initial yields of the *n*-dodecane ionization and excitation products were studied using time-resolved picosecond electron pulse radiolysis with spectrophotometric absorption detection, employing molecular probes, such as biphenyl. Steady-state cobalt-60 gamma irradiations were used to determine the suite of products formed by *n*-dodecane radiolysis in aerated and deaerated solutions as a function of absorbed dose. Using iodine as an alkyl radical scavenger, the loss of molecular iodine with dose was quantified, and the concomitant formation of iodoalkane species was quantitatively measured using gas chromatography with an electron capture detector (GC-ECD). By correlating these measurements with the molecular hydrogen yields of the same solutions, the initial yields of the various carbon-centered radicals formed from fragmentation of excited state *n*-dodecane were also determined. Additionally, the *n*-dodecane ionization products, namely the radical cation ($C_{12}H_{26}^{+\cdot}$) and solvated electron (e_S^-), were studied as a function of temperature from 10 - 40 °C to determine their rates of reaction with oxygen and with diglycolamide ligands proposed for use in spent nuclear fuel reprocessing.

The Use of Pulse Radiolysis in the Bio-Inspired Light-Escalated Chemistry (BioLEC) Energy Frontiers Research Center

Lakshmy Kannadi Valloli[1], Seokjoon Oh[1], Michele Myong[1], Matthew J. Bird[1]
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Bio-Inspired Light-Escalated Chemistry (BioLEC) is an Energy Frontiers Research Center (EFRC) funded by the U.S. Department of Energy. This Princeton-led multi-lab collaboration seeks to use light harvesting and solar photochemistry to enable unprecedented chemical reactions that generate useful products from abundant feedstocks and waste.

A key feature of this center has been the bringing together of leading synthetic organic chemists with experts in advanced spectroscopic techniques (x-ray spectroscopy, ultrafast optical transient absorption, pulse radiolysis, dielectric loss spectroscopy). By going beyond the typical tools used by synthetic chemists (e.g. NMR, Stern-Volmer quenching and electrochemistry) the center has enabled new insights into mechanisms of light-driven chemistry with applications including depolymerization, alkene isomerization, nickel-mediated cross-coupling, ammonia generation, hydrogen production and enantioselective synthesis. Along the way, new discoveries relating to fundamental principles such as proton-coupled electron transfer (PCET), light-harvesting, the photophysics of first-row metal complexes, ion-pairing and the electronic properties of open-shell substituents have been made.

Pulse radiolysis at BNL's Laser Electron Accelerator Facility (LEAF) has demonstrated itself to be a powerful tool for generating short-lived intermediates relevant to these chemistries and following their reactivity and properties with visible and infra-red transient absorption. This presentation will summarize some of the contributions of pulse radiolysis to BioLEC including its application to nickel-mediated cross-coupling,[1,5] photo-driven ammonia generation from manganese nitrides,[3] and quantifying the Hammett constants of open-shell substituents.[2,4]

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The Contribution of Isotopic Labeling to Better Understand the UO_2 Oxidative Dissolution Mechanisms Under Water Radiolysis

Christophe Jegou[1]

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Understanding the oxidative dissolution mechanisms of uranium dioxide under water radiolysis is a major challenge in the context of the storage or disposal of spent nuclear fuels [1,2]. Although many articles are available on this subject, this work proposed an original approach based on the use of oxygen isotopes to better understand, at the atomic scale, the respective role of the radiolytic species involved in the oxidation of uranium or in the formation of alteration products. To achieve this objective, two kinds of isotopically labeled reactional interfaces ($U^{18}O_2/H_2{}^{16}O$ and $U^{16}O_2/H_2{}^{18}O$) submitted to gamma irradiation and thus to water radiolysis were studied by Raman spectroscopy. This vibrational spectroscopy is a very suitable technique to monitor the isotopic exchanges over time.

The production of labeled $U^{18}O_2$ pellets was successfully achieved according to an original method for the first time (Figure 1). This delicate synthesis required, on the one hand, the production of a saturated ammonia solution in $H_2{}^{18}O$ labeled water and, on the other hand, an acid attack of metallic uranium shavings by hydrochloric acid diluted in $H_2{}^{18}O$ labeled water. The gradual addition of the ammonia solution prepared in the labeled water to the UCl_6^{2-} solution led to the precipitation of a uranium hydroxide which was recovered and washed. The powder was calcined at 700°C under reducing atmosphere then pelletized and sintered at 1600°C under Ar/4% H_2 for 6 hours.

Leaching experiments were carried out in an aerated water under external gamma irradiation (^{60}Co source with a dose rate ranging from 70 to 750 $Gy.h^{-1}$) on both types of interfaces over few days. In addition, leaching experiments with a simple addition of H_2O_2 were also carried out. In parallel to the Raman spectroscopy characterizations of the surface, the concentrations of uranium and hydrogen peroxide were measured in solution.

The comparison of the results obtained made it possible to establish the respective role of radicals and hydrogen peroxide in the formation of the uranyl ion and the exchange of oxygen atoms between the solution and the solid including the precipitated secondary phases.

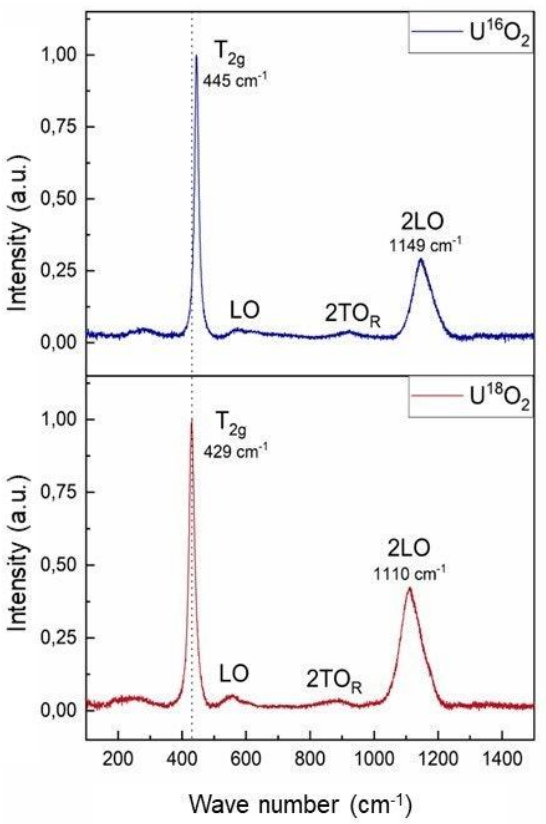

Figure 1. Comparison of Raman spectra between $U^{16}O_2$ and the prepared $U^{18}O_2$ pellet (observation of a shift in the T2g band showing the incorporation of oxygen ^{18}O).

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Further Insights Into the Discolouration of TATB Under Ionising Radiation

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TATB (1,3,5-triamino-2,4,6-trinitrobenzene) undergoes a discoloration process when exposed to ionizing radiation, which is attributed to the formation of a paramagnetic cation radical. This discoloration, from yellow to green, is widely reported and correlates with the total radiation dose.

To determine degradation products formed by exposure of TATB to ionising radiation, a computational and experimental study is presented. Thermochemical and spectral data have been calculated using Density Functional Theory (DFT) at the MH06-HF/aug-cc-pVTZ level which suggest the formation of the cation radical derivative of TATB, supporting the proposed mechanism of discolouration. MH06-HF/aug-cc-pVTZ is the computational method using the M06-HF density functional and the augmented triple-zeta basis set for calculations. Irradiated TATB samples showed the widely reported yellow-to-green discolouration, with measured International Commission on Illumination (CIE) L*, a*, b* and RGB values correlating with total dose.[10] The three-dimensional colour space parameters represent L* for lightness and a* and b* for chromaticity, with a* representing a red/green axis and b* representing the blue/yellow axis. Trace quantities of a mono-furazan derivative were detected by HPLC-MS; the discolouration is not attributed to this, but rather to the presence of a paramagnetic species (i.e. the cation), as detected by Electron Spin Resonance (ESR) measurements. Recrystallised irradiated TATB samples reverted to their original colour, further suggesting it is the cation radical that is responsible for colour change.

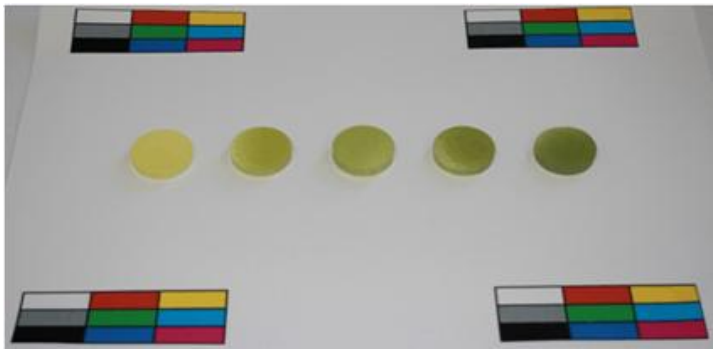

Figure 1. Colour change of TATB upon irradiation exposure

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High Energy eBeam Technology for the Destruction of PFAS in Solid Matrices

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PFAS contamination has quickly become one of the key global challenges facing society. Given that they have a variety of applications in both industrial and consumer product, PFAS-impacted materials have become ubiquitous. There are several technologies to remove PFAS for liquid waste streams and drinking water. However, there are virtually no field tested technologies for the removal of PFAS from solid materials. High energy electron ebeam (HEEB) technology holds great promise for the destruction of PFAS in solid media such as sediments, sludges, soils and filtration media and absorbent resins. Our research has shown that eBeam doses as high as 2000 kGy will be required for complete (>99%) destruction of short and long chain PFAS. At such high doses there is a concomitant increase in temperatures between 500C and 600C. We have now delineated the transformation of PFAS molecules when exposed to 2000 kGy as well as when they are exposed to incremental doses up to 2000 kGy (to avoid the involvement of temperature). The results demonstrate the extreme versatility of energetic electrons to break down the C-F bond which has a bond dissociation energy of 450 kJ/mol.

Effect of Radiation and Temperature on Rhenium Ion Added Molten LiCl-KCl Eutectic

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The molten salt reactor (MSR) is a leading candidate for next generation nuclear reactors. The fuel will be dissolved in the molten salt and molten salt is also used as the coolant and heat transfer media in the MSR. During operation cycle, the fission products alter the reaction kinetics, and their spent fuel separation is also challenging for MSR deployment. Therefore, understanding radiation effect on molten salt and speciation of radiation induced species in the molten salt is necessary for safe operation of MSR. Technetium-99 (Tc) is a high-yield problematic fission product in nuclear fuel cycle which has a 210,000-year half-life. Understanding of Tc behavior in molten salt is essential for sustainable nuclear fuel cycles. Rhenium (Re) is used while establishing experimental capability for Tc containing molten salt as it is the third-row congener of Tc and a non-radioactive surrogate.

Earlier studies observed primary molten salt radiolysis products, the solvated electron (e^-_{sol}) and dichloride radical anion ($Cl_2^{\bullet-}$) in molten chloride salt, and observed their reaction kinetics with and without metal ion additives such as Zn^{2+}, Cr^{3+} and Cr^{2+} in LiCl-KCl[1,2]. Their speciation and kinetics are expected to vary depending on metal additives and/or salt media which may lead to product formation such as chlorine gas or nanoparticles. Here we report on the effect of temperature and radiation on the speciation and reaction kinetics for the e^-_{sol} and $Cl_2^{\bullet-}$ in molten LiCl-KCl eutectic doped with rhenium ions. The pulse radiolysis experiment was carried at the Brookhaven National Laboratory Laser-Electron Accelerator Facility using a custom-designed high temperature sample holder.

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Acknowledgments. This was supported by the US Department of Energy, Office of Science, Basic Energy Research Grant number DE-SC0024597 to CUNY and at BNL under contract DE-SC0012704. Use of the LEAF Facility of the BNL Accelerator Center for Energy Research was supported by the US Department of Energy, Office of Basic Energy Sciences under contract DE-SC0012704.

Influence of Rare Earth Cations on the Chemical Behavior of Radiolytic Transients in Molten LiCl-KCl Eutectic

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Pyrochemical reprocessing technologies can recover valuable materials like uranium from used nuclear fuel. However, recovering other critical materials, such as the rare earth fission products neodymium (Nd) and praseodymium (Pa), is challenging. This difficulty arises from them possessing more accessible redox chemistry in molten salt media, which facilities disproportionation reactions leading to their re-dissolution. This chemistry is expected to be further complicated by understudied radiation-induced processes involving transient solvated electron (e_s^-) and dihalogen radical anion ($Cl_2^{\bullet-}$) resulting from the radiolysis of molten chloride salts. Therefore, optimizing the recovery of these rare earth cations requires a comprehensive understanding of their behavior in radiation environments. We report chemical kinetics for the reactions of Nd(III) and Pr(III) with the e_s^- and $Cl_2^{\bullet-}$ in molten lithium chloride-potassium chloride (LiCl-KCl) eutectic as temperatures ranging from 400-600 ^oC. These measurements were made using the Brookhaven National Laboratory Laser Electron Accelerator Facility (LEAF).

Acknowledgments
Glenn T. Seaborg Institute.

Nanoparticles Combined with Particle Therapy for the Treatment of Tumors

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The challenge of radiotherapy is to increase radiation damage on tumor whilst preserving healthy tissue. Particle therapy is superior to conventional x-ray modality thanks to ballistic properties, which improve tumor targeting. Also, carbon ion irradiation is more efficient than other modalities to treat radioresistant cases. This work aims to improve particle therapy's performance at tumors by adding Platinum Nanoparticles (PtNPs) that amplify ionizing radiation effects [1].

To evaluate the effectiveness of combining PtNPs with carbon beams, experiments are conducted on 3D cell models for the first time. This tumor-like model, called "spheroid," mimics the geometric (3D) and environmental (nutrient and oxygen gradients) conditions of a tumor.

Spheroids obtained using human cell lines from different cancers: Hela (cervical), BxPC3 (pancreatic), and U-87 (glioma), were used in this study. The internalization and localization of metallic PtNPs in the cytoplasm of the spheroid cells were observed using confocal and light sheet microscopies (figure below). Irradiations were conducted using a Carbon ion beam (290 MeV/uma) at the Heavy Ion Medical Accelerator (HIMAC) in Chiba, Japan, a world leader in particle therapy and a long-term collaborator. A radio-enhancement effect of PtNPs was observed when irradiating the spheroids with this carbon beam, showing a 23% increase of efficiency at 2 Gy dose irradiation. A similar effect was observed with 6 MV photon irradiation (reference beam in radiotherapy).

Analysis of cell proliferation and DNA double-strand break (DSB) repair, assessed by γ-H2AX immunostaining, in tumor spheroids shows that DSB repair is delayed in the presence of NPs. This may be attributed to decreasing the recruitment of DNA repair proteins. It is known that the elementary mechanisms of radio-enhancement start with radiation-induced auto-amplified electronic cascades within the NPs, which successively cause the production of highly reactive water radical clusters and biomolecule damage [2]. The biological damage responsible for the DNA repair slowdown is to be identified.

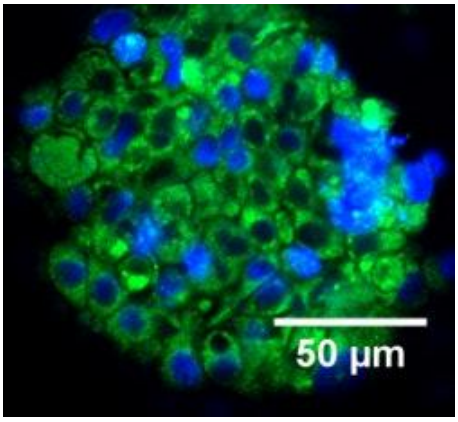

Figure 1. PtNPs (in green) localized in the cytoplasm of BxPC3 spheroid cells (cell nuclei in blue).

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Mechanistic Insights into Photosensitizer Activation by Ionizing Radiation for Enhanced Radiotherapy

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Photosensitizers (PSs) have attracted growing attention as potential radiosensitizers due to their ability to generate reactive oxygen species (ROS) when activated by ionizing radiation[1]. Unlike conventional chemotherapeutic agents, which often cause severe systemic side effects, PSs exhibit minimal toxicity in their inactive form, reducing damage to healthy tissue. Even though clinical studies have shown promising results[2-4], the mechanism underlying their activation by ionizing radiation, rather than light, remains unknown. Obtaining an understanding of the activation mechanisms can help to improve their effectiveness when combined with radiotherapy.

This study explores the radiation-induced activation of chlorin e6 (Ce6), focusing on how photon energy, dose and dose rate influence the generation of singlet oxygen ($^1O_2$). Experiments were conducted using X-rays (up to 310 kV) and ^{60}Co gamma rays (1.17 and 1.33 MeV) across a range of doses and dose rates. The formation of $^1O_2$ was measured using the singlet oxygen sensor green (SOSG) probe and the imidazole/RNO method. Our results revealed that both energy and dose rate significantly impact $^1O_2$ production, with unexpectedly high yields observed at very low dose rate. Scavenger experiments further showed that the superoxide anion ($\cdot O_2^-$) is a critical intermediate in the activation pathway.

Furthermore, our results suggest that the typical triplet-state mediated energy transfer involved in light activation does not play a role in ionizing radiation exposure. Instead, our data supports a radical-driven mechanism in which Ce6 radical cations together with $\cdot O_2^-$, play a key role in generating $^1O_2$. The activation at low dose rates (0.005 Gy/min) suggests that photosensitizers are best combined with radionuclide therapy or low dose brachytherapy.

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Dissociative Electron Attachment Mediated Nitrogen-Centered Radical Formation

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For over six decades, azido(N_3)-nucleosides have demonstrated versatile applications spanning from fundamental research to therapeutic development. Of special significance, N_3-nucleosides have been utilized in (i) click chemistry; (ii) bioconjugation and ligation; (iii) aminonucleoside synthesis; (iv) metabolic labeling of DNA and RNA for live-cell imaging; (v) enzyme inhibition, such as the inhibition of ribonucleotide reductase (RNR), which underlies their antiviral activity, etc. Recently, the use of N_3-nucleosides as radiosensitizers has garnered significant attention. In particular, 3'-azido-3'-deoxythymidine (AZT) has been reported to exhibit strong radiosensitization effects in irradiated human colon cancer, laryngeal squamous carcinoma, and malignant glioma cells and in aids patients having skin cancers. This is of considerable interest in radiotherapy, where radiosensitizers are required to maximize tumor damage while minimizing the damage in surrounding healthy tissues. To address this, we have conducted picosecond pulse radiolysis in solution at ambient conditions, complemented by electron paramagnetic resonance (EPR) spectroscopy in homogeneous glassy solutions at low temperature,and DFT calculations employing commercially available and in-house synthesized N_3-nucleosides. For N_3 substitution at C4 of Pyridine base-ring systems, combination of EPR studies and DFT calculations establish formation of stable azide anion radical, $R\text{-}N_3^{\bullet-}$ after addition of radiation-produced electrons. For N_3 substitution at C5, the DEA leads to a π-type aminyl radical, $R\text{-}NH^{\bullet}$ formation. This is supported by EPR at 77 K, pulse radiolysis at ambient temperature and DFT calculations. For N_3 substitution at C6, a conjugated enol iminyl σ-radical, $R{=}N^{\bullet}$ is formed via DEA. $R{=}N^{\bullet}$ is observed to be in tautomeric equilibrium with its keto form $R\text{-}NH^{\bullet}$. Thus, this work reports a significant finding that stabilization and reactivity of each of these types of nitrogen-centered radicals ($RN_3^{\bullet-}$, $RNH^{\bullet}$, $R{=}N^{\bullet}$) are affected by the position of N_3 substitution on the pyrimidine base-ring.

Impact of Different Doses of Ionising Radiation on the Optical and Morphological Properties of Gold Nanoparticles

Philip Marinov[1, 2], Ivo Petrov[2], Tsvetoslav Lazhovski[2], Krum Stoilov[2], Petar Temnishki[3], Silviya Simeonova[4], Peter Georgiev[4], Konstantin Balashev[4]

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There is significant potential for gold nanoparticles (AuNPs) applications in medicine, particularly for enhancing X-ray-based imaging and therapeutic methods due to AuNPs' excellent X-ray absorption properties and the increased local emission of secondary electrons upon their irradiation. AuNPs are studied as radiosensitizing agents capable of improving radiotherapy efficacy. Understanding their interaction with ionizing radiation is crucial for ensuring their safe and effective clinical application. This study investigates how different doses of ionizing radiation from medical linear accelerator affect the physicochemical and morphological characteristics of AuNPs. We employed UV-Vis spectroscopy, atomic force microscopy (AFM), and transmission electron microscopy (TEM) to analyze the nanoparticles before and after irradiation. The results reveal distinct, dose-dependent alterations in the optical and structural properties of the AuNPs. These findings provide critical insights into the behavior and stability of AuNPs under ionizing radiation, which is vital for optimizing their design and use in biomedical applications.

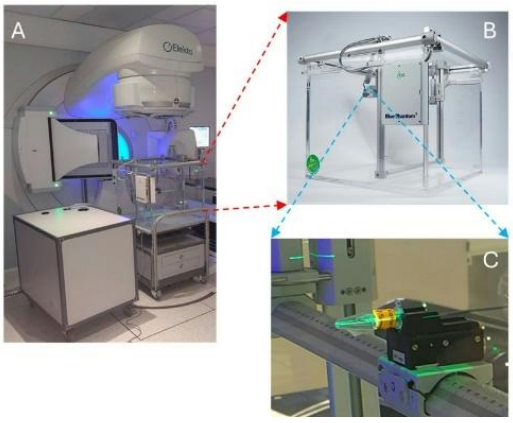

Figure 1. The image shows (A) LINAC (Elekta, UK) used to irradiate AuNP solutions. The setup includes an aqueous phantom (B) filled with distilled water, which ensures uniform distribution of radiation. A sample of the AuNP solution contained in a 1,5 ml Eppendorf tube was placed stably on a support (C) within the water phantom. This arrangement facilitates controlled and precise irradiation under constant conditions

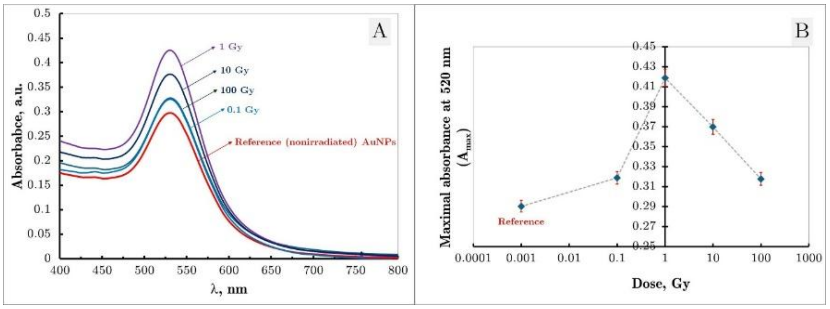

Figure 2. (A) UV-Vis spectra of solutions of gold nanoparticles (AuNPs) showing the spectrum of the non-irradiated sample (red curve) and the spectra of irradiated samples at increasing doses, indicated by arrow. (B) Plot of maximum absorption values derived from the spectra in (A) as a function of irradiation dose. The X-axis is represented on a logarithmic scale. The dashed line illustrates the general trend of variation.

Radiolytic Yields of Main Water Radiolysis Products Along Ion Tracks: Experiments and Simulations

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Radiation therapy with accelerated ions, known as particles therapy or hadrontherapy, has the advantage of a localized high energy deposition in the tumor, around the "Bragg peak". Compared to conventional X-Rays, heavy ions also present a better biological efficiency. The energy deposition of accelerated ions is heterogeneous along their tracks, resulting in a variation in radical density, and hence chemical effects. Being able to describe the chemical yields of water radiolysis reactive species formed along the path of an ion gives valuable insights in better understanding the *indirect effects* of the radiation. Several studies have described yields of some reactive species with high-energy ions, at various LETs (Appleby *et al.*, 1986; Maeyama *et al.*, 2011; Yamashita *et al.*, 2008).

Here, we will present the simultaneous determination of radiolytic yields of e^-_{aq}, $HO^\bullet$ and H_2O_2 along the track of 400 MeV/u C and 230 MeV/u He ions. Irradiation experiments were performed at Himac, Japan, in the Physic and Bio rooms. These yields were determined using several scavenging probes, the kinetics of $HO^\bullet$ and H_2O_2 being reconstructed along the track using various probe concentrations.

Data obtained with He ions were then simulated using the Monte Carlo tool Geant4-DNA, with a rather good agreement. The variation of the radiolytic yield as a function of depth will be discussed for the plateau, the Bragg peak and the fragment regions.

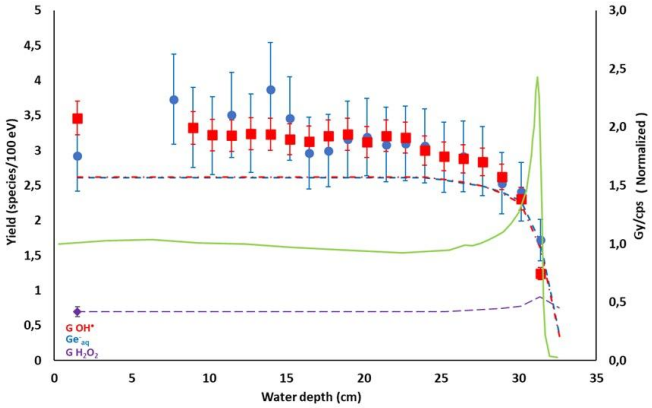

Figure 1. Evolutions of the experimental yields of $OH^\bullet$ (■) and e^-_{aq} (●) along the 920 MeV helium ion track and comparison with yields of $OH^\bullet$ (-), e^-_{aq} (-) and H_2O_2 (-) calculated with Geant4 DNA.

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Improving the Long-Term Structural Stability and Porosity of PHB Biopolymers Through Radiation Processing

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Biodegradable biopolymers, such as polyhydroxyalkanoates (PHAs), offer a sustainable and eco-friendly alternative to fossil-based plastics. They are particularly suitable for high-waste applications such as packaging (including food and single-use items), disposable consumer goods (e.g., cutlery, plates, straws), and hygiene product components. These materials are ideal where composting is feasible, such as in compostable garbage bags and organic product packaging. At end of life, PHAs can also serve as raw materials in anaerobic digestion (AD) processes to produce biogas and natural fertilizers [1, 2].

Among PHAs, polyhydroxybutyrate (PHB) stands out for its favorable properties. Produced by bacterial biosynthesis from renewable carbon sources, PHB is biodegradable, non-toxic, biocompatible, and thermoplastic. It has mechanical properties comparable to polypropylene, including good tensile strength, high crystallinity, good barrier properties, and moderate UV resistance [3]. Additionally, PHB can still be used in AD systems at the end of life.

Despite these advantages, PHB adoption faces challenges: brittleness, narrow processing range and limited thermal stability. These drawbacks restrict its use in long-term storage or under harsh environmental conditions, particularly compared to conventional synthetic packaging polymers.

This study focuses on enhancing PHB's long-term structural stability (robustness, thermal resistance and porous morphology) through controlled crosslinking by radiation processing. PHB films were gamma irradiated up to 5 kGy (dose rate 0.6 kGy h^{-1}) and e-beam irradiated up to 50 kGy (dose rate 660 kGy h^{-1}), in both normal and oxygen-free atmospheres. The films were characterized using FTIR, TGA, DSC, SEM, and PALS.

Results showed improved structural properties, especially in gamma-irradiated films (3-5 kGy) under oxygen-free conditions. No significant loss in flexibility or rigidity was observed. Melting temperature increased by 2 °C, degradation temperature by ≈5 °C, crystallinity decreased by 12%, and pore size by 2%, indicating slight crosslinking. These enhancements support PHB's potential as a replacement for synthetic polymers in demanding applications and even in medical uses (e.g., drug delivery, single-use devices, non-permanent implants). Anaerobic digestion experiments confirmed that the material retained its biodegradability even after undergoing radiation processing.

Figure 1. PHB membranes produced through bacterial synthesis (Burkholderia sachari DSM 17165).

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Development of Reversible Radio-Curable Resins for Consolidation and Restoration of Cultural Heritage Degraded Objects

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Consolidation using radio-curable resins is a remedial conservation process used in cultural heritage degraded objects where the final result is a denser object. Usually, this process is applied in porous material-based artefacts as wood where after a stage impregnation of object using vacuum and pressure with a combination of styrene and unsaturated polyester resin. The impregnation process ensures that resin reaches the microporosity of the object and remains inside even after the cleaning pre-irradiation processes thanks to the capillarity properties. In the irradiation process, the resin inside the object is cured promoting cross-linking resulting in a dense and stable material. Even though consolidation improves the physical-chemical properties also induces changes the material because the final product is a mix of the original material with a hard polymer and there may still a wetting effect of the resin on surface parts been able to enhance some colors. Then, the changes induced by the consolidation process in the object are irreversible for the traditional radio-curable formulations resins. For these reasons, this technique has been restricted and fully justified, limited to cases when mechanical properties must be reinforced, preserving the structural function of the object or when it is so degraded that other conventional treatment cannot be effective such as extremely worm-eaten wooden sculptures, polychrome and archaeological waterlogged wood. In this work are presented the main results of the new reversible radio-curable resin formulations using monomers as methyl methacrylate (MMA), ethyl methacrylate (HEMA), butyl methacrylate (MaBu), propyl methacrylate (HPMA), polyester, methyl 2-(hydroxymethyl) acrylate (HEMA) and paralloid B72. Several samples were prepared using different compositions and irradiated to promote cross-linking using low dose rates at the Multipurpose Gamma Irradiation Facility -IPEN. DSC, TGA, FTIR and Raman spectroscopy analyses were performed in the cured samples. Wood degraded samples were also consolidated using the new reversible new formulations and subjected to tomography analysis, before and after resin impregnation. Results shown that the reached formulations can be a new alternative for consolidation in wooden objects with the characteristic of reversibility.

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On the Mechanisms and Kinetic Synthesis of Poly(vinylpyrrolidone) Nanogels By Ionizing Radiation

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Studies of the radiation-induced synthesis of poly(vinylpyrrolidone) (PVP) nanogels, intended to provide a basis for obtaining intra-molecular cross-linked products, which are more useful in drug delivery, show that a sharp change in the controlling mechanism from inter-molecular to intra-molecular cross-linking occurs above a threshold temperature around 50 Ce55 C, even though the rate of inter-molecular cross-linking is enhanced as the temperature is raised. When aqueous solutions of PVP are irradiated, the activation energy of the decay of the PVP radical is observed to rise sharply above this threshold temperature. This can be attributed to the collapse of the polymer chains, which occurs at temperatures above approximately 55 C and leads to a reduction of the R_h of the irradiated polymer molecules at 77 C to (44 3) % of that of PVP molecules that were not irradiated at 20 C, as shown by the results of AFFFF measurements. The abrupt transition to a mechanism controlled by intra-molecular cross-linking is due to the thermal collapse of the polymer structure. This accounts for the observation that activation energy is higher within the temperature range above 55 C. Higher pulse repetition rates during electron irra- diation also promote intra-molecular cross-linking.

Posters

Unexpected Radiation Chemistry of Borate Buffers

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Since the 1995 work of Buxton and Sellers[1], boric acid buffers were thought to be the ideal radiation-inert buffer for use in radiation chemistry studies. This is mostly true for acidic and neutral solutions, but Buxton and Sellers overlooked a relatively slow reaction (2.7 x 10^6 $M^{-1}s^{-1}$) of OH radicals with borate anions. In this extensive work[2] we have measured transient absorption of borate anion radicals following pulse radiolysis of N_2O-saturated solutions for boron concentrations from .01 to .2M, pH from 9.3 to 12, and temperatures from ambient up to 300°C. Initial spectra in borax (disodium tetraborate) solutions are shown in figure 1. The kinetics has proven quite complicated, as the second order decay of the radicals depends on the inverse of the boron anion concentration. In the end we are able to conclude that the species under observation in figure 1 are actually cyclic borate trimer dianion radicals, formed in rapid equilibria with the parent boric acid and borate anion species. Two trimer dianion configurations exist in equilibrium, one with radical center on a 3-oxygen-coordinated boron atom, the other at 4-coordinated boron. Ab initio calculations suggest the 3-coordinated radical absorbs more strongly in the visible and becomes prevalent at high temperature.

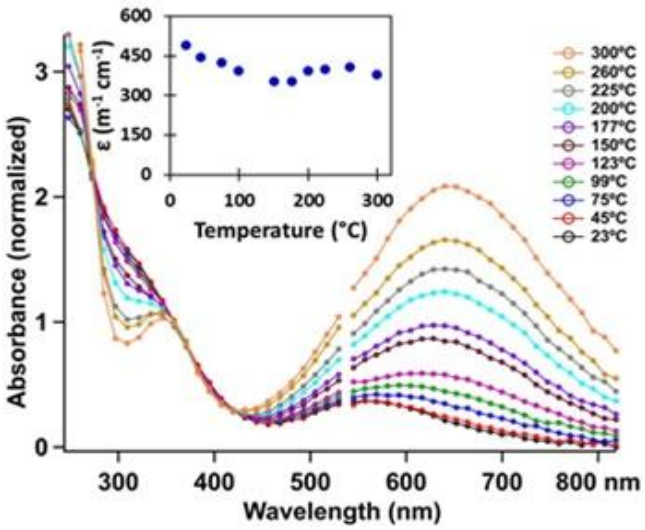

Figure 1. Initial spectra recorded upon pulse radiolysis of N_2O-sat borax solutions up to 300°C.

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The Reaction of $CO_3^{\cdot-}$ Radicals With $Co^{II}(HCO_3)_n^{2-n}$

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Carbonates and bicarbonates are present in all neutral and alkaline solutions. While generally considered buffers or proton donors, recent research indicates they play a crucial role in oxidation-reduction processes that are significantly important in biological and environmental contexts. Carbonate is a strong, hard base and an excellent σ-donor, enabling the stabilization of transition metal complexes at high oxidation states, such as $Co^{III}(CO_3)_3^{3-}$. This study investigated the reaction kinetics between carbonate anion radicals ($CO_3^{\cdot-}$) and Co^{II} carbonate complexes using pulse radiolysis. Spectroscopic analysis revealed two immediate absorption peaks post-pulse at 600 nm ($CO_3^{\cdot-}$) and approximately 300 nm (Co^{III} carbonate charge-transfer complex), followed by the disappearance of the 600 nm peak, alongside an increase in the 300 nm absorption and the emergence of d-d transitions at 450 nm and 650 nm. The initial electron transfer reaction proceeds with a rate constant of 1.0×10^7 $M^{-1}s^{-1}$, followed by a ligand exchange reaction with bicarbonate at 3.0×10^7 $M^{-1}s^{-1}$. Surprisingly, the charge-transfer bands of the $Co^{III}(CO_3)_n(H_2O)_{6-2n}^{3-2n}$ shift to the red as an increases, even though the redox potential is lowered. DFT analysis revealed that the $Co(CO_3)_2(H_2O)_2^-$ complex has an absorption peak at 293 nm, observed at higher carbonate concentrations (0.1, 0.5, and 1 M). In contrast, at a lower concentration (0.001 M), the $Co(CO_3)(H_2O)_4^+$ complex was detected with an absorption peak at 285 nm, indicating that the oxidation potential of the ligand shell is further diminished.

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Study on the Transient Species of N,N,N',N'-tetraoctyldiglycolamide (TODGA) via Picosecond Pulse Radiolysis and DFT Calculations

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Nuclear energy is an efficient strategy to reduce the global warming, and the separation of trivalent minor actinides (An(III)) from trivalent lanthanides (Ln(III)) is one of the major challenges for the development and innovation of advanced used nuclear fuel (UNF) reprocessing. *N,N,N',N'*-tetraoctyl diglycolamide (TODGA) has been extensively used as an extractant of An(III) and Ln(III) due to its high affinity for An(III) and fulfilling the CHON principle, which is beneficial to environment without the generation of secondary waste streams. However, in the presence of UNF, the TODGA ligand will be exposed to the ionizing radiation fields, thus leading to its destruction due to the indirect and direct radiolytic processes.

The steady-state radiolysis and radiation stability of TODGA in n-dodecane and biphasic solvent systems comprised of n-dodecane diluent and nitric acid contacts have been studied widely in recent years [1-2]. Most pulse radiolysis study from nanosecond to picosecond (ps) focused on the reaction between TODGA or Ln ion-complexed TODGA and cation radical of n-dodecane [3-5]. Unfortunately, the primary radiolysis reaction of neat TODGA in ps time scale has seldom investigated, which is of very importance to understand the radiolysis mechanism of TODGA ligand and to aid in the design of new radiation-resistant DGA ligands.

By using ps pulse radiolysis, the transient absorption spectra and kinetic curves of neat TODGA were studied to determine the transient species produced from the radiolysis of TODGA. In order to identify the transient species, density functional theory (DFT) calculations were used to decipher the UV-Vis spectra of various radiolytic species of TODGA. According to the DFT calculations and the experimental results in the presence of different scavengers, some important transient species were confirmed in this work.

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Pulse Radiolysis Studies of Water-Ethanolic Solutions of Albumins

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The effect of ethanol on the albumin aggregation process before and after irradiation of HSA or BSA of aqueous solution was investigated using spectroscopic methods and pulse radiolysis. We have shown that the addition of ethanol before irradiation of the protein solution promotes the formation of HSA self-aggregates, but in the case of relatively large amounts of alcohol (above 40% vol.). No significant changes in the shape of albumin fluorescence spectra and their intensity and lifetime observed by us between 0% and about 30% ethanol, indicating absence the impact of such ethanol concentrations on the secondary structure of HSA or BSA. Recently, we investigated the process of albumin reduction with the participation of hydrated electron and $H^{\bullet}$ [1,2]. In these studies, irradiation took place in the presence of 0.1 M *t*-BuOH. Here, another reducing radical used in our measurements is the $CH_3C^{\bullet}HOH$ radical, which differs from the above-mentioned radicals in terms of redox potential, size and diffusion coefficient. In general, the process of protein reduction in solutions containing *t*-BuOH or ethanol is the same, and the main scavengers of reducing radicals are albumin disulfide bridges. These sulfur-centered radicals play a key role in the production of HSA nanoparticles, which are stabilized by intermolecular disulfide bonds. The presence of ethanol in an amount below 40% does not favor the albumin aggregation process induced by ionizing radiation in relation to the solution containing *t*-BuOH. It is reported in the literature that the main product of high-energy irradiation of protein solutions containing various concentrations of ethanol were albumin aggregates stabilized with dityrosine bridges. The results of our pulse radiolysis measurements and steady-state and time-resolved fluorescence measurements very clearly indicate the lack of tyrosine-tyrosine bridge formation between albumin molecules in the presence of ethanol.

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Picosecond Time-Resolved Investigation of Nitrate radical NO_3 in Tributyl Phosphate and Water Mixtures

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The early phenomena induced by irradiation of solvents used in the PUREX process are studied by picosecond electron pulse radiolysis. Various concentrations of the solvent components, nitric acid, TBP and, water, are investigated without the interference with radioactive solutes reactions. The specific optical absorption band of the radical $NO_3^{\bullet}$ with a maximum at 640 nm is observed as early as 10 ps. It is produced by both the direct radiation effect on HNO_3 and indirectly by the excitation and ionization energies transferred from TBP* and TBP^+ to HNO_3. The doses of the direct and indirect effects change quantitatively as the opposite variations of HNO_3 and TBP fractions. However, the total radiolytic yield is almost constant. The decay of the radical NO_3 is due to the H^- atom transfer to TBP, implying oxidizing properties of the radical.

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Radiolysis at Interfaces: Characterization by XPS and IBA of the Passive Film on 316L Stainless Steel in Contact with Radiolysis Products

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The stainless-steel passive film, only a few nanometers thick, is described as having a duplex structure. The inner layer consists mainly of dense chromium oxide, which plays a protective role against corrosion. The outer layer is an amorphous layer, composed primarily of iron hydroxide, in which water molecules are bound [1]. In previous studies, we demonstrated using electrochemical techniques that passivation of 316L stainless steel in aqueous environments is affected by water radiolysis phenomena at interfaces [2, 3], and in particular by the radiolysis of bound water [3].

It is necessary to analyze the passive film using techniques that allow for elemental analysis of the film components: H, Fe, Cr, and Ni. However, due to the small thickness of the passive layer and the kinetics of water radiolysis, studying radiolysis at the solid/solution interface remains an experimental challenge. To address this, a dedicated experimental setup enabling the coupling of irradiation and characterization was implemented. Thanks to an irradiation cell described elsewhere [2], a proton beam was used to irradiate the liquid - 316L stainless steel interface. Electrochemical analysis methods were performed *in situ* to monitor both the evolution of the redox potentials of the solution and the passive film's properties on the steel surface. The resonant $^{1}H(^{15}N, ag)^{12}C$ [4] nuclear reaction was used to profile hydrogen with nanometer-scale resolution. The results are discussed in comparison with those obtained by X-ray Photoelectron Spectroscopy (XPS), providing Fe, Cr, and Ni depth profiles.

Comparing the results obtained under irradiation and without irradiation allowed us to distinguish the impact of radiolysis on the passivation of 316L stainless steel.

These experiments were carried out at the Namur Institute of Structured Matter (University of Namur) through the NFFA network [5].

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Gamma Irradiation as a Tool for Tailoring the Morphological, Structural, and Functional Properties of Nano- and Microstructured Materials for Energy and Biomedical Applications

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The ability to precisely tune material properties at the micro- and nanoscale has become a milestone of innovation in a variety of emerging technologies. Among the various post-synthesis modification strategies, gamma irradiation has demonstrated as a powerful and non-invasive tool to modulate the morphological, structural, and functional characteristics of advanced materials, enabling tailored performance without the need for additional chemical treatments or high-temperature processing. Thanks to deep penetration and ionizing nature, gamma radiation can induce a wide range of effects—such as cross-linking, chain scission, defect formation, and surface chemistry modification—making it highly effective for the engineering of various material classes.

On these bases, the present contribution explores the use of gamma irradiation to engineer three classes of nano- and microstructured materials, such as hard carbon (HC), detonation nanodiamond (ND), and hyaluronic acid-based microsponges (MSPs), respectively targeting applications in sodium-ion batteries, superconductivity and drug delivery systems. HC is a carbonaceous material with a disordered structure composed of graphitic turbostratic domains, offering high microporosity and expanded interlayer spacing. These features make HC suitable as an anode in Na-ion batteries [1]. The surface chemistry modification assisted by gamma irradiation is an approach promising to modulate the electrical and electrochemical properties of such materials. ND are nanostructures unique for mechanical and electronic properties [2]. Gamma-induced surface modification offers a route to tailor their integration into superconducting systems. MSPs are nano-enabled, porous, biocompatible microparticles used in sustained drug delivery [3]. Irradiation-driven changes in their surface chemistry is a promising strategy to enhance their functionalization with bioactive molecules.

The irradiation experiments were conducted at the Calliope facility (ENEA Casaccia) [4], treating dry powders and/or aqueous dispersions. Post-irradiation effects were studied through a combination of techniques, such as optical and electron microscopy, Raman spectroscopy, FTIR, and EPR. Functional performance of HC was evaluated in sodium-ion battery cells.

The preliminary results are encouraging for a broad applicability and tunability of gamma irradiation as a transformative approach to engineer advanced materials for next-generation energy, super-conduction and biomedical technologies.

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Understanding the Radiolysis of Pentaerythritol Tetranitrate

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Materials used in successful space missions must be able to withstand harsh environments, including ionizing radiation. Many of the radiolysis studies for space missions are focused on electronics and the personnel that may be aboard, and very little has been done to understand how energetic materials, necessary for many safety features, respond to an ionizing radiation field. This presentation will discuss investigations into the radiolysis of pentaerythritol tetranitrate (PETN), one of the most commonly used explosives for safety features on space missions. Chemical investigations include proton nuclear magnetic resonance (NMR) spectroscopy and ultra-high performance liquid chromatography - quadrupole time-of-flight (UHPLC-QTOF) mass spectrometry. Physical investigations include small-scale sensitivity testing (SSST), micostructural analysis with (ultra) small angle X-ray scattering ((U)SAXS), electron paramagnetic resonance (EPR) spectroscopy, and zeta potential analysis. Discussions will include anticipated effects of the chemical and physical changes and how to interpret the interplay between the two.

Nickel (II) Oxide Formation and Optimization Using Ionizing Radiation

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Nickel (II) oxide (NiO) is a p-type semiconductor which finds many applications. Among the most interesting ones is using this material in photocathode in photoelectrochemical (PEC) cells. Those kinds of cell aim to produce various chemical compounds (e.g. fuels) using abundant substrates and sunlight energy as a driving force. NiO is a p-type large bandgap semiconductor (3.6-4.0 eV) [1]. Its p-type character is due to non-stoichiometric behavior: there are some nickel vacancies in the structure, where holes can be captured [2]. The natural p-type behavior is however not enough to ensure sufficient charge mobility in the material. In order to obtain high efficiency device it is necessary to modify the material in such a way that holes mobility will be higher. The modification of the semiconductor can be performed by doping of the semiconductor (chemical modification), by radiating the material by various form ionizing radiation (physical modification) or by combining both of those methods. The moderation aims to introduce some lattice defects to the material and thanks to that increase the hole mobility in the material. The increased hole mobility helps the positive charges to 'escape' into the bulk of the material and decrease the charge recombination on the surface [2,3]. Those radiation was previously done with another semiconductor which is titanium dioxide TiO2 [4]. The material was irradiated with electron beam (B- radiation) and electromagnetic gamma (γ) radiation, and thanks to that the bandgap was diminished. Similar attempts has been made with NiO, however the biggest drawback of this method is that the material in order to work as a photocathode should be transparent and after irradiation it darkened which made it less transparent. It was necessary to omit this problem by alternating the way of preparation the material: instead of irradiation the material we tried to obtain nickel nanoparticules fron the solution and consequently obtain NiO using calcination methods as it was done by Cuba et al [5]. Here, we present the oxide formation with the potential of extending the results for the broader application and conjunction with other photocathode components.

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On the Reactions of $OH^{\cdot}$, $CO_3^{\cdot -}$ and $CH_2CO_2^{\cdot -}$ Radicals With Pt^0-NPs

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Previous investigations have demonstrated that $CH_3\cdot$ radicals react rapidly with noble metal nanoparticles (M^0-NPs), while significantly slower kinetics are exhibited with metal oxide/hydroxide layers present on their surfaces. It was decided to study the interactions of more potent oxidizing radicals ($OH^{\cdot}$, $CO_3^{\cdot -}$ and $CH_2CO_2^{\cdot -}$) with Pt^0-NPs by Pulse radiolysis. The results point out that these radicals react both with the Pt^{II}-oxide/hydroxide layers and the bare Pt^0 surfaces. Pt^{III}-oxide/hydroxides are formed in the reactions with the Pt^{II}-oxide/hydroxide layers. The Pt^{III} transients are short-lived, especially in the presence of acetate. These radicals are adsorbed on the bare Pt^0 surface. These adsorbates have no absorption bands between 300-700 nm.

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Development of Organic Radiophotoluminescence Materials for Radiation Dosimetry

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Radiation dosimetry has long been used to protect the health of persons who may be exposed to radiation. In addition to conventional personal dosimetry of personnel working at nuclear power plants, accelerator facilities, and hospitals, dosimetry of patients is necessary owing to recent advances in radiation therapy of cancers, in which high dose is delivered to cancer tissue whereas the dose on the healthy issue should be minimized. Hence, complicated dose distribution is realized around the cancer issue of the patients. To confirm the appropriateness of a radiotherapy plan, the complicated dose distribution should be recorded using a dosimeter which does not disturb the dose distribution. The absorption characteristics of the energy of ionizing radiation depend on the atomic numbers of the constituent elements of matter. For dosimetry in radiation therapy, energy absorption characteristic equivalent to biological tissue, that is called "tissue equivalence", is necessary for dosimeters.

Thus far, luminescent-type dosimeters have long been used for personal dosimetry. Most of them are based on inorganic compounds with little tissue equivalence. Hence, our group has been developing dosimeters based on organic solids. Among them, we will report the radiophotoluminescence (RPL), which is defined as photoluminescence property emerged after irradiation. The RPL has been realized by production of luminescent molecules via radiation chemical reactions.

The RPL characteristics were realized based on coumarin-3-carboxylic acid in different polymer hosts of polystyrene, PMMA, and PVC. Among the hosts, PVC yielded the highest sensitivity possible owing to the high yield of radicals upon irradiation. The RPL characteristics were also realized based on 2',7'-dichlorofluorescein diacetate. These achievements indicate that the radiation chemical reaction of fluorescence probes can be used for dosimetry based on organic RPL.

Microstructural Characterization and Potential Environmental Protection Applications of Composite Iron Oxide/Ag Nanoparticles

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Magnetic iron oxide/noble metal nanostructures have promising applications and offer advantages over individual noble metal or magnetic nanoparticles due to their combined optical, antibacterial, electrical, and magnetic properties. By merging the high catalytic activity of noble metals with the easy magnetic recoverability of iron oxide nanoparticles, these hybrid systems have become powerful tools in environmental protection, including wastewater treatment, advanced oxidation processes, and soil remediation.

While γ-irradiation is a well-established method for synthesizing noble metal nanoparticles, its application to magnetic iron oxides has only recently gained interest due to the complexity of iron oxide chemistry. In our earlier work [1], we have successfully used γ-irradiation to synthesize superparamagnetic iron oxide (SPION)/Au nanostructures, and demonstrated for the first time that δ-FeOOH (ferohyxyte)/Au nanostructures synthesized via this new procedure exhibit high catalytic efficiency in pollutant (4-nitrophenol) reduction, attributed to the excellent dispersion of non-aggregated AuNPs on δ-FeOOH nanodiscs.

In this study, the same technique was applied to synthesize SPION/Ag nanoparticles. Using DEAE-dextran as a stabilizing polymer enabled complete Fe(III) to Fe(II) reduction at 75 kGy. The Fe^{2+} formed radiolytically reduced Ag^+ ions, leading to the formation of δ-FeOOH nanodiscs decorated with AgNPs (11–34 nm). The AgNPs size and surface coverage of nanodiscs increased with higher $AgNO_3$ concentrations. The synthesized nanocomposite particles were evaluated for catalytic activity in the reduction of highly toxic 4-nitrophenol (4-NP) to industrially important 4-aminophenol (4-AP), and for SERS (surface-enhanced Raman scattering) activity for detection of low concentrations of organics in aqueous solutions, using probe molecules. The conversion of 4-NP to 4-AP was faster at higher concentrations of sample and at higher concentrations of Ag^+ in sample. Although, δ-FeOOH/Ag NPs particles showed significantly lower catalytic activity compared to equivalent δ-FeOOH/Au NPs, they remained efficient over multiple cycles, fully catalyzing the reaction even in the 7th reuse, within 30 minutes. In contrast to their catalytic performance, δ-FeOOH/Ag NPs proved to be a better SERS substrate compared to δ-FeOOH/Au NPs, enabling good SERS enhancement and detection of 4-MBA down to 10^{-9} M. SERS enhancement improved with higher initial Ag^+ concentrations.

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Synthesis of Gold-Coated Nanodiamonds via Green Chemistry and Their Physicochemical Characterization as Potential Radiosensitizers for Proton Therapy

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Participation cancelled.

Gamma Radiolysis of DNA Bases in the Presence and Absence of Ggold Nanoparticles

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Gold nanoparticles are known to cause a radiosensitizing effect during radiolysis but the radiosensitization mechanism is not yet fully understood. In this work, the effect of gold nanoparticles interaction with radiations on guanosine monophosphate (GMP), a DNA base, was studied using gamma radiations from a Co-60 source. Radiolytic products from GMP-gamma radiation interaction was studied with UV Visible spectroscopy and High-Performance Liquid Chromatography. Radiolysis of GMP was conducted in the presence and absence of AuNPs under hydroxyl radicals and solvated electrons. Under solvated electrons, there was an observed radiolytic effect shown by an increase in the quantity of each radiolytic product formed in the presence of AuNPs. However, with hydroxyl radicals, the was no obvious difference in the radiolytic activity on GMP in the presence and absence of AuNPs. The type of radiolytic product formed in the presence of AuNPs under both OH radicals and $e^-_{(aq)}$ was different from radiolysis without AuNPs. This indicated that, the reaction mechanism and pathway for GMP radiolysis is altered with the inclusion of AuNPs in the radiolysis process and its more pronounced in the presence of solvated electrons showing the effects of AuNPs on radiolysis.

Study of the Effect of Gamma Irradiation of Alpha Fiber Reinforced Polypropylene Composites on Mechanical and Thermal Properties

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Recently, the interest in plant fiber composites has considerably increased due to the new environmental legislation as well as consumer pressure that forced manufacturing industries to search substitutes to the conventional materials. The aim of this article is to assess the effects of different doses of gamma irradiation on the physico-mechanical properties of the composites Polypropylene (PP) / alfa fiber treated and untreated. The Young's modulus of composites increases in the presence of alfa fiber and it was more pronounced with untreated ones resulting by the cross-linking, whereas elongation and maximum strain decreased as dose irradiation raised. Fourier transform infrared spectroscopy results showed that the virgin PP has better stability to gamma irradiation than treated and untreated composites. Thermogravimetric analysis showed that the addition of the treated and untreated fiber greatly improves the thermal stability of the polymer matrix before and after gamma irradiation. Composites based on treated and untreated fiber have better storage modulus than virgin matrix.

Ionizing Radiation-Induced Morphological Changes in Polylactic Acid: The Role of Crystallinity

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Polylactic acid (PLA) is a biodegradable polymer derived from renewable resources, widely used in packaging, biomedical devices, and 3D printing due to its biocompatibility and environmental benefits. However, its relatively low thermal stability, brittleness, and susceptibility to hydrolytic degradation pose challenges that limit its applicability. In many applications medical or food packaging, exposure to ionizing radiation (e.g., sterilization) is common. PLA responds to such irradiation with chain scission, leading to reduced molecular weight and accelerated degradation. Therefore, understanding how radiation influences its properties is essential. Ionizing radiation can induce both chain scission and crosslinking, which alter the morphology that affects the mechanical and thermal behavior of the material. Although numerous studies have addressed the general effects of irradiation on PLA, comparative investigations across multiple grades are scarce, particularly with respect to how crystallinity affects radiation response. Since crystalline regions are more resistant to radiation-induced damage than amorphous ones, this structural factor may play a critical role in the degradation mechanisms and the resulting material properties.

We investigated the effects of ionizing radiation on three commercially available PLA grades - NatureWorks Ingeo 3001D, 3052D, and 6302D - which differ in their D-lactide content, molecular weight distribution, and resulting crystalline fraction. These structural and compositional differences played a critical role in determining how each PLA grade responded to irradiation. To fully understand these effects, both amorphous and post-crystallized samples were examined. Samples were prepared using appropriate processing techniques for each grade and subjected to different absorbed doses of ionizing radiation, ranging from 0 to 200 kGy, under controlled conditions.

To assess the impact of irradiation, a multi-technique characterization approach was applied. Thermal properties and crystallinity changes were analyzed using differential scanning calorimetry (DSC). This technique provide insight into the change mechanisms at the microstructural and also on molecular levels. Differences in degradation patterns and thermal transitions were observed between the grades, with implications for targeted material design in applications requiring radiation sterilization, controlled degradation, or improved long-term stability. The findings contribute to a more nuanced understanding of radiation-PLA interactions and support the selection or modification of PLA grades for specific end-use environments.

Gamma Radiation Induced Rapid Heat and Light Responsive Shape Memory Polymer with High Strain as Remote Light-Controlled Actuators

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Shape memory polymers (SMPs) possess the remarkable ability to revert to their original shape from a programmed temporary form when exposed to external stimuli such as light, heat, and magnetism. However, achieving multi-stimuli responsiveness within a single material system remains a significant challenge. In this context, a straightforward one-step method has been developed for fabricating heat and light-responsive shape memory polymers by directly subjecting poly(chlorotrifluorethylene-vinylidene fluoride) (P(CTFE-VDF)) films to gamma radiation. This solid radiation process introduces cross-linking points and photosensitive moieties into the polymer structure simultaneously. The extent of chemical crosslinking can be precisely controlled by the absorbed dose of radiation, thereby enhancing the shape fixity capacity. By integrating the crystalline PCTFE region as the reversible phase of shape memory, the radiated copolymer exhibits a high-strain shape memory effect, achieving recoverable strains of up to 853%. Additionally, the unsaturated groups generated through dehydrochlorination during radiation cause the copolymer's color to shift from translucent to black, significantly enhancing its photo-thermal properties. Utilizing near-infrared (NIR) laser technology, the radiated P(CTFE-VDF) can facilitate the remote-controlled and precise movement of objects in both horizontal and vertical directions by manipulating the light spot position and power density, thus demonstrating considerable potential for applications in remote light-controlled actuators.

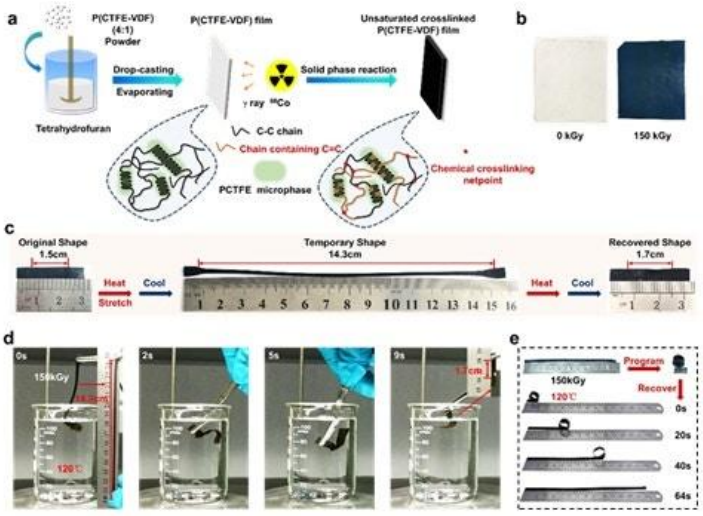

Figure 1. The preparation, characterization and thermally induced shape memory behavior of radiated P(CTFE-VDF) film.

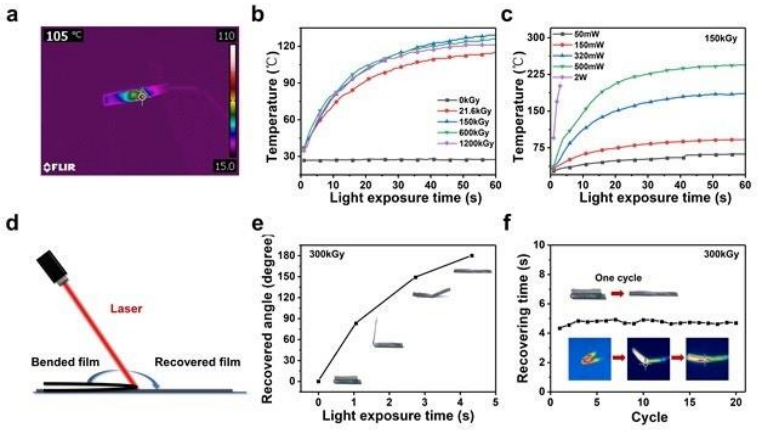

Figure 2. The photothermally induced shape memory behavior of irradiated P(CTFE-VDF) film.

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Irradiation Modification of Face Masks for Use in Asphalt Mixtures

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The aim of this research was to determine an alternative approach of polymer plastic waste recycling and/or disposal safe for the environment. Single use personal protective equipment (PPE), made of mostly polypropylene, is unavoidable in medical care worldwide and often ends up in landfills. A major problem with used PPE from hospitals is their contamination and at the moment used PPE from hospitals in Croatia is incinerated. So the idea of this research is to use ionizing radiation for sterilization and modification of the contaminated disposable face masks which after shredding were used as additive for the road construction material such as asphalt mixtures and for the reduction of the pavement materials cost. In this work, we have explored the physical and chemical properties of the masks before and after irradiation using DSC, FTIR-ATR, SEM, and other methods. The post-radiation and long term storage of sterilization masks effects were also investigated. The validity of using irradiated masks instead of cellulose fibers in bitumen and asphalt mixtures was evaluated by standardized tests such as binder drainage test, needle penetration, elasticity return and softening point, as well as rutting test and water sensitivity. Optimization of the size and the concentration of added shredded masks to asphalt mixtures was investigated and determined to be 0.4% added shredded masks for optimal fraction. Mechanical testing of asphalt mixtures with irradiated and non-irradiated masks did not give completely satisfactory results and this investigations are still ongoing.

Acknowledgments. This work was funded by the IAEA CRP project "Recycling of polymer waste for structural and non-structural materials by using ionizing radiation".

Sustainable Electron-Induced PLA Structure Formation in Dynamic Melts

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The modification of polymer properties to meet specific application requirements is typically achieved through physical blending or chemical reactive approaches. Among these, reactive processing is widely employed, as it enables simultaneous physical and chemical modification of the polymer matrix. However, conventional reactive processing often depends on temperature-sensitive initiators to trigger chemical reactions, which limits precise control over reaction kinetics and process stability. To overcome these limitations, an alternative method utilizing electron beam (EB) technology has been developed. Instead of relying on thermal initiators, EB technology offers spatially and temporally precise energy input, enabling the initiation of chemical reactions through high-energy electrons. Building on these advantages, the Electron-Induced Reactive Processing (EIReP) technique was established. EIReP facilitates temperature-independent polymer modification and has been successfully applied to a variety of polymer compounds. The results confirm the method's potential to produce high-performance polymeric materials without the need for thermal initiators or chemical additives. As a significant step toward industrial implementation, EIReP has been scaled up for the first time into a continuous inline demonstrator equipped with a 300 keV electron emitter.

Comparison of the Use of Electron Beam Irradiation and Sonochemistry in Synthesis of PEGDA Hydrogels with Bioactive Substance for Biomedical Applications

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Hydrogels have found their applications in a variety of field, one of the most predominant being the use in biomedical field, in medical devices such as aortic grafts, breast implants, as cell culture scaffolds, in drug delivery systems or as wound dressings. The use of ionising radiation techniques, such as electron beam irradiation, to synthesise polymeric hydrogels is well documented and utilised commercially. Main disadvantage of utilising e-beam radiation method, or alternative sources of ionising radiation, is the requirement of the extensive knowledge and experience in handling the radiation sources by the operator. Additionally, the maintenance of the apparatus and the need to replenish the radiation sources is costly and can be impeded by the current geopolitical situation.

As an alternative way to synthesise hydrogels for biomedical applications, we have suggested the use of sonochemistry. Sonochemistry utilises the interaction of acoustic waves in the range of ultrasound (here between 50 and 1 000 kHz) with the aqueous solutions of polymers (oligomers, monomers). Due to the mechanism of the interaction, the action of ultrasound on aqueous solutions results in the creation of •OH radicals, which then can react with the polymeric chains, which leads to the creation of macroscopic structures - hydrogels. This mechanism of sonochemical creation of hydrogels is similar to the mechanism of the radiation-induced creation of hydrogels, which is why it has drawn attention of scientists in the recent years.

In the work I have compared the synthesis of poly(ethylene glycol) diacrylate (PEGDA) hydrogels with the addition of trigonelline hydrochloride as an active substance, with the use of both sonochemical method and ionising radiation. The hydrogels synthesised with both techniques were compared by the corresponding amount of generated •OH radicals, which were analysed with the use of suitable dosimetry methods. The properties of the hydrogels, such as gel fraction, degree of swelling and the release of the non-cross-linked compounds, were analysed.

Based on the obtained results, it can be concluded that sonochemical synthesis of biocompatible hydrogels can be used as a more affordable and accessible alternative to ionising radiation technique.

Radiation-Induced Synthesis of Carboxymethylcellulose Nanogels: Synthesis, Characterisation and Applications

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Hydrogel is a stable two-component system composed of a three-dimensional polymer network and a solvent, usually water, filling its free spaces. One of the fundamental standards for classifying hydrogels is their size, distinguishing between macrogels, microgels, and nanogels (1-100 nm). Nanogels, due to their high specific surface area, potential for functionalization with ligands, and stability in an aqueous environment, are promising nanocarriers for controlled drug delivery systems, gene therapy, and cancer theranostics.

Nanogels can be synthesized by linking the segments of a single macromolecule using ionizing radiation, through intramolecular recombination of polymeric radicals[1]. The primary advantage of this technique is the elimination of the need for monomers, catalysts, stabilizers, or crosslinking agents, making the final product an ideal candidate for biomedical applications. To date, ionising radiation has enabled the synthesis of nanogels from poly(N-vinyl-2-pyrrolidone)[2], poly(vinyl alcohol)[3], poly(acrylic acid)[4] and poly(ether methyl vinyl)[5]. However, successful synthesis of nanogels from polysaccharides has yet to be achieved.

Our aim was to obtain a new class of nanomaterials - polysaccharide-based nanogels - using a preparative pulse radiolysis technique. We investigated the effect of ionising radiation on dilute carboxymethylcellulose (CMC) solutions by varying selected parameters such as polymer concentration, energy dose, dose rate, and degree of substitution (DS) of the polymer in order to identify optimal conditions for the formation of polymer nanogels. We characterised the physicochemical properties by determining the average molecular weight and dimensions of the products using light scattering techniques and AFM imaging.

The development of a novel one-step process for synthesizing CMC nanogels will advance progress in molecularly targeted therapies. The degradability of polysaccharide-based nanogels will help minimize toxicities associated with the accumulation of nanocarriers in the patient's body. In the future, radiation-synthesized CMC nanogels, once functionalized, will be tested as carriers for the delivery of radionuclides to cancer cells.

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Preparation and Properties of Structural Self-Regulation Crosslinked Silicone with Excellent Radiation Resistance

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Organosilicone elastomers have broad and significant application prospects in the field involving high energy radiation, and how to improve their radiation resistance is one of the hot research topics. In this work, a novel disulfide-bond modified crosslinked polydimethylsiloxane (PDMS) was prepared by the crosslinking reaction between PDMS and bis[γ-(triethoxysilyl)-propyl]-disulfide. γ-Ray response of disulfide bonds, as well as the changes of crosslinking degree, crystallization properties and mechanical properties of the prepared crosslinked PDMS were investigated under the irradiation of γ-rays at a certain absorbed dose range. The disulfide bonds were proved to undergo dynamic breaking-recombination reactions in gamma-ray radiation fields, which means that the crosslinking points in the novel crosslinked PDMS are also in dynamic change, that is to say, the PDMS network structure is in a dynamic self-regulation status in the radiation field, and its crosslinking density can be maintained within a certain dose range, so the mechanical properties of the novel crosslinked PDMS can also be maintained in a certain dose range, showing excellent radiation resistance. This work not only provides theoretical and practical guidance for expanding the application of silicone elastomers in high-energy radiation environment, but also opens a new idea for the development of high-performance radiation resistant crosslinked polymer materials.

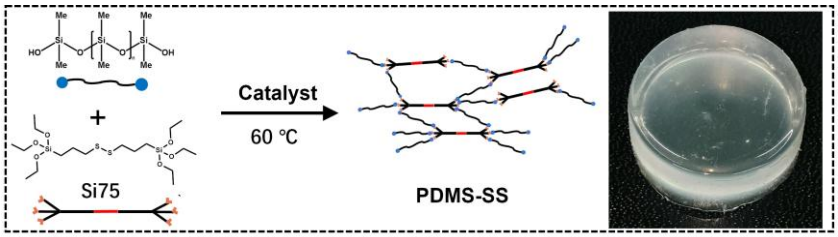

Figure 1. Preparation of disulfide-bond modified crosslinked polydimethylsiloxane (PDMS-SS).

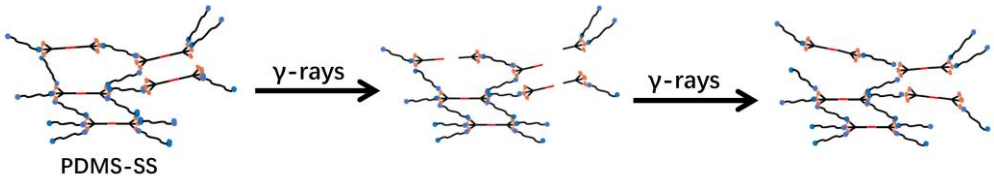

Figure 2. The disulfide bonds undergo dynamic breaking-recombination reactions in gamma-ray radiation fields, which makes the crosslinking points in PDMS-SS also in dynamic change, i.e. the PDMS network structure in a dynamic self-regulation status in the radiation field, resulting in a unchanged crosslinking density within a certain dose range.

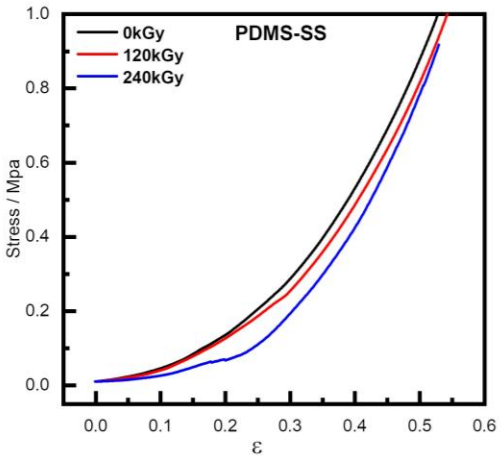

Figure 3. The compressive stress-strain curve of PDMS-SS before and after being irradiated by gamma rays

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Single-Component, Photoacid-Free and High-Resolution Dual-Tone EUV Photoresists Based on Precision Self-Immolative Polycarbamates

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Lithography is an important fabrication process that relies on photoresists, typically polymer formulations, which switch solubility when being exposed to light of a specific wavelength. During the past few decades, lithography has relentlessly advanced towards achieving smaller critical dimensions to enable higher levels of integration in integrated circuits, which has been fueled by advancements in reducing lithographic wavelengths and developing innovative patterning materials. As technology nodes continue to advance, extreme ultraviolet (EUV) lithography that utilizes 13.5 nm radiation and electron beam (EB) lithography have emerged as the state-of-the-art fabrication technology to produce sub-10 nm features, which poses significant challenges for resist materials. Conventional photoresists for EB and EUV lithography face an ongoing challenge in efficiently balancing resolution, line edge roughness (LER), and sensitivity-commonly referred to as the RLS trade-off. We reported the development of single-component, photoacid-free photoresists based on self-immolative polymers (SIPs) with discrete molecular weights for both EB and EUV lithography (Scheme 1). Starting from a small library of disperse self-immolative polycarbamates with varying side chain functionalities, *iso*-octyl ether (**^{i}Oc**)-appended polymer was identified with the best film-forming performance. Upon low-dose exposure to EB or EUV irradiation, such polycarbamates could fragment into multiple azaquinone methides through selective cleavage of benzyl-O linkages and ensuing cascade degradation, thus acting as positive-tone photoresists. Unexpectedly, the fragmented products could further undergo efficient cross-linking reactions under high-dose exposure, thereby transforming the polycarbamates into negative-tone photoresists (Scheme 1a). To further elucidate the effect of molecular weight distribution (MWD) of polycarbamates on the lithographic performance of self-immolative polycarbamates, discrete SIPs with precisely defined degree of polymerization (DP) were synthesized using an iterative growth approach (Scheme 1b). It was revealed that MWD had a significant impact on LER for both EUV and EB lithography. Moreover, nanopatterns from discrete photoresists exhibited higher resolution and lower LER compared to disperse counterpart with similar average chain lengths, as evidenced by the line space patterns with a width resolution of ~18 nm and an LER of ~1.8 nm (Scheme 1b). In addition, these photoresists, enriched with aromatic structures, displayed superior etch resistance to enable pattern transfer.

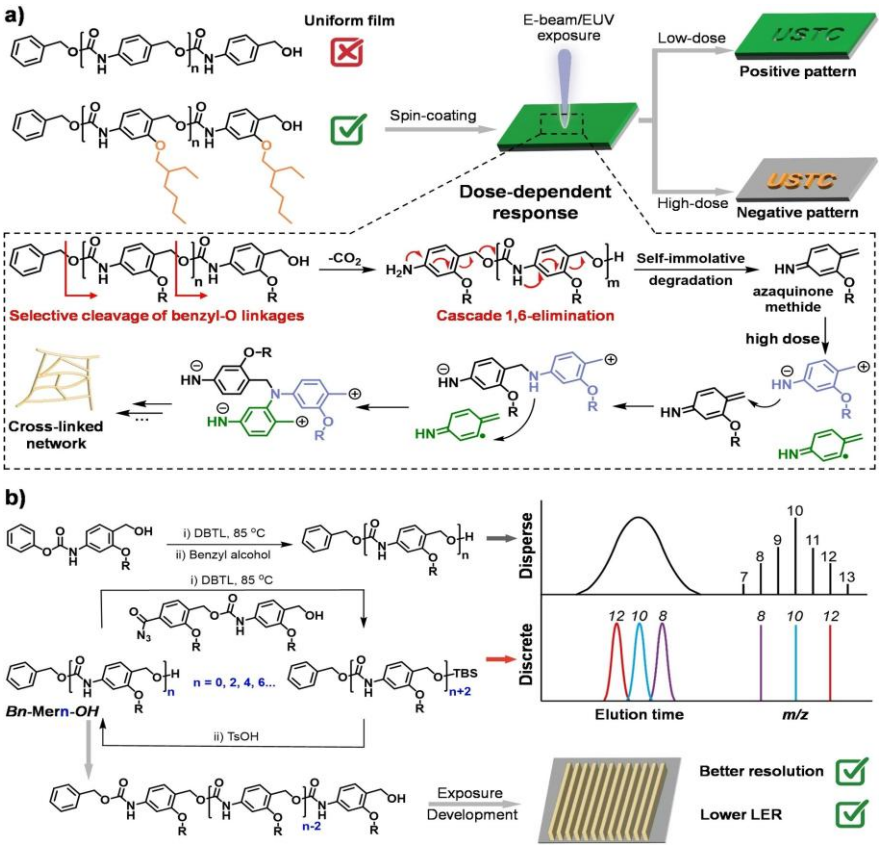

Figure 1. (a) SIPs bearing appendant *iso*-octyl ether (^{i}Oc) moieties could serve as both positive-tone and negative-tone photoresists in EB or EUV lithography. (b) Discrete self-immolative polycarbamates synthesized using an iterative growth approach exhibit higher resolution and lower LER.

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Radiation-Induced Synthesis of Silver-Loaded Silica Drug Delivery Systems with Antimicrobial Properties

Andreea Simona Baltac[1, 2], Raul Augustin Mitran[2], Daniela Culita[2], Irina Atkinson[2], Simona Ionita[2], Florin Albota[1], Andreea Serban[1], Paul Mereuta[1], Florina Zorila[1], Daniel Negut[1], Mioara Alexandru[1]

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Antimicrobial resistance is a growing global health challenge, making the search for new treatment strategies more important than ever. One promising approach involves mesoporous silica nanoparticles (MSNs), which have gained attention for drug delivery due to their unique properties—high surface area, large pore volume, tunable pore size, biocompatibility, and low toxicity. [1] Controlled drug release using these systems could help enhance the effectiveness of antimicrobial agents while reducing bacterial resistance. Radiation reduction of metal precursors offers a reliable and sterile path to obtaining antimicrobial delivery systems. [2,3]

FDU-12 mesoporous silica was obtained using the sol-gel method, impregnated with silver nitrate ($AgNO_3$) and then exposed to gamma irradiation at 50 kGy using a ^{60}Co gamma chamber, forming silver nanoparticles (Ag^0). The material was further loaded with two broad-spectrum antibiotics, chloramphenicol and vancomycin, creating a multifunctional system with enhanced antimicrobial properties.

A comprehensive physicochemical characterization of the synthesized materials was conducted to confirm their structural and morphological properties. X-ray Diffraction (XRD) was used to analyze crystallinity, while Scanning Electron Microscopy (SEM) provided details on particle morphology. Surface area and pore size distribution were measured using N_2 adsorption-desorption isotherms. UV-Vis spectrometry was used to monitor the drug release profile and additional analysis of sample composition was performed using Fourier Transform Infrared Spectroscopy (FT-IR). The silver content was quantified through Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

The antimicrobial potential of the obtained materials was tested against three bacterial strains: *Staphylococcus aureus* ATCC 6538, *Escherichia coli* ATCC 8739, and *Pseudomonas aeruginosa* ATCC 9027. Antibacterial activity was assessed using well agar diffusion and broth microdilution methods, with minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) determined for each sample. Bacterial viability in the presence of the synthesized materials was also examined using resazurin.

The synthesized materials exhibited antimicrobial activity against all tested bacterial strains. The combination of mesoporous silica, silver nanoparticles, and antibiotics significantly enhanced antibacterial effects, highlighting the potential of these systems for controlled drug release applications in the fight against antimicrobial resistance. Further studies should focus on optimizing drug loading efficiency and evaluating long-term stability to advance their biomedical applications.

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Steviol Glycosides and their Interaction with Ionizing Radiation

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Stevia (*Stevia rebaudiana* Bertoni) is a flowering plant in the aster family (*Ateraceae*), known for its sweet-tasting leaves. Although endemic to humid and wet regions in South America, stevia is now grown across many countries, including China, Kenya, Zambia, and the United States. Stevia leaves have been used for more than 1,500 years by the Guarani people. Traditionally, the plant has been used to sweeten “yerba mate” and other forms of tea, and it has a number of applications in folk medicine. Stevia is commercially valuable for its steviol glycosides contents, which is about 300 times sweeter than commercial sugar. Steviol glycosides are noncaloric, noncarcinogenic, nonfermentative, and present no harmful effects on human health. These glycosides possess medicinal activities, showing strong antioxidant potential, antiproliferative, antimicrobial, hepatoprotective, anti-inflammatory activities owing to the presence of various compounds with medicinal significance such as phenolic compounds, flavonoids, diterpene glycosides, condensed tannins, anthocyanins, and phenolic acids. Research conducted in recent decades has explored the effects of gamma radiation on stevia, particularly to enhance its growth and increase the content of its beneficial compounds, known as steviol glycosides (like stevioside and rebaudioside A). Studies have shown that gamma radiation can induce mutations in stevia plants, leading to improved growth traits and higher concentrations of steviol glycosides; irradiated stevia plants have shown increased biomass production and higher levels of rebaudioside A and stevioside compared to non-irradiated plants. Additionally, gamma irradiation has been used to improve the plant's tolerance to abiotic stresses, such as salinity, making stevia more resilient and potentially more productive in challenging environments. In the present work the focus will be on the interaction of the chemical components, steviol glycosides, with ionizing radiation.

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Radiation Damage to DNA and DNA-Binding-Proteins Exposed to Various Particle Sources, Dose-Rates and Oxygen Levels.

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One of the main challenges during radiotherapy is to spare healthy tissue while delivering a sufficient dose to the tumor. Here, the problem is, that under conventional treatment conditions with low dose-rates the mutated cancer cells are often more radiation resistant than the healthy cells. In contrast, recent experiments in animal models have shown that the relative radio-sensitivity of various cancer cell lines increases in comparison to their healthy counterparts, when ultra-high dose-rates are applied. This improved selectivity directly leads to better tumor control. Despite it's high potential, little is known about the underlying, molecular mechanisms of the FLASH effect. In particular, the question needs to be answered which intrinsic differences between healthy and cancerous tissues lead to their different dose-rate dependent radiosensitivity, to fully exploit the potential of FLASH based therapies. In addition to DNA, proteins are essential for all cellular functions and play an important role in the radiation response of cells. In order to understand the radiation response of proteins under FLASH conditions, the dose-rate dependence, the influence of the oxygen content in the cells and the radical chemistry involved, are of great interest. Therefore, we investigate the influence of these parameters in model systems of selected DNA binding proteins. The first type are single-strand binding proteins, which are involved in DNA replication and repair. These proteins were irradiated with 20MeV at the PITZlab of DESY and analysed in terms of structural, functional and chemical changes. The results provide quantitative information about the radiation response of the protein systems at different dose-rates, ranging from settings used in conventional radiotherapy to the ultra-high dose rates where the FLASH effect is observed. Here the change in structure and DNA binding ability is quantified. The conclusions to be drawn will be based on the combined analysis of the changes in protein structural, chemical modification and loss of DNA binding ability, accompanied by additional work on amino acids and peptides, which allow for detailed understanding of the chemical mechanisms involved in the radiation response.

Acknowledgments. This work was funded by the DFG grant Grant 442240902 / HA8528/2-1, HA8528/2-2.

Enhancing Magnetic Hyperthermia via Phase and Morphological Control of Radiolytically Synthesized Iron Oxide Nanoparticles

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Magnetic hyperthermia is a promising technique for cancer treatment, utilizing heat generated by superparamagnetic nanoparticles exposed to an alternating magnetic field. This heat arises from Néel (rotation of magnetic moments due spin realignment) and Brownian (rotation of magnetic moments due thermal motion of particles) relaxation mechanisms and must elevate tumor tissue temperature to 41–45 °C to activate cellular pathways leading to cell death. Usually, heating efficiency is quantified by the specific absorption rate (SAR), which depends on magnetic field parameters, particle size distribution, phase, viscosity, and anisotropy (shape or magnetocrystalline). Therefore, in this study we have investigated the influence ofthe mentioned parameters on SAR values of radiolytically synthesized iron oxides. Two types of samples were examined: (1) ferrofluids, synthesized radiolytically with varying initial Fe^{3+} concentrations and polymer types; and (2) nanoparticles, differing in phase (magnetite, feroxyhyte) and morphology (spherical, disc-shaped).

Ferrofluids were prepared by irradiating 20% and 40% Fe^{3+}/polymer (w/w) precursor solutions at doses of 50 kGy and 100 kGy, using DEAE-dextran, dextran, and PVA as stabilizers. These conditions were selected to achieve 25–40% reduction of Fe^{3+} to Fe^{2+}.

In the nanoparticle group of samples, feroxyhyte nanodiscs were synthesized by irradiating a 5% Fe/DEAE-dextran solution at 75 kGy to achieve complete Fe^{3+} reduction. The resulting nanoparticles were isolated, and half of the feroxyhyte discs were annealed in a H_2/N_2 atmosphere at 375 °C for 6 hours to obtain magnetite. Spherical magnetite nanoparticles were obtained by drying the ferrofluids obtained from the 40% precursor solution.

SEM confirmed the spherical morphology of dried ferrofluids and the disc-shaped morphology of irradiated and annealed samples. XRD analysis showed the presence of exclusively magnetite in dried ferrofluids and annealed discs, and feroxyhyte in non-annealed discs. Mössbauer spectroscopy and SQUID magnetometry verified the superparamagnetic nature of all particles. SAR measurements were conducted using pristine ferrofluids and nanoparticles dispersed in 10% DEAE-dextran solution (4 mg/mL), demonstrating the influence of morphology, size, and phase on heating efficiency. The results highlight the importance of precise control over synthesis parameters to optimize nanoparticle performance for magnetic hyperthermia applications.

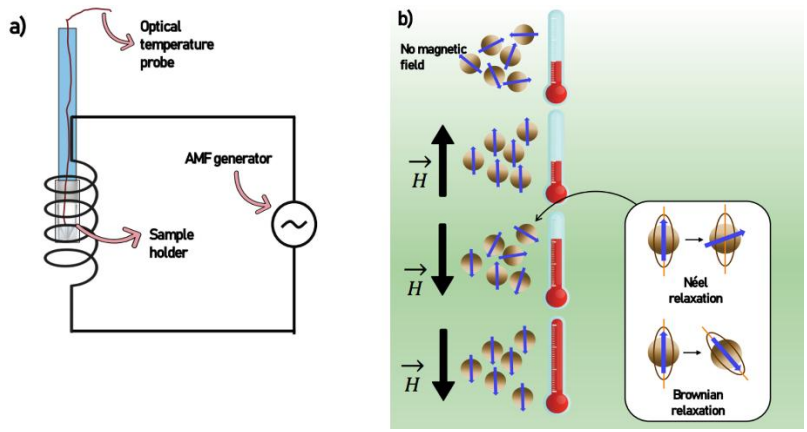

Figure 1. Schematic representation of: a) SAR measuring setup and b) superparamagnetic nanoparticle heating mechanism.

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Dose Estimation of Wild Animals Captured in the Contaminated Area of Fukushima Prefectur

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Tokyo Electric Power Company Holdings' Fukushima Dai-ichi Nuclear Power Station (FDNPS) was severely damaged by the earthquake and resulting tsunami that struck on March 11, 2011. After the FDNPS accident, radioactive materials were released into the environment. From the viewpoint of radiation biological effects due to low-dose and low-dose-rate irradiation of wild animals, dosimetry for these animals has attracted public concern. In this work, we estimated the radiation dose of the wild animals by using electron spin resonance (ESR) spectrometer. Dose estimation using ESR relies on the fact that CO_2^- radicals generated in tooth enamel by radiation have a very long lifetime, which can be used as an indicator to estimate individual doses. Tooth enamel of large Japanese field mice and wild Japanese macaques captured in the contaminated area of Fukushima Prefecture were collected and subjected to dose estimation. CO_2^- radical intensity was extracted from the ESR spectrum using EPR Dosimetry programme [1]. Doses for young and old groups of Japanese field mice (15 mice teeth were put together for each group) were estimated to be ~57 mGy and ~270 mGy, respectively. Dose estimated by ESR for old group is much higher than that estimated from the environmental dose at the capture site and the accumulation of ^{137}Cs in mouse body; older individuals are more likely to move farther away from the capture site, therefore, they did not reflect environmental variables around the capture site. On the other hand, estimated doses for 18 Japanese macaques were ranged from several mGy to ~300 mGy, 15 of them agreed with the doses estimated by PHITS within 100 mGy. It is thought that the three individuals happened to be captured in an area with a highly contaminated area.

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Quantum-Chemical Insight into the Radiosensitizing Mechanism of Nimorazole

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Over 50% of patients diagnosed with cancer will require radiotherapy as part of their treatment. Ionizing radiation (IR) can damage DNA directly or indirectly through radiolysis of water leading to the formation of reactive oxygen species. A common feature of many solid tumors — which account for approximately 80% of all cancers — is a low oxygen level. This condition, known as hypoxia, is caused by rapid tumor growth and insufficient angiogenesis. Reduced oxygen levels limit the formation of reactive oxygen species, which contributes to reducing the number of DNA lesions in irradiated tissues. Therefore, healthy cells are up to three times more susceptible to the harmful effects of radiation than cancer cells, which is a serious limitation of radiation therapy.

A promising approach involves the application of oxygen mimetic radiosensitizers - chemical substances capable of sensitizing cancer cells to IR by imitating the action of oxygen. Despite great interest in oxygen mimetics from the nitroimidazole group, the mechanism of action of this class of radiosensitizers is still unknown. In this work, density functional theory (DFT) calculations were performed to verify two main hypotheses regarding the mechanism of action of this class of compounds, using the example of nimorazole. One of the hypotheses is based on the action of low-energy electrons, while the other is based on the action of hydroxyl radicals. Both secondary electrons and hydroxyl radicals are the most abundant products of water radiolysis under hypoxic conditions. Understanding the mechanism by which nimorazole acts as a radiosensitizer can guide experimental research on nitroimidazole derivatives, support the design of new compounds within this class, and ultimately enhance the effectiveness of radiotherapy.

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Nanosolutions to Macroproblems - Platform for Targeted Delivery of Radioisotopes Based on Radiation-Derived Nanocarriers

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The widespread adoption of the Western lifestyle, characterized by dietary changes, sedentary behavior, and increased stress, has led to a range of new challenges for medicine, including the increased prevalence of cancers. Currently, cancers have become the second most common cause of death, making it vital to develop innovative methods of cancer management. Radionanomedicine has emerged as one of the most promising approaches in this context. It combines the well-understood fundamentals of nuclear medicine with the latest advancements in nanomedicine.

Among various implementations of radionanomedicine, one of the most prominent strategies is to radiolabel preformed nanoparticles with isotopes characterized by short half-lives and proper emissions, such as gamma for diagnostic purposes and beta for cancer cell eradication. A great example of such radioisotope is 177-Lutetium.

Here, we exploit radiation-derived nanomaterials to synthesize targeted nanocarriers of radioisotopes. Carboxymethyl cellulose-based polymer nanogels, synthesized with accelerated electrons from a linear accelerator, are functionalized with proper chelating moieties and peptide ligands to obtain actively targeted nanocarriers for radioisotopes. Previously, we demonstrated the feasibility of this approach for nanoparticles based on synthetic polymers. Now, we extend our platform to biodegradable cellulose derivatives with potentially more beneficial biological properties. Our research paves the way for a more sustainable, efficacious, and safer cancer management strategy through the application of radiation in various forms.

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XUV Laser-Induced Damage to Plasmid DNA at Temperatures Below and Above Freezing

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The temperature dependence of radiation-chemical reactions and radiobiological processes can provide valuable insights into their underlying mechanisms [1-3]. In this study, plasmid DNA samples were exposed to low-energy ionizing electromagnetic radiation at temperatures below freezing (−10 °C) and at ambient temperature (20 °C). Irradiation was carried out using a compact, table-top plasma-based source of coherent extreme ultraviolet (EUV) radiation [4-6]. The EUV source is a capillary-discharge Ne-like Ar laser that emits nanosecond pulses at 46.9 nm, corresponding to photon energies of 26.4 eV. All irradiations were conducted in high vacuum, and sample temperature was controlled using Peltier thermoelectric modules.

The results showed a pronounced temperature dependence in the yields of double-strand breaks (DSBs), whereas single-strand break (SSB) yields remained largely unaffected by temperature changes. The reduction in DSB yield at subzero temperatures supports the hypothesis that indirect effects—rather than direct, correlated strand interactions—are the dominant pathway for DSB induction. A high number of reactive species formed within the DNA's hydration shell are capable of reaching both strands to cause breaks. At −10 °C, their diffusion is significantly limited as they become immobilized in the icy hydration matrix, favoring recombination over interaction with DNA.

In contrast, SSB formation, which involves direct action on a single strand through local excitations or nearby reactive species, appears independent of temperature. At low temperatures, the DNA molecule and its surrounding hydration shell undergo structural and physicochemical changes that influence the nature and yield of radiation-induced damage.

Ionization of DNA generates radical cations and solvated electrons, which trigger a cascade of secondary processes including charge transfer, base modification, and strand scission. The reduced mobility of secondary radicals at lower temperatures decreases the contribution of indirect damage pathways, while stabilized ionization products such as radical cations enhance charge migration along the backbone, promoting localized damage. Additionally, the suppression of recombination events prolongs the lifetime of reactive intermediates, increasing the likelihood of strand breaks.

These findings have implications for radiotherapy, cryopreservation, and astrobiology, where DNA integrity under extreme conditions is of central importance.

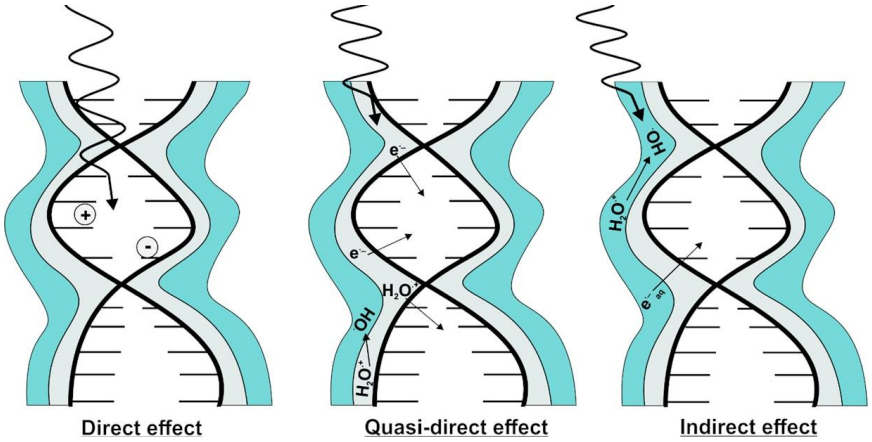

Figure 1. DNA ion-radicals are generated through direct and indirect mechanisms. In the direct effect, ionization occurs directly on DNA bases or the sugar-phosphate backbone, forming primary radical species. The quasi-direct effect involves ionization-induced hole formation in water molecules ($H_2O^{\cdot+}$) within the first solvation shell (8-10 water molecules per nucleotide), which subsequently transfer to DNA, while electrons from the surrounding hydration layer (approximately 21 water molecules per nucleotide) migrate into the DNA. In the indirect effect, ionization in bulk water (beyond 21 water molecules per nucleotide) produces reactive species such as hydroxyl radicals ($OH^{\cdot}$), hydrated electrons (e_{aq}^{-}), and hydrogen radicals ($H^{\cdot}$), which diffuse through the solution and interact with DNA, potentially inducing damage.

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Advanced Methodology Combining UPLC-MS, Isotopic Labelling and H/D Exchanges Reveals New Tyrosine-Tyrosine Cross-Links Induced by Oxidative Radicals

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Di-tyrosine is one of the major protein cross-links involved in a large number of neurodegenerative or ageing-related diseases. [1]. Combining oxidative radical production by gamma radiolysis with very performant chromatographic separation coupled to mass spectrometry detection, we brought into light new insights of tyrosine dimerization. No less than four different di-tyrosine bridges isomers have been highlighted while only two structures are characterized in the literature [2,3]. Through UPLC-MS analysis, specific deuteration and isotopic (H/D) exchanges with the solvent, we propose new original di-tyrosine types of crosslinking [4,5]. Absorption and fluorescence characterization of the four species were performed and consolidate the proposed formation mechanism. These results raise some questions about their respective role and toxicity *in vivo* as well as the legitimacy of using di-tyrosine as a biomarker.

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Modifying g-C_3N_4 with Gamma Irradiation: Toward Improved Photocatalytic Water Treatment

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Graphitic carbon nitride, g-C_3N_4 (gCN), is an organic polymer characterized by semiconductor properties, non-toxicity, and ease of synthesis, making it an ideal candidate for applications in various photoelectrochemical and photocatalytic processes [1]. However, due to its relatively low specific surface area and fast recombination of photogenerated charges, its widespread usage is somewhat hindered [2]. It has been shown that γ-irradiation treatment of gCN can reduce the charge carrier recombination, enhance visible light absorption, and modify crystallinity and optical properties of the material [3,4].

In this work, the effect of γ-irradiation on the properties and photocatalytic performance of gCN was examined. gCN was synthesized via thermal treatment of urea[2] Subsequently, synthesized gCN samples were exposed to γ-irradiation (Co^{60} source, dose rate 5.5kGy/h) at three irradiation doses: 25, 50 and 75kGy, in an aqueous medium, with the presence of scavenging agents, ethanol or N_2O, to selectively eliminate hydroxyl radicals or electrons, respectively.

γ-irradiated gCN samples were characterized by FTIR spectroscopy. The positions of the bands in the FTIR spectra of γ-irradiated gCN samples are consistent with those reported in the literature [2,3], while slight shifts in band positions of irradiated samples may indicate partial element exchange. Specifically, the band at around 1070cm^{-1}, attributed to C-O vibrations, is broadened and emphasized, probably due to nitrogen-oxygen substitution in the edge amino groups.

The photocatalytic activity of the samples was evaluated by monitoring the degradation of the Acid Orange 7 dye, under simulated solar light irradiation. In the case of samples treated with γ-irradiation in the presence of N_2O, a gradual decrease in photocatalytic activity was observed with increasing radiation dose. In contrast, the photocatalytic activity of gCN treated with γ-irradiation in the presence of ethanol at a dose of 25kGy was slightly reduced compared to pristine gCN. However, upon further increase in the irradiation dose, a notable enhancement in photocatalytic performance was observed. Compared to pristine gCN, the sample irradiated at 50kGy showed an enhancement of 30% in photocatalytic activity. This study opens new possibilities for using γ-irradiation as a tool for modifying and fine-tuneing the properties of gCN by controlling the irradiation conditions.

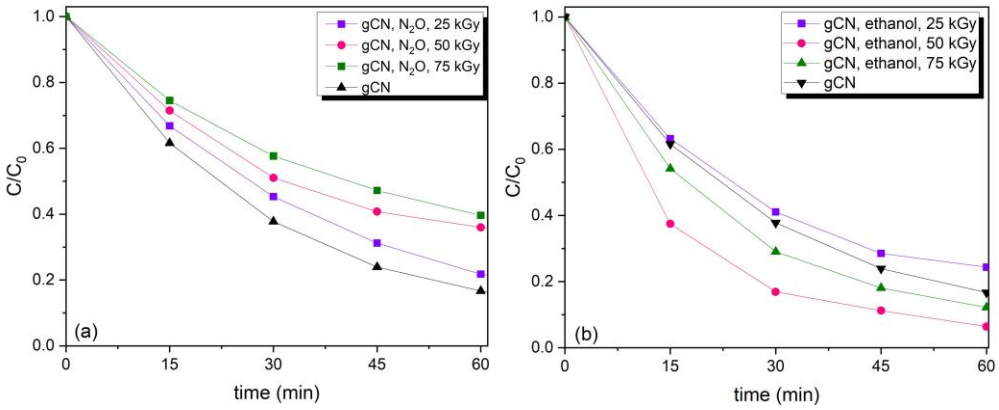

Figure 1. Kinetic curves of photocatalytic degradation of Acid Orange 7 using pristine gCN and gCN samples treated with γ-irradiation in the presence of nitrous oxide (a) and ethanol (b).

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E-Beam Irradiation as a Sustainable Solution for Improving the Properties of Recycled Acrylonitrile-Butadiene-Styrene (ABS) Derived from Electronic Waste

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The rapid increase in electronic waste (e-waste) poses a major environmental challenge, especially in terms of sustainable material management and recycling. Acrylonitrile-Butadiene-Styrene (ABS), a widely used thermoplastic copolymer in electronics, is one of the most common plastics found in e-waste. However, recycling e-waste ABS is complicated by factors such as contamination from other materials and the degradation of its properties over time. As global e-waste volumes rise, it is crucial to develop innovative and sustainable methods to improve the recovery and recyclability of ABS from discarded electronics. One promising solution is the use of e-beam irradiation, a technique that exposes materials to high-energy electron beams. In this study, the effect of e-beam irradiation on the thermal stability, mechanical properties, and recyclability of e-waste ABS was investigated in the dose range comprised between 5 and 15 kGy. Thermogravimetric Analysis (TGA) data show that e-beam irradiation slightly enhances thermal stability, by increasing the $T_{5\%}$ value which corresponds to 5% mass loss and a higher residue rate compared to the non-irradiated sample. Differential Scanning Calorimetry (DSC) analysis indicates a significant rise in the glass transition temperature (Tg) and material integrity after irradiation. Mechanical tests reveal notable increases in Young's modulus and tensile strength, particularly at 10 kGy, due to the formation of cross-linking within the ABS matrix. In conclusion, e-beam irradiation seems to be a promising approach for improving the thermal stability, rigidity, and mechanical properties of e-waste ABS, offering a potential solution for enhancing its recyclability and performance.

Molecular Weight Determination of Gamma-Irradiated Cellulose for Solubility in Sodium Hydroxide

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Cellulose, the most abundant natural polymer on earth, has been limited in its application to industrial processes due to its low solubility. It is a difficult compound to dissolve largely due to its intra- and intermolecular hydrogen bonding. While not soluble in water, cellulose is soluble in some ionic liquids that can break the hydrogen bonds that help cellulose retain its crystalline form. However, ionic liquids are expensive and not very environmentally friendly as they are largely made up of organic compounds that are water soluble with high toxicity and low biodegradability. Sodium hydroxide can be used in conjunction with gamma irradiation in place of ionic liquids because NaOH fully dissociates, creating ions in solution and gamma irradiation has been shown to break the β-1-4 glycosidic bonds in glucose. Together, sodium hydroxide and gamma irradiation provide more available surface area per gram of cellulose, which has been shown to increase its solubility. Previous work has shown that irradiating cellulose increases the solubility in sodium hydroxide but was only able to provide the percent solubility based on the mass of carbon. Because cellulose has varying molecular weights, and ionizing radiation is known to decrease the molecular weight of cellulose, it is necessary to determine the molecular weight ranges at different doses of ionizing radiation to be able to determine the overall percent solubility of cellulose in sodium hydroxide. This study proposes to do just that via a cellulose derivatization method to allow the cellulose to dissolve in Tetrahydrofuran (THF) and be analyzed by Gel Permeation Chromatography (GPC). It is expected to show larger ranges of molecular weight as the ionizing radiation dose increases, as there will be more, smaller pieces of cellulose at higher doses of radiation.

Effect of Gamma Radiation on Thermal and Structural Properties of Polylactid Acid - Can Irradiation Assist Controlled Polymer Degradation?

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Pollution with plastic materials has become a environmental and health challenge so the need for ecological and sustainable solutions is in high demand. As the alternative to polyolefin polymers, polylactic acid (PLA) has become one of the commonly used commercial polymers derived from natural sources. Polylactic acid is partially biodegradable depended on the conditions but the overall usage of PLA is increasing the need for degradation mechanism research.

In this research the thermal and structural analysis of PLA is studied for creating and uderstanding effective enzymatic degradation approach. It is well known that irradiation can alter sensitive materials such as polymers, either causing them to degrade or cross-link, depending on their chemical structure. Also the enzymatic attack is generally favored in the amorphous regions of polymer chains while the crystal regions are resistent to enzyme attact.

Controlled degradation of polylactid acid PLA hence can be enchanced with radiation pretreatment of polymer since the irradiation breaks down the long polymer chains of into smaller fragments providing possible easier access for enzymes. At the same time the dose of 25 kGy is chosen as the sterilization dose to explore also the possibility to reuse and recycle the polylactid acid material before undergoes the degradation. The PLA samples, non irradiated and irradiated with the dose of 25 kGy, are investigated with differential scanning calorimetry DSC for changes in glass transition temperature T_g, melting temperature T_m, changes in enthalpies and in overall crystallinity. Since the glass temperature T_g of PLA is relative low around 60 °C and the irradiation dose of 25 kGy is shifting T_g to even lower values and causes structural changes in polymers the synergic effect is expected for more sufficient degradation.

Chemical changes due to radiation at 25 kGy, are analyzed using FTIR-ATR spectroscopy.

The possible changes in supramolecular structure of polylactic acid till 200 °C with irradiated and non-irradiated samples wil be observed with optical microscopy paired with heating stage. Possible structural changes in the semi-crystalline structure caused by radiation of the PLA will be monitored by X-ray diffraction (XRD) on irradiated and nonirradiated samples.

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Cellulose/g-C_3N_4 Eco-Friendly Hydrogel Nanocomposites for Waste Water Treatment Obtained by Gamma Irradiation

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The protection of clean water resources and wastewater treatment has become increasingly important concern worldwide, particularly in light of the growing industrial sector and population growth. Therefore, is crucial to develop cost-effective, eco-friendly, and stable materials or processes that may efficiently decrease or eliminate contaminants from wastewater before they are released into the environment. Among numerous purification methods, using of solar energy, as an available energy source, in combination with photocatalytic materials, stands out as an especially promising and environmentally sustainable approach. Graphitic carbon nitride, g-C_3N_4(gCN) is a promising photocatalyst with optimal electronic and light absorption properties. However, its large-scale applications are limited by challenges in separation from the reaction solution and restricted reusability [1,2]. Studies suggest that immobilizing photocatalysts on supports can facilitate performance, prevent agglomeration, and provide stable active sites. Polysaccharide-based hydrogels are ideal for photocatalytic applications due to their biodegradability, biocompatibility and porous structure allowing molecule diffusion [2,3]. In line with the growing awareness of environmental protection, radiolytic synthesis was employed, allowing synthesis without chemical agents, and synthesis and sterilization in a single step [4]. The main objective of this study was to develop eco-friendly, biodegradable and stable cellulose/gCN hydrogel nanocomposites with efficient photocatalytic performance. gCN was synthesized from urea through thermal treatment[5], while hydrogel nanocomposites were prepared by g-irradiation (^{60}Co source, 25kGy) of paste-like solutions with varying wt% of gCN mixed with hydroxyethylcellulose(HEC), high-viscosity carboxymethylcellulose(9-CMC), and medium-viscosity carboxymethylcellulose(12-CMC). Obtained hydrogels have gel fraction in the range of 57-78%, while swelling study revealed that cellulose hydrogels belong to class of superabsorbent materials with SD_{eq} in the range of 23-213. Incorporation of gCN into the cellulose matrix reduces SD_{eq} and improves mechanical performance. Morphological properties (SEM) showed stable crosslinked and porous structures of hydrogels. FTIR spectroscopy reveals the nature of the electronic interactions between the incorporated gCN and specific polymer chain groups. Finally, the photocatalytic efficiency of samples in wastewater treatment was confirmed by monitoring the photodegradation of Acid Orange 7. These results confirm the suitability of cellulose-based hydrogels as carriers for photocatalytic materials, providing a basis for further research aimed at enhancing photocatalytic performance and reusability.

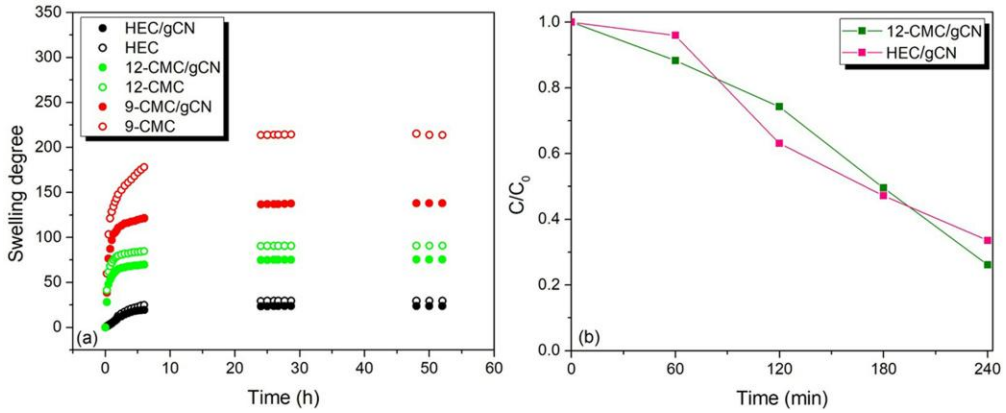

Figure 1. Swelling degree of cellulose/gCN hydrogel nanocomposites in distiled water at 25°C (a) and kinetic curves of photocatalytic degradation of Acid Orange 7 using HEC/gCN and 12-CMC/gCN hydrogel nanocomposites (b).

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Tailoring the Structural and Mechanical Characteristics of Bacterial Nanocellulose via Gamma Irradiation and Biowaste Media

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Bacterial nanocellulose (BNC), a biopolymer synthesised by certain bacterial strains such as Komagataeibacter xylinus, has attracted considerable attention due to its high purity, nanostructure, mechanical strength, biodegradability, and compatibility with other materials.[1] These properties make it highly valuable for applications in biomedicine, packaging, cosmetics, and other industries. However, large-scale production of BNC remains a challenge due to the low yield and high cost of conventional synthetic media, such as the Hestrin-Schramm medium.

This study investigates a cost-effective and sustainable approach to improve BNC production using agro-industrial waste, particularly citrus peels, as an alternative carbon source. Citrus peels are rich in soluble sugars and polysaccharides, making them a promising substrate for microbial fermentation. To further increase the yield of BNC and modify its structural properties, the bacterial species were treated with gamma irradiation as an environmentally friendly, chemical-free treatment method.

The research investigated the effects of gamma irradiation on the growth of Komagataeibacter xylinus, BNC yield, and the resulting nanocellulose morphology and mechanical properties. Comparisons between BNC from citrus peel media and BNC from standard media showed that irradiation has a positive effect on production yield and material properties. Structural analyses showed significant changes in fibre arrangement, porosity, and mechanical strength, indicating the potential for tuning BNC properties by irradiation.

Overall, this work presents an innovative and sustainable method for BNC production by integrating biowaste utilisation and irradiation technology. It contributes to the development of cost-efficient, environmentally friendly biomaterials and supports the promotion of circular bioeconomy principles by converting waste into high-value products suitable for scalable industrial utilisation.

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Efficiency of Removing Emerging Contaminants from Wastewater Using Electron Beam

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Despite the implementation of regulated and established approaches to the treatment of wastewater, it is well-established that it contains a vast array of contaminant compounds. Regrettably, these conventional methods may not effectively eliminate all emerging contaminant compounds present in wastewater. Consequently, the release of undesirable compounds into the environment, including pesticides, pharmaceuticals, plasticizers, corrosion inhibitors, and other similar substances, becomes an unavoidable consequence. In pursuit of a more efficient and wide-ranging wastewater treatment strategy, radiation technology has been proposed and has gained prominence in the field as one of the novel and efficacious methodologies. The application of radiation technology in wastewater treatment has been recognized for several decades. Its implementation varies, with radiation being employed either as a standalone approach or in combination with existing methods to execute the treatment process effectively. The primary objective of this project was to achieve substantial degradation of organic compounds within wastewater effluent. This was pursued through the utilization of electron beam irradiation, administered at a carefully determined dose, in conjunction with conventional treatment methods. Wastewater samples were obtained from the effluent of the Syracuse Metro Wastewater Treatment Plant during various seasons. These collected samples were subjected to irradiation at varying doses, and subsequent analysis of the irradiated water samples was carried out using untargeted high-resolution liquid chromatography/mass spectrometry (LC/MS). The results demonstrated that electron beam treatment exhibited substantial effectiveness in degrading contaminants. At least 80% of individual contaminant species were degraded up to 84.52% by the electron beam treatment.

Ammonia Synthesis Utilizing Ionizing Radiations: Stable Product Quantification and Transient Intermediate Observation.

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Introduction

Ammonia is attracting attention not only as a material for traditional use but also as a fuel and hydrogen carrier from a carbon-neutral perspective. Instead of the Haber-Bosch method, which requires high-temperature, high-pressure conditions, it may be synthesized under milder conditions using radiation chemical reactions. This study aimed to investigate the possibility of reducing nitrogen oxides (nitrate and nitrite ions) to ammonia in aqueous solutions by reducing radicals produced in water radiolysis.

Methods

Samples of aqueous solutions containing a few millimolars of sodium nitrate ($NaNO_3$) and sodium nitrite ($NaNO_2$) were used. Pulse radiolysis experiments with a beam of 35-MeV electrons were conducted at Nuclear Professional School (Tokai mura), UTokyo, Japan, to observe reactions of water radiolysis radicals with NOx species and formate ions and to investigate their reaction rate constants. Steady-state radiolysis experiments with ^{60}Co γ-rays were conducted at Takasaki Institute for Advanced Quantum Science, QST, Japan. The ammonia productions in the irradiated samples were analyzed using the indophenol blue coloring method or ion chromatography. In addition, we conducted simulations with Facsimile software. Reducing nitrate ion to ammonia requires an eight-electron reduction from +V to −III in terms of oxidation number. Since the reaction pathway is very complicated, we also attempted to explain it using radiation chemical reaction simulation.

Results and Discussion

The production of ammonia in the steady-state radiolysis was confirmed, but very little in the aqueous solutions of $NaNO_3$ and $NaNO_2$. This was due to interference by oxidizing radicals like hydroxyl radicals ($^{\bullet}OH$). Thus, we added sodium formate (HCOONa) to convert the oxidizing radicals into reductive formate radicals ($COO^{\bullet-}$). As a result, the ammonia production was much enhanced. In the pulse radiolysis experiments, we observed some intermediates, and then, it was found that the reaction between nitrite radicals ($NO_2^{\bullet}$) and formate radicals is not negligible and should be considered in further study. As a summary, this study showed a possibility to synthesize ammonia through the radiolytic reduction of NOx species in aqueous environments.

Oxalic Acid Formation by Radiation-Induced Reactions in Water Under a Simple Model Condition of Geological Disposal of Radioactive Wastes

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Deep geological disposal has been studied as a safe and reliable technology for the long-term management of vitrified high-level radioactive waste or spent nuclear fuel. In scenarios of failure of the geological repository, direct contact of water with the waste form results in water radiolysis. Groundwater at the depth of the geological repository is reductive in general, and also anaerobic corrosion of the metallic materials of the canister generates H_2[(1)]. The water radiolysis under such reductive conditions could produce organic acids through reduction of CO_3^{2-}/HCO_3^- contained in groundwater[(2)]. Organic acids may affect the solubility and migration of radioactive elements. Therefore, the formation of organic acids by irradiation of aqueous bicarbonate solution under H_2 atmosphere was studied.

The aqueous solution of sodium bicarbonate ($NaHCO_3$) was prepared and purged with mixture gas of Ar, H_2, and CO_2. CO_2 was added to the purge gas for adjusting the sample pH to 8. The samples were irradiated in septum-sealed vials. An X-ray irradiator (Acrobio, AB-320) was used. After the irradiation, the sample was analyzed by an ion chromatography (Dionex ICS-1000, Thermo Fisher Scientific). Formation of oxalic acid was detected. The measured concentrations of oxalic acid are shown in Figure 1 as functions of absorbed dose. Formic acid and acetic acid were also analyzed, but the concentrations of them were not significant. The formation of oxalic acid was clear in 1 mmol dm^{-3} $NaHCO_3$ solution. At a $NaHCO_3$ concentration of 10 mmol dm^{-3}, oxalic acid formation was much less than that in the sample of 1 mmol dm^{-3} $NaHCO_3$. The results were analyzed by using a kinetic simulation of water radiolysis. The decrease in oxalic acid formation by the increase in $NaHCO_3$ concentration can be explained by the reaction of $^{\bullet}OH$. At low concentrations of HCO_3^-, $^{\bullet}OH$ reacts with H_2 to generate $H^{\bullet}$ and $H^{\bullet}$ contributes the reduction of HCO_3^-. At high concentrations of HCO_3^-, $^{\bullet}OH$ reacts with HCO_3^- to generate $CO_3^{\bullet-}$ and suppress the reaction between $^{\bullet}OH$ and H_2. The results of this study indicate that oxalic acid generation by water radiolysis is strongly dependent on concentrations of CO_3^{2-}/HCO_3^- and dissolved H_2.

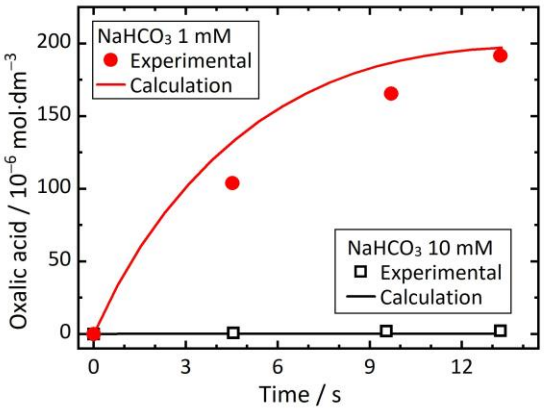

Figure 1. Oxalic acid formation by the X-ray irradiation of aqueous $NaHCO_3$ solution saturated by Ar, H_2 and CO_2 mixture gas. The gas contained 50 % H_2 and 0.08 % CO_2 for the $NaHCO_3$ 1 mmol dm^{-3} sample and 50% H_2 and 0.80 % CO_2 for the 10 mmol dm^{-3} sample.

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Radiation-Induced Degradation of Cement Hydrates and Implications for Molecular Hydrogen Production: Focus on Ettringite

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The degradation of cement hydrates under radiation exposure is a critical aspect of understanding the long-term behavior of cementitious materials in radioactive waste disposal environments (1). Among the various phases present in cement hydrates, ettringite ($Ca_6Al_2(SO_4)_3(OH)_{12}\cdot 26H_2O$, see Figure 1 (2)), has garnered significant attention due to its potential role in the integrity and stability of cement pastes, and its high-water content (32 water molecules). This study examines the effects of electron irradiation on ettringite, focusing on its degradation mechanisms and the consequences for dihydrogen (H_2) formation. The aim is to better determine the radiolysis potential of cementitious hydrates, a key parameter for assessing the quantities of H_2 likely to be generated under radioactive waste disposal conditions, and to anticipate the consequences.

The present study specifically explores the impact of electron irradiation on dry ettringite and its meta-form (2) (containing between 9 and 13 water molecules), which forms when ettringite loses part of its water content. By examining ettringite with varying amounts of water, including dry ettringite and meta-ettringite (containing between 9 and 13 water molecules), we aim to isolate the effect of water on radiolysis and H_2 production, avoiding interference from adsorbed water. Irradiation experiments were conducted using an electron accelerator, and H_2 production was measured by micro-gas chromatography. Characterization of ettringite before and after irradiation was performed using Thermogravimetric Analysis (TGA), X-ray Diffraction (XRD) (3), and Nuclear Magnetic Resonance (NMR) (4).

Our results indicate that molecular hydrogen production varies with water content, showing that the different types of bound water in ettringite respond differently to ionizing radiation. Molecular hydrogen production will be presented and reaction mechanisms will be proposed.

The findings of this work provide insights into the reaction mechanisms at stake in irradiated cementitious materials and highlight the importance of identifying the corresponding mechanisms in other mineral phases, which is particularly important in the context of radioactive waste disposal.

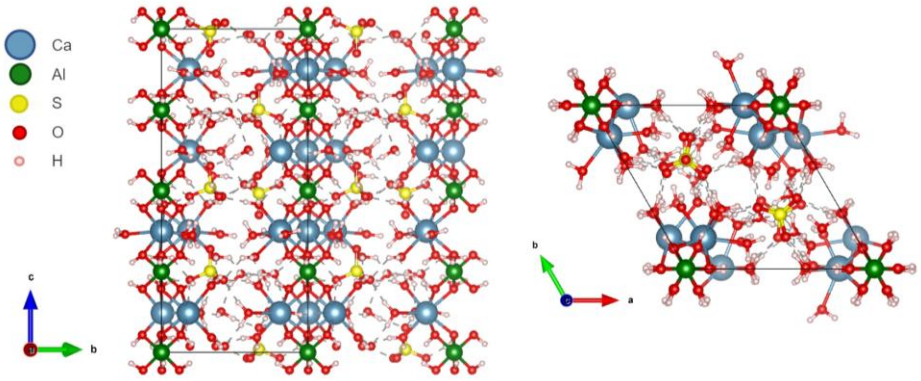

Figure 1. Crystal structure of ettringite ($Ca_6Al_2(SO_4)_3(OH)_{12}\cdot 26H_2O$) (2)

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Synthesis of Functionalized Porous Resorcinol-Formaldehyde Resin via High Internal Phase Emulsion for Photocatalytic Production of Hydrogen Peroxide

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Hydrogen peroxide (H_2O_2) is an efficient green oxidant and a highly promising liquid clean fuel.[1] Photocatalytic H_2O_2 production is regarded as an economical, environmentally friendly and safe approach.[2] Resorcinol-formaldehyde (RF) resin prepared by readily available and inexpensive reagents can photocatalytically generate H_2O_2 from pure water and oxygen systems.[3] However, RF resin typically synthesized consists of smooth soild microspheres with a relatively small specific surface area.[4] Additionally, the commonly used approach of combining it with other catalysts to enhance its catalytic performance is cumbersome, which also increases the cost. Herein, hierarchical porous RF-based resins with good photocatalytic properties were synthesized by high internal phase emulsion (HIPE) template method using resorcinol (R), thiourea (T), melamine (M) and formaldehyde (F) as monomers at 140ºC. It was found that the specific surface area of the RTMF and RTF resin reached 172.5 and 182.4 m^2/g, respectively, when the volume fraction of the internal phase was 80%. The effects of thiourea/melamine ratio, reaction temperature and the light source on the photocatalytic activity of the resins were investigated. When the molar ratio of thiourea to melamine was 2:0 keeping the molar ratio of (T+M)/F/R constant at 2:8:1, the synthesized RTF resin exhibited remarkable photocatalytic performance with a high H_2O_2 yield of 751 µmol h^{-1} g^{-1} under the irradiation of 300 W Xe lamp and 295 µmol·h^{-1}·g^{-1} under visible light illumination, which was 3.6 and 3.1 times that of RF resin, respectively, and also higher than that of RTF-h resin prepared by high-temperature hydrothermal method. As the reaction temperature was increased to 180ºC, the photocatalytic H_2O_2 generation rate of RTF-180 was increased to 640 µmol·g^{-1} h^{-1} under visible light illumination. The systematical experiments revealed that the quinone content in resins played an important role in photocatalytic production of H_2O_2. In addition, the mechanism studies proved that RTF resin could photocatalyze the generation of H_2O_2 through both single-electron and two-electron reduction pathways. This study introduces a simple, economical and feasible approach for the straightforward and efficient synthesis of photocatalysts with enhanced catalytic performance, and the as-prepared modified RF resins show potential application in the field of photocatalytic H_2O_2 production.

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Alpha-Radiolysis of Carbon Monoxide on Plutonium Dioxide Surface

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Due to its high stability, plutonium dioxide is one of the main end-product of nuclear spent fuel reprocessing. During fuel manufacturing and storage steps, plutonium dioxide could be in close contact with various gaseous atmospheres. Yet, plutonium dioxide, and more generally all plutonium materials, interact with their environment through radiolytic processes induced by alpha particles emitted from plutonium decay. Then, the gaseous components of plutonium dioxide conditioning atmosphere adsorb more or less quantitatively on the surface of material [1-3] and under the effect of alpha-radiolysis induced by plutonium these gases should decompose and/or react with plutonium dioxide surface [4-5]. Among the gas that could be present in the storing atmosphere of plutonium dioxide, the behaviour of carbon oxides in contact with a plutonium dioxide surface has been quite poorly studied up to now.

This work provides a preliminary overview about carbon monoxide CO behaviour present in an atmosphere surrounding some plutonium dioxide. For instance, analysis of the gaseous atmosphere changes from plutonium dioxide samples stored under initial atmospheres made of CO ranging from 1% vol. to 10% vol. diluted in argon shows that carbon monoxide CO is extremely reactive and decompose according to a first-order rate law (figure 1). It is then converted into carbon dioxide CO_2 with a yield close to 50%. Moreover, formation of small amount of hydrogen H_2 have been observed too. This latter probably results from trace amount of remaining adsorbed water on plutonium dioxide surface.

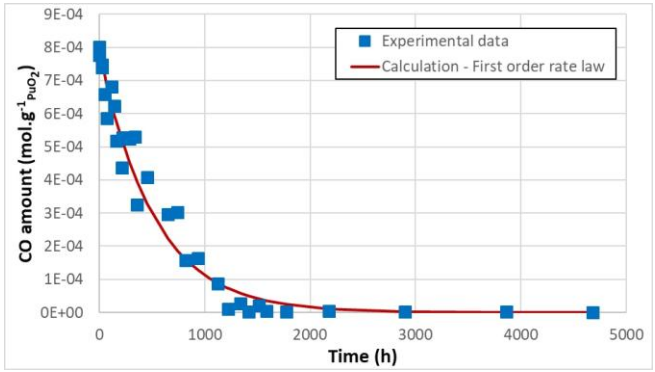

Figure 1. Comparison of experimentally measured amounts of CO in the conditioning atmosphere of a plutonium dioxide sample with a calculated consumption assuming a first-order rate law. $mPuO_2$ = 805 mg / Vcell. = 127 mL / Initial atmosphere 10% vol. CO in Ar.

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Underlying Mechanisms of Sparing Effects by Ultra-High Dose Rate Irradiation

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FLASH radiotherapy has attracted attentions due to its advantages, sparing effects of healthy tissues for example. A lot of studies have been done in wide research fields, however, the underlying mechanisms of sparing effects by ultra-high dose rate irradiation have not been clarified.

We have addressed to evaluate dose rate dependence of changes in yields of water radiolysis products. It is not feasible to experimentally obtain full datasets of water radiolysis species, so that in-silico studies are necessary to elucidate the mechanisms of dose rate effects from a radiation chemistry point of view.

To do so, we have employed MPEXS-DNA based on Geant4 ver. 10.7. patch 4, which is a radiation simulator computing on NIVIDA GPU devices. MPEXS-DNA enables us to exactly reproduce an experimental condition, and to estimate yields of water radiolysis species using a step-by-step approach faster more than 1000 times relative to conventional Geant4-DNA simulations. Namely, MPEXS-DNA is one of the most suitable simulators for the simulation under ultra-high dose rates.

Under protons, yields of OH radicals decrease with increasing dose rate (Figure 1). The trend is reasonable with experimental results. In hydrated electrons and hydrogen peroxide, significant changes in their yields are not observed with dose rate. With increasing dose rate, reactions of radiolysis species generated by a certain proton track with those by neighboring tracks occur significantly, leading to the reduction of reactive oxygen species (e.g., OH radicals). In addition, local and instantaneous reduction of oxygen concentration is seen. These findings suggest a decrease in indirect action and base damage. This would be one of the mechanisms of sparing effects under ultra-high dose rate irradiations.

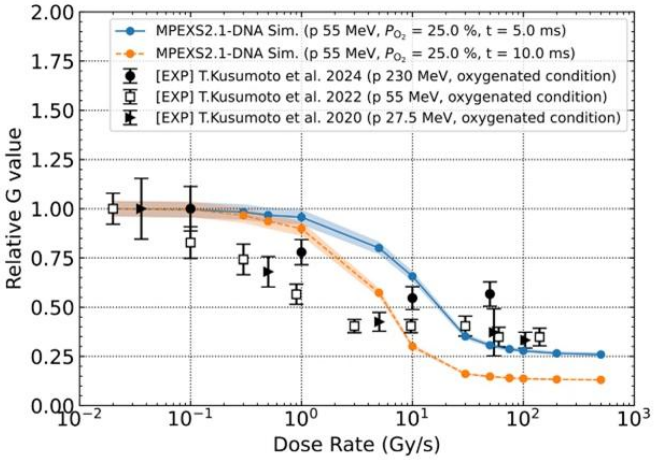

Figure 1. Dose rate dependence of yields of OH radicals under protons.

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Spinning Wineglass: a Novel Apparatus for Radiation Chemistry for Ion Beam Irradiations

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When performing radiation chemistry experiments with MeV ions most of the sample is not irradiated by the primary beam, as the range of these ions is very short. This leaves much of the sample as essential dead volume, with more than a thousand to one ratio between the unirradiated volume and irradiated volume. Irradiations are thus thousands of times longer than if the whole sample was irradiated fully. There is therefore an impetus to reduce the volume of samples during such irradiations, to increase the throughput of experiments.

Thus, we, at the Dalton Cumbrian Facility, have designed a novel system for ion irradiations of liquid samples, which irradiated much smaller volumes (hundreds of microliters). This uses new kind of glass sample holder, with an open top, that is spun at around 600 RPM called the "Spinning Wineglass". The sample is then held on the equator of the wineglass by centrifugal forces. The sample is then irradiated without a window on the sample holder through the open top. Preliminary results with the Fricke dosimetry, show promising replicability of dose. This hardware has been used in some ongoing radiation biology experiments.

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Modelling the Gas Generation of Actinide Bearing Materials in Storage Containers

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Actinides reprocessing generates by-products, placed in dedicated packaging arrangements involving several containers for short to medium-term storage (Figure 1). However, during storage, the products evolve by generating gases because of chemical and radiochemical reactions. Indeed, molecules of the packaging material (plastic containers, plastic bags) or adsorbed water on the product can be decomposed under ionizing radiation. Radiolysis generates primary radicals that may react with each other or with surrounding materials by homogeneous reactions to form stable gases (H_2, HCl, CO_2) [1-5]. In the same way, chemical reactions between water and strongly reductant pure metals may also generate gases. These phenomena may cause safety issues in storage vaults.

To improve our knowledge of the evolution of these alpha emitters containing products, a model was developed using a macroscopic approach. This phenomenological model can be divided in two parts: first, plastic and water radiolysis models were implemented to evaluate gas generation close to the nuclear materials, secondly, the transportation of gases between the different containers was evaluated. The model takes into account two transfer phenomena: leakage as a result of a total pressure difference between two compartments and permeation as a result of a partial pressure gradient from each side of a plastic wall. The model was computed in Matlab® using ODE solvers and was confronted to experimental measurements. Chosen key-parameters were adjusted to fit the experimental data. The model allows us to highlight the key parameters influencing the gas generation.

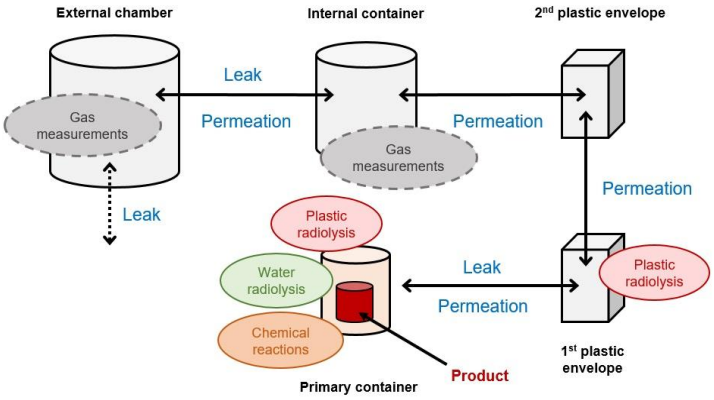

Figure 1. Scheme of each phenomenon taken into account in the model.

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Conservation of Leather Cultural Heritage Objects by Gamma Irradiation

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The conservation of leather materials in cultural heritage objects presents a complex challenge due to leather's vulnerability to degradation from environmental factors, microbial growth, and chemical reactions. Irradiation by gamma rays has emerged as a promising technique for conserving leather artefacts, offering a non-invasive method to disinfect and stabilize the material without causing physical damage. This process, in this case, involves using gamma rays (Co-60), which can effectively inactivate mold, bacteria, and insects. However, careful optimization of irradiation parameters is essential to prevent adverse effects, such as discoloration or molecular breakdown, which could compromise the leather's integrity. Recent research highlights the potential of controlled irradiation to extend the lifespan of leather artefacts while preserving their historical and aesthetic value. This research investigated the optical and mechanical properties of natural calf, cow, sheep, and goat leather samples treated with different doses of gamma irradiation. We analyzed the obtained results of irradiation effects on leather, assessed its advantages and limitations, and explored the best practices for its application in cultural heritage conservation.

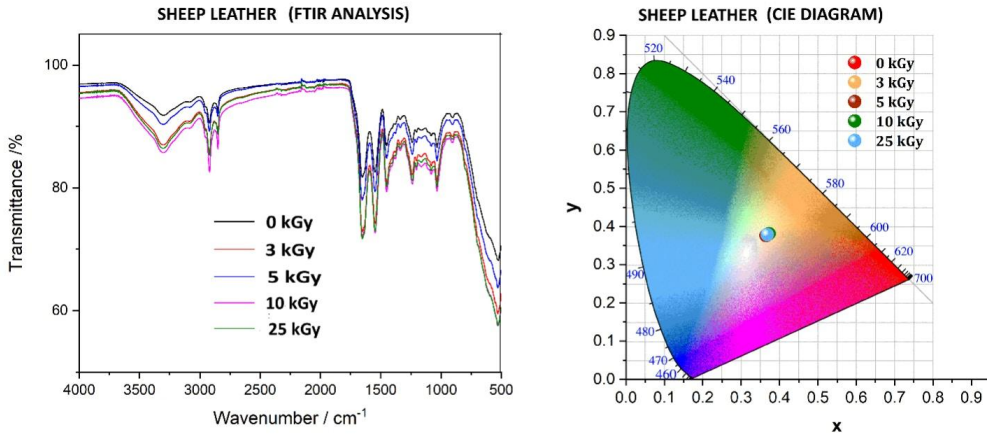

Figure 1. FTIR analysis and CIE diagram of sheep leather.

Preserving Colour: Assessing the Impact of Gamma Irradiation on Early Synthetic Dyes in Historical Textiles

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Historical textiles are continuously exposed to environmental and biological degradation, leading to fading and structural deterioration that compromise their longevity and cultural significance. Gamma irradiation is widely recognized as an effective disinfection technique due to its ability to eliminate fungi and bacteria. However, its application in textile preservation must be carefully controlled to prevent adverse effects on dyes and fibers. While past research has largely focused on the mechanical properties of irradiated textiles, the impact of gamma radiation on dyes remains underexplored, particularly for synthetic colourants commonly found in 19th- and 20th-century textiles.

Expanding upon previous studies that investigated gamma irradiation effects on natural dyes and selected synthetic dyes, this work presents a broader examination of early synthetic dyes. Wool samples dyed with representative synthetic colourants were irradiated at a dose rate of approximately 1.5 kGy/h, with absorbed doses reaching up to 20 kGy. Post-irradiation, dyes were extracted from fibers using supramolecular solvents [1] and analyzed by reversed-phase liquid chromatography with diode array detection (RPLC-DAD). Chemometric approaches were applied to assess structural modifications induced by irradiation.

The results contribute to a comprehensive understanding of the stability of early synthetic dyes under gamma irradiation. By identifying potential alterations and degradation pathways, this study provides valuable insights into optimizing gamma disinfection protocols for historical textiles. The findings support the development of evidence-based guidelines for the conservation community, ensuring the effective preservation of cultural heritage objects while maintaining the integrity of their dyed components.

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Picosecond Radiolysis Facility Using Electron Pump-Probe Spectroscopy

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ELYSE is a fast kinetic center located in France at Université de Paris-Saclay. ELYSE's 4 to 9 MeV accelerator ultrafast pump-probe facility at Orsay can initiate reactions using both ultrashort electron pulses (picosecond pulse radiolysis) or photon pulses (photolysis) to produce different re-active species for the observation of reaction pathways. Kinetics can be measured on a wide range of wavelengths (from the UV to the near infrared) and on timescales ranging from picoseconds to one millisecond.

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