



Erasmus+

# “Joint innovative training and teaching/learning program in enhancing development and transfer knowledge of application of ionizing radiation in materials processing” - TL-IRMP

**Romanian partner project coordinator:**

❖ **Prof. Ass. Dr. Cornelia Vasile**

**Research team:**

❖ **Dr. Elena Butnaru and Dr. Daniela Pamfil**  
• **persons in charge with administrative and financial management**

❖ **Dr. Elena Stoleru**

❖ **Dr. Raluca Dumitriu**

❖ **Dr. Raluca Darie Niță**

❖ **Dr. Mihai Brebu**

❖ **Ec. Lucia Mocanu**

**Period: 2014 – 2017**

Erasmus+ Programme, Key Action-Cooperation for innovation and the exchange of good practices, Strategic Partnerships for higher education  
**PROJECT NUMBER 2014-1-PL01-KA203-003611**

# Participating Organizations



Erasmus+



kaunas  
university of  
technology



PETRU PONI



Consiglio Nazionale  
delle Ricerche CNR



UNIVERSITÀ  
DEGLI STUDI  
DI PALERMO



UNIVERSITÉ  
DE REIMS  
CHAMPAGNE-ARDENNE

Name of the Organisation	Country of the Organisation
INSTYTUT CHEMII I TECHNIKI JADROWEJ	Warsaw, Poland
UNIVERSITA DEGLI STUDI DI PALERMO	Palermo, Italy
CONSIGLIO NAZIONALE DELLE RICERCHE	Naples, Italy
KAUNAS UNIVERSITY OF TECHNOLOGY	Kaunas, Lithuania
INSTITUTUL DE CHIMIE MACROMOLECULARA PETRU PONI	Iasi, Romania
UNIVERSITE DE REIMS CHAMPAGNE-ARDENNE	Reims, France
HACETTEPE UNIVERSITY	Ankara, Turkey

- Coordinator: Institute of Nuclear Chemistry and Technology (INCT), Warsaw
- The partnership was established based on previous cooperation between coordinator INCT - Poland and partners in other research projects.
- Participants of this project will involve 18 professors, 10 senior scientists, 10 young staffs, 85 students, 10 technicians.

# Related projects

- IAEA - 17689 (2013-2015), *Ionizing radiation and plasma discharge mediating covalent linking of stratified composites materials for food packaging*, project funded by the International Agency of Atomic Energy, Vienna, Austria; project coordinator CSI Dr. Cornelia Vasile.

In Erasmus+ project, International Atomic Energy Agency (IAEA) is collaborating center for radiation processing and industrial dosimetry.

- *Improving food safety through the development and implementation of active and biodegradable food packaging systems* **ACTIBIOSAFE** - 1SEE/30.06.2014, Romania - Norway bilateral project.

# Related projects

**plasticity** | Innovative value chain development  
for sustainable plastics in Central Europe



A Romanian focal point for public information about progress and activities in the degradable polymeric materials is created:  
<http://www.icmpp.ro/sustainableplastics/en/contact.php>



# Objectives

The objectives of this project are:

- to enhance teaching education level in chemistry and material science in higher education sector through intensive lectures delivered by world recognized scientist active in such research field;
- to increase students competence in labor markets through the visit and training in industrial radiation facilities for material process;
- strength international cooperation by this joint project;
- to improve Universities/ research institution education and research level and improve their reputation in the world through cooperation and dissemination knowledge on the internet.

# Activities

- International world recognized scientists and professors will be invited to deliver lectures to the students and staff in the field of chemistry and material science through the basic knowledge till to up to date knowledge.
- It will combine with Erasmus+ action 1 (see PL Warszaw83, agreement with University of Pavia) to realize this project;
- This project will offer the students the visit and training in industrial radiation facilities for material process to obtain real-on site and practical knowledge out of classroom.
- It provide equal opportunity for different gender and disable person, it is also a life learning project to encourage research and academic staffs to participate in the project.
- It will provide e-learning for students through project deliver web-based teaching materials.
- Pilot training of students following developed course curricula at KTU .

# First cycle of the intensive programme

- 7-17 September 2015 Warsaw, Poland (Institute of Nuclear Chemistry and Technology, INCT)
- 28.09.2015 - 02.10.2015, Palermo, Italy (University of Palermo, UNIPA)

## Scope

- ✓ 60 hours of lectures in INCT (6 ECTS)
  - ✓ 30 hours of lectures in UNIPA (3 ECTS)
  - ✓ Visiting of the irradiation facilities
  - ✓ Practices in dosimetry systems
  - ✓ Laboratory and exercises
- 6 hours in INCT (09.11.2015)  
6 hours in UNIPA (02.10.2015)



M.Eng. Sylwester Bułka is showing ILU-6 accelerator to the students.



Dr. Jarosław Sadło introduced alanine dosimetry by using EPR to the students. photo taken on Sept. 11, 2015 at INCT



# Participants: 1<sup>st</sup> intensive course

- ✓ 39 participants from Poland, Italy, Turkey, Lithuania, France and Romania
- ✓ 8 lectures from: Italy, Poland, Turkey, Lithuania and France

## Romanian participants

First Name	Last Name
Alina	Diaconu
Dragos Lucian	Isac
Andrei Victor	Oancea
Andra	Humelnicu
Daniela	Ailincai
Daniela	Pamfil
Oana	Chirila



### Topics

- ✓ Radiation chemistry of polymers
- ✓ Application of ionizing radiation in technology of polymers
- ✓ Nuclear physics
- ✓ Dosimetry
- ✓ Ionizing radiation influence on natural polymers
- ✓ Radiation technology in food industry
- ✓ Hydrogels, nanocomposites and nanomaterials



# Training/learning courses at INCT (7-11 September 2015)

First week	September 7 (Monday)	September 8 (Tuesday)	September 9 (Wednesday)	September 10 (Thursday)	September 11 (Friday)
9:00-10:30	Basic radiation physics <b>Diana ADLIENĖ</b> <i>Kaunas University of Technology, Kaunas, Lithuania</i>	Dosimetrical principles and radiation protection <b>Diana ADLIENĖ</b>	Radiation measurements: instruments and methods <b>Diana ADLIENĖ</b>	Radiation engineered hydrogels <b>Clelia DISPENZA</b>	Practice in sterilization plant (dosimetry)
break					
10:45-12:15	Radiation interaction with matter <b>Diana ADLIENĖ</b>	Radiation generators <b>Diana ADLIENĖ</b>	Radiation effects in polymers <b>Dilek SOLPAN</b>	Radiation synthesis of polymer nanoparticles <b>Clelia DISPENZA</b>	Practice in sterilization plant (dosimetry)
break					
13:00-14:30	Radiation chemistry of liquid systems <b>Dilek SOLPAN</b> <i>Hacettepe University, Ankara, Turkey</i>	Radiation chemistry of organic molecules <b>Dilek SOLPAN</b>	General aspects of radiation initiated polymerisation <b>Clelia DISPENZA</b> <i>Universita degli Studi di Palermo, Palermo, Italy</i>	Radiation engineered multifunctional nanoparticles <b>Clelia DISPENZA</b>	Practice in sterilization plant (dosimetry)
break					
15:00-16:30	Radiation chemistry of water and aqueous solutions <b>Dilek SOLPAN</b>	Radiation chemistry of organic solids <b>Dilek SOLPAN</b>	Radiation-induced polymerisation in solution, dispersion and emulsion. <b>Clelia DISPENZA</b>		

# Training/learning course at INCT (14-17 September 2015)

Second week	September 14 (Monday)	September 15 (Tuesday)	September 16 (Wednesday)	September 17 (Thursday)	September 18 (Friday)
9:00-10:30	Radiation-induced grafting: General aspects <b>Dilek SOLPAN</b>	Optimization of the grafting process <b>Dilek SOLPAN</b>	Application of radiation induced grafting I <b>Dilek SOLPAN</b>	Active packaging (nanotechnology) of food and its combination with irradiation <b>Clara SILVESTRE</b>	departure
break					
10:45-12:15	Comparison of the different methods of radiation grafting <b>Dilek SOLPAN</b>	Influence of polymer morphology Effect of the irradiation conditions: under vacuum, and in air <b>Giuseppe SPADARO</b>	Application of radiation induced grafting II <b>Dilek SOLPAN</b>	Modified atmosphere packaging of food and its combination with irradiation processing <b>Clara SILVESTRE</b>	
break					
13:00-14:30	Ionizing radiation effects on polymers Parameters affecting radiation effects on polymers <b>Giuseppe SPADARO</b> <i>Universita degli Studi di Palermo, Palermo, Italy</i>	Heterogeneous oxidative degradation ; influence of the dose rate <b>Giuseppe SPADARO</b>	Reasons to apply irradiation pasteurization in food processing <b>Clara SILVESTRE</b> <i>Consiglio Nazionale delle Ricerche, Bologna, Italy</i>	Survey on the relevant methodologies for characterisation of irradiated materials and Future trends of irradiation applied to food packaging <b>Clara SILVESTRE</b>	
break					
15:00-16:30	Radiation effects on the most common polymers <b>Giuseppe SPADARO</b>	Effects of radiation on polymer properties <b>Giuseppe SPADARO</b>	Radiation processing to improve functionality of biodegradable food packaging <b>Clara SILVESTRE</b>		

# Training/learning course at UNIPA (September 28 – October 2, 2015)

Week	September 28 (Monday)	September 29 (Tuesday)	September 30 (Wednesday)	October 1 (Thursday)	October 2 (Friday)
9:00-10:30	Interaction of ionizing radiation with matter Polymer crosslinking via chemical and physical methods <b>Grazyna PRZYBYTNIAK</b> <i>Institute of Nuclear Chemistry and Technology, Warsaw, Poland</i>	Additives influencing industrial polymer crosslinking by EB Evaluation of radiation crosslinking process in industry <b>Grazyna PRZYBYTNIAK</b>	Radiation supported production of shrinkable tubing and tapes Radiation long-chain branching and crosslinking in polymeric films <b>Grazyna PRZYBYTNIAK</b>	Radiation-initiated cross-linking polymerization – Part 2 – Applications (coatings, adhesives, composites) – Optimization of performances <b>Xavier COQUERET</b>	Lab Excise (whole day)
break					
10:45-12:15	Natural polymer systems: structural properties, related applications and desirable modification: 1. Basic components and raw materials 2. Composites/Nanocomposites and nanoparticles <b>Krystyna CIEŚLA</b> <i>Institute of Nuclear Chemistry and Technology, Warsaw, Poland</i>	Radiation crosslinking in cable industry  Radiation crosslinking of medical devices <b>Grazyna PRZYBYTNIAK</b>	Radiation-initiated cross-linking polymerization – Part 1 – free radical chemistry – cationic chemistry – reaction monitoring – kinetics and microstructural aspects <b>Xavier COQUERET</b>	Radiation modification of proteins and composites/nanocomposites based on proteins. Basic knowledge and practical applications <b>Krystyna CIEŚLA</b>	
break					
13:00-14:30	Determination of radiolytic yields for scission and cross-linking in polymers exposed to high energy radiation <b>Xavier COQUERET</b> <i>Université de Reims Champagne Ardenne, France</i>	Basic aspects of chain polymerization mechanisms and kinetics: from conventional initiation to radiation-induced processes <b>Xavier COQUERET</b>	Radiation modification of polysaccharide: hydrogels formation and microencapsulation of active components Application of radiation modified polysaccharide hydrogels <b>Krystyna CIEŚLA</b>	Radiation supported production of foam and radial tires Recycling of crosslinked polymers Perspective of radiation technologies <b>Grazyna PRZYBYTNIAK</b>	
break					
15:00-16:30	Radiolytic synthesis of metal nanoparticles – Basics and applications <b>Xavier COQUERET</b>	Chemical and physical modification of polysaccharide systems: specific features of electromagnetic radiation Radiation degradation of polysaccharides and modification of activity of active polysaccharides <b>Krystyna CIEŚLA</b>	Radiation modification of polysaccharide composites for packaging Radiation modification of polysaccharide composites: potential for the other areas. <b>Krystyna CIEŚLA</b>		



## Second cycle of the intensive programme

- 5-15 September 2016 Reims, France (Universite De Reims Champagne-Ardenne, URCA)
- 3-7 October 2016, Kaunas, Lithuania (Kaunas University of Technology, KTU)

### Scope

- ✓ 60 hours of lectures in URCA (6 ECTS)
- ✓ 30 hours of lectures in KTU (3 ECTS)
- ✓ Laboratory and exercises
- ✓ Scientific visit facilities and practice

6 hours in KTU  
6 hours in URCA



At Kaunas University of Technology

# Participants: 2<sup>nd</sup> intensive course

- ✓ 44 participants from Poland, Italy, Turkey, Lithuania, France and Romania
- ✓ 11 lectures from: Italy, Poland, Turkey, France and Romania

## Romanian participants

First Name	Last Name
Gabriela	Pricope
Ana Lacramioara	Lungoci
Irina Alexandra	Crudu
Andrei	Bejan
Petru Marcel	Popovici
Bogdan Constantin	Condurache



## Training /learning course – 1<sup>st</sup> week at URCA (September 5-9, 2016)

Week	Sept.5 (Mon.)	Sept.6 (Tues.)	Sept.7 (Wes.)	Sept.8 (Thurs.)	Sept.9 (Fri.)
8:30-10:00  break	Basics of radiation physics ( <b>Zbigniew Zimek</b> )	Comparison between e <sup>-</sup> , gamma and X-ray facilities: advantages and limitations ( <b>Zbigniew Zimek</b> )	Electrical measurements and computed prediction of dose distribution, computer modeling for the control of radiation dose ( <b>Zbigniew Zimek</b> )	Radiation synthesis of hydrogels ( <b>Clelia Dispenza</b> )	Lab Exercises (EB polymerization kinetics,
10:15-11:45  break	General aspects of particle accelerators technology (electrons, protons, helions, swift heavy ions) X-ray sources ( <b>Zbigniew Zimek</b> )	General aspects of (radiation initiated) polymerisation. ( <b>Clelia Dispenza</b> )	Changes in physical and chemical properties: Natural and synthetic polymers ( <b>Dilek Solpan</b> )	Radiation engineered nanogels ( <b>Clelia Dispenza</b> )	...EB grafting, material characterization) ( <b>C. Kowandy</b> )
13:00 - 14:30  break	<b>Radiation chemistry of liquid systems:</b> Techniques in radiation chemistry - Steady-state techniques - Pulse radiolysis ( <b>Dilek Solpan</b> )	Organic solvents/solutions: Alkanes, alken and aromatic hydrocarbons Other organic molecules (sterilization of drugs) ( <b>Dilek Solpan</b> )	Radiation-induced polymerisation in water media: homogeneous and heterogeneous polymerisation ( <b>Clelia Dispenza</b> )	Criteria for accelerator selection on the basis of technical performance and cost of operation ( <b>Zbigniew Zimek</b> )	Nanostructural characterization of radiation processed materials by AFM, SEM, TEM
15:00 - 16:30	Radiation chemistry of water and aqueous solutions: Water radiolysis - Reactions of intermediates Characteristics of primary and secondary products ( <b>Dilek Solpan</b> )	Radiation chemistry of organic solids: Primary and secondary effects. Radiation yield ( <b>Dilek Solpan</b> )	Radiation-synthesis of polymer nanoparticles ( <b>Clelia Dispenza</b> )	Tutorials - interactions between students and teachers	( <b>M. Molinari</b> )



## Training /learning course – 2<sup>nd</sup> week at URCA (September 12-15, 2016)

Week	Sept.12 (Mon.)	Sept.13 (Tues.)	Sept.14 (Wes.)	Sept.15 (Thurs.)	Sept.16 (Fri.)
8:30-10:00  break	Irradiation assisted polymer surface functionalization – bioactive compounds immobilization (Cornelia Vasile)	Optimization of the process for grafting  (Olgun Güven)	Radiation crosslinking for the cable industry, rubber materials and for medical devices (Andrzej G. Chmielewski)	Radiation supports synthesis of nanostructures Functionalized track membranes Metal and metaloxide nanoclusters  (Olgun Güven)	Departure
10:15-11:45  break	Irradiation assisted polymer surface functionalization – proteins immobilization (Cornelia Vasile)	Relevant methodology for characterization of radiation exposed polymeric materials (Cornelia Vasile)	Applications of radiation-induced grafting  (Olgun Güven)	Nanostructural characterization of radiation processed materials – Instrumental aspects and physical significance of measurements  (Michael Molinari)	
13:00-14:30  break	Radiation-induced grafting General aspects (Olgun Güven)	Gamma irradiation and industrial facilities (Andrzej G. Chmielewski)	Influence of radiation on biological media (Cornelia Vasile)	Future development of radiation processing State of the art of radiation processing Emerging technologies Commercialization (Andrzej G. Chmielewski)	
15:00-16:30	Comparison of the different methods of radiation grafting (Olgun Güven)	Additives influencing the radiation crosslinking of industrial polymers (Andrzej G. Chmielewski)	Enhanced degradability of inert materials by using gamma or plasma exposure (Cornelia Vasile)	Tutorials - interactions between students and teachers	

## Training /learning course – 3<sup>rd</sup> week at Kaunas University (October 3-7 2016)

Week	Oct. 3 (Mon.)	Oct. 4 (Tues.)	Oct. 5 (Wes.)	Oct.6 (Thurs.)	Oct. 7(Fri.)
8:30-10:00	Ionizing radiation effects on polymers Radiation-induced molecular modification of polymers: Chain branching; crosslinking; degradation; Influence of molecular structure and crystallinity <b>(Giuseppe Spadaro)</b>	Basic aspects of chain polymerization mechanisms and kinetics: from conventional initiation to radiation-induced processes <b>(Xavier Coqueret)</b>	Radiation-curing by cross-linking polymerization – Part 1. Free radical chemistry – cationic chemistry – reaction monitoring – kinetics and microstructural aspects <b>(Xavier Coqueret)</b>	Radiation-curing by cross-linking polymerization – Part 2. Applications (coatings, adhesives, composites) Optimization of performances <b>(Xavier Coqueret)</b>	Lab exercises oriented on dosimetry
break					
10:15-11:45	Radiolytic synthesis of metal nanoparticles – Basics and mechanistic aspects – Overview of current and prospective applications <b>(Xavier Coqueret)</b>	Influence of polymer morphology Effect of the irradiation conditions: under vacuum and in air <b>(Giuseppe Spadaro)</b>	Effects of radiation on polymer properties <b>(Giuseppe Spadaro)</b>	Radiation processing to improve functionality of biodegradable food packaging <b>(Clara Silvestre)</b>	and materials sciences (whole day)
break					
13:00-14:30	Determination of radiolytic yields for scission and cross-linking in polymers exposed to high energy radiation <b>(Xavier Coqueret)</b>	Heterogeneous oxidation of a solid polymer irradiated in air, dose rate effects; Post-irradiation oxidation; Effects of ionizing radiation on physico-chemical, mechanical and electrical properties. <b>(Giuseppe Spadaro)</b>	Reasons to apply radiation pasteurization in food processing <b>(Clara Silvestre)</b>	Ecosustainable issues; LCA, waste management <b>(Clara Silvestre)</b>	
break					
15:00-16:30	Radiation effects on the most common polymers <b>(Giuseppe Spadaro)</b>	Modified atmosphere packaging of food and its combination with irradiation processing Diffusion concepts and evaluation of barrier properties <b>(Clara Silvestre)</b>	Active packaging (nanotechnology) of food and its combination with irradiation. Migration concepts and evaluation through food simulants <b>(Clara Silvestre)</b>	Tutorials - interactions between students and teachers	

# Evaluation test

- ❖ 23.10.2015 – 1<sup>st</sup> intensive course
  - ❖ 04.11.2016 – 2<sup>nd</sup> intensive course
- 14pm – 17pm; At the same time for all of participants in their countries.  
45 multiple choice questions  
9 ECTS points (6 – INCT/URCA; 3 – UNIPA/KTU)





# Activities

- Numbers of students and staff participation (quantitative), percentage of attendance lectures, succeed rate of students passing the course examination, and the polling score given by participants (mainly the students) are the indicators of the project achievements. 9 ECTS credits were counted for students.
- 12 hours laboratory exercises, including radiation dosimetry and instrumental techniques for product analysis in irradiated polymer materials have been organized.
- 12 hours scientific visits to industrial irradiation facilities, including practice of radiation dosimetry applied in industrial irradiation facility have been organized.

# Activities

- Conventional communication methods, such as telephone, fax etc. and internet based communications, for e.g., e-mail, internet conference (skype) were used among all project partners for cooperation.
- Transnational project meetings (total 6 times) to ensure project implementation.

Warsaw - December, 8-9, 2014

Palermo - June, 18-19, 2015

Reims - December, 3-4, 2015

Kaunas - July, 7-8, 2016

Naples - February, 23-24, 2017

Iasi - September, 21-22, 2017

Project coordinator, coordinator of each partners and leaders of each activity participate to the meetings.

- New innovative curricula/educational methods/development of training courses - open and distance learning was used.

# Activities

- Book entitled **"APPLICATIONS OF IONIZING RADIATION IN MATERIALS PROCESSING"** was elaborated.
  - Edited by Yongxia Sun and Andrzej G. Chmielewski
  - Institute of Nuclear Chemistry and Technology, Warszawa 2017
- ISBN 978-83-933935-8-9

ISBN 978-83-933935-9-6 (Volume 1)

ISBN 978-83-946412-0-7 (Volume 2)

## Volume 1



## Volume 2





# Activities

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# Intellectual Output

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The knowledge gained during the project helped participants to improve their skills and influence of ionizing radiation on materials, new methods and techniques applied to production materials with desired properties.