



Newsletter #1

A word from the Coordinator

The PuMMA project is an exciting new initiative aimed at shaping the future of nuclear energy. This European project aims to explore the possibilities for Plutonium management in Generation IV nuclear reactors, with a focus on evaluating the impact of high Plutonium content on the fuel cycle, reactor safety and fuel performance.

The project has made significant progress, with three workshops taking place since its start. The results have been positive, demonstrating the project's success in bringing together a diverse group of experts from across the EU to work towards a common goal.

The PuMMA project is paving the way for sustainable and safe nuclear energy for future generations. We are proud to be a part of this innovative project and look forward to sharing updates on its progress.

Nathalie Chauvin,
Coordinator of PuMMA
International expert on fuels for advanced reactors at CEA

PROJECT'S OBJECTIVES

WORK PACKAGE UPDATES



Work Package 1 - Study of plutonium management in connection with the fuel cycle: scenario studies

WP1 is led by CIEMAT and aims to highlight the flexibility of the Generation-IV reactors on the Plutonium management (breeding, burning or iso-generation). This objective will be achieved by means of the study of the performances and impact of these PuM options on all the operations involved on the FC scenario (manufacturing, storage, transportation, reprocessing, core design, and fuel behaviour).

Work package 2 - Fuel Pin behavior in reactor with high PU content: nominal and transient

WP2 is led by CEA and is devoted to the behaviour of SFR fuel with high Pu content, including simulation and experimentations, and the sizing associated methodology. This goal will be achieved by doing Post Irradiation Examination (PIE) on 3 experimental fuel pins, comparing a large set of simulations of these experiments obtained with various fuel performance codes, and on the basis of the results comparisons, propose safety analysis methodology and recommendations.

Work package 3 - Fuel properties with high PU content: measurements and modelling

WP3 is led by EK and aims to evaluate the main properties of irradiated and non-irradiated MOX fuel in order to reduce the significant sources of uncertainty in the safety evaluation: in nominal conditions uncertainties of thermal and mechanical properties will be reviewed and the margin to melting of pellet will be estimated; and in accidental conditions, incidents and accidents the effect of uncertainties of mechanical properties on cladding failure and the uncertainties of thermal properties on fuel melting fraction will be evaluated.

Work Package 4 - Comparison of irradiation results in fast spectrum VS thermal spectrum

WP4 is led by NRG and is intended to go further in the analysis on how MTR (Materials test reactor) fuel irradiations can be compared to irradiation in a fast reactor, i.e. to what extent are MTR irradiations representative for performance in a fast neutron spectrum. The main objectives are to study of the design differences of the irradiation devices in MTR vs FR; to interpret irradiation results in MTR and FR, starting at core characteristics and including experiment designs; to analyse the advantages / disadvantages of irradiations in FRs / MTRs for future programs; and for MTR and experimental FR irradiations to contribute to the fuel qualification (steady state and transients).

Work Package 5 - Impact of PU content on fuel dissolution

WP5 is led by NNL and aims to evaluate the impact of high Pu content on key issues that affect the reprocessing and multi-recycling of Pu from spent fuels. It is assumed that Pu contents will be in the range of 10-45%, that is typical fuels for Generation-IV fast reactors. The factors that will be investigated are Pu dissolution rate; Pu and FP distribution in solid residues; and impact of irradiation of high Pu content spent fuel in SFR on Pu dissolution behaviour.

Work Package 6 - Education and training, dissemination and communication


WP6 is led by JRC and aims to encourage mobility of PhD students, post-doc; to organize workshops for PhD students, post-docs, designers, and stakeholders, highlighting the issues related to FC scenarios, fuel behavior and spent fuel reprocessing; to improve educational tools (MOOC and data base) and learning methodologies taking advantage of past workshops and

seminars organized over the last 30 years in the various EU projects related to multi-recycling and closed FC; to communicate and disseminate the outcomes of PuMMA to a larger audience.

Learn more on the project


PROJECTS ACHIEVEMENTS

HIGHLIGHT ON DISSOLUTION OF IRRADIATED MOX FUEL



DISSOLUTION OF IRRADIATED PHENIX MOX FUEL WITH HIGH PLUTONIUM CONTENT

Technical correspondents: Nathalie Reynier-Tronche, Laurent Huyghe, Morgane Bisel, Jean-Gabriel Peres




WP5: IMPACT OF PU CONTENT ON FUEL DISSOLUTION 17/06/2022

The PuMMA (Plutonium Management for More Agility) project brings together 20 partners from 12 European countries to address issues related to Generation IV reactors and the fuel cycle. One of the objectives of this project is to increase the technological maturity of the cycle associated with high Pu content fuels, typically close to 45%, but to date, the dissolution of MOX fuel has only been fully qualified for Pu contents of less than 30%. The CEA has studied the dissolution of these fuels with high Pu contents before and after irradiation

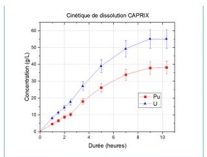
To study the post-irradiation dissolution behaviour, 400 mm of the CAPRIX fissile column irradiated at 110 GWj/MTL in PHENIX were received at Atlatante at the end of 2021. The fuel was cut into 4 sections of 25 mm prior to the dissolution test which was carried out in a shielded chain, under the following conditions: [U+Pu] 100 g/L, [HNO₃] 10 M, 10 hours at boiling point.

Samples taken allowed to trace the dissolution kinetics of U and Pu. A dissolution plateau seems to be reached after a period of 10 h of dissolution.

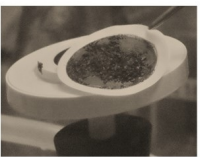
- At the end of the treatment, the solution was filtered on a 0.3 µm porosity membrane and the primary dissolution residues were calcined at 400°C. The mass of the residues is 167 kg per ton of initial heavy metal (TML), i.e. about 6 times more than for a Phénix fuel (Pu_{ini} 29%) with an equivalent burnup.



CAPRIX sections



Dissolution kinetics U and Pu
X-Hybrid analysis by LZAT on CBA




Dissolution residues

- The tailings, obtained from the primary dissolution, are currently undergoing an advanced dissolution procedure, including oxidising silver (I) dissolution and alkaline and acid melts, to bring the constituent elements of the tailings, including uranium and plutonium, into solution.
- According to the current results, the plutonium insolubility of CAPRIX fuel is between 15 and 19%, well below the value obtained for unirradiated pellets, for which the insolubility measured was 82%. This demonstrates the very favourable impact of irradiation on Pu insolubility, particularly through the modification of the fuel micro-structure (restructuring, appearance of cracks, etc.).

One of the objectives of the PuMMA project is to acquire the experimental data needed to reach technological maturity around TRL-4 for fuels containing up to 45% Pu. To this end, work has been carried out at the CEA to conduct dissolution tests in medium and high activity on fuels with high Pu contents before and after irradiation.


Read more

PuMMA WORKSHOP IN PETTEN



Workshop on fuel qualification and code validation

WP6 JRC and NRG Petten, 6-7 Sept. 2022






topics covered:

- Fuel Qualification
- Validation of fuel performance codes
- Link to Irradiations in MTR and SFR
- Integral and analytical irradiations
- Illustration with past irradiations and PIE

- 2 days, 3 sessions
- 17 presentations
- 20 speakers
- 64 attendants
- Dedicated session for students
- Visit of HFR (Control Room and Hot Cells) and JRC Laboratories

Contributions from CEA, ENEA, EPFL, JRC, NNL, NRG, ORNL, POLIMI, US NRC






Successful mixed on site/remote Workshop

Next Workshop on the Nuclear Fuel Cycle, including the aspects of fabrication, dissolution, and reprocessing
Coordinated NNL


PuMMA's Workshop in Petten took place on September 6 and 7, tackling the subject of fuel qualification and code validation. A great opportunity for PhD students to present their work and get some feedback from nuclear scientists.

HIGHLIGHT ON MEASUREMENTS OF THERMAL PROPERTIES



Elaboration and characterization of a $U_{0.40}Pu_{0.60}O_{2-x}$ mixed oxide pellet

Marie-Margaux DESAGULIER, Romain VAUCHY, Philippe M. MARTIN,
Julien MARTINEZ, Nicolas CLAVER, Christine GUENEAU



WP3.4 : Measurements of thermal properties
18/06/2021

Subject

Elaborations and measurement of thermodynamic and structural properties of $(U, Pu)O_{2-x}$ mixed oxides with high plutonium content

Goals

- Fill the lack of data (structural, microstructural, thermal and thermodynamic) for MOX with Pu content greater than 45 mol% and more specifically for Pu > 60 mol%
- Improvement of the U-Pu-O phase diagram

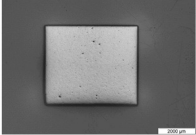
Elaborations by co-milling process

- Study of the minimum region of melting temperature: three Pu contents 60, 65 and 70 mol%
- Evaluation of the C_p and $\lambda_{thermal}$ model
- Study of stoichiometric (O/M = 2.00) and hypo-stoichiometric (O/M < 2.00) MOX
- Dimensions of the pellets: height of 5 mm and diameter of 5 mm

Elaboration of the 60% mol. Pu content test pellet

Targeted properties:

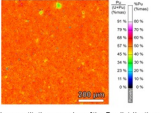
- Monophasic (solid solution) and stoichiometric (O/M = 2.00) material $U_{0.40}Pu_{0.60}O_{2.00}$
- Homogeneous chemical distribution of cations (U and Pu) and oxygen (O/M ratio)
- Density after sintering >95% of d_{theor}
- Clean microstructure without large defects (no micro/macro-cracks)



Optical microscopy observation of the obtained $U_{0.40}Pu_{0.60}O_{2.00}$ sintered mixed oxide pellet

Characterizations

- Optical microscopy:** clean microstructure without cracks
- XRD at room temperature:** monophasic material (FCC structure) with $a = 5.426 \pm 1.10^{-3} \text{ \AA}$ $\rightarrow y=0.6$ for O/M=2.00 (Vegard's law) and O/M=1.964 $\pm 4.10^{-3}$ (Dunez law)
- Density:** 96 % of d_{theor}
- Electron Probe Micro-Analysis:** $y = 0.595 \pm 6.10^{-3}$ and homogeneous distribution of cations with acceptable uranium heaps
- Raman Spectroscopy:** T_{2g} band position is $467.5 \text{ cm}^{-1} \rightarrow y = 0.597 \pm 3.10^{-2}$ [1]
- SEM/EDS:** Grain size of $15.7 \pm 5.10^{-1} \mu\text{m}$
- Chemical analysis:** $U_{0.40}Pu_{0.59}Am_{0.01}O_{2.00}$



Pseudo-quantitative mapping of the Pu distribution determined by Electron Probe Micro-Analysis

Conclusions:

- Monophasic and stoichiometric $U_{0.40}Pu_{0.60}O_{2.00}$ mixed oxide
- Clean microstructure without cracks
- Homogeneous cationic distribution
- Dense pellet (96% of d_{theor})

Manufacturing parameters are validated

Next steps:


- Pelletizing and sintering of a batch of 20 pellets at 60 mol% Pu (July 2021)
- Manufacturing of pellets with 65 mol% and 70 mol% of Pu (planned in September and October 2021)
- Measuring thermodynamic properties of MOX with two O/M ratios at JRC-Karlsruhe (melting temperature, enthalpy, heat capacity, thermal conductivity, ...) and at Marcoule (thermal expansion and oxygen potential)

[1] L. Medyk, D. Manara, J.-Y. Colle, D. Bouesrière, J.F. Vigier, L. Marchetti, P. Simon, P. h. Martin, Determination of the plutonium content and O/M ratio of (U,Pu)O_{2-x} using Raman spectroscopy, Journal of Nuclear Materials, 541 (2020) 152439. <https://doi.org/10.1016/j.jnucmat.2020.152439>

A highlight in PuMMA project from the PhD Marie-Margaux DESAGULIER at CEA-Marcoule working for the Work Package 3 on elaboration and characterization of a mixed oxide pellet. The experiments relates to the Measurements of thermal properties.


Read more

PuMMA WORKSHOP IN MADRID



Workshop of Fuel Cycle Scenarios

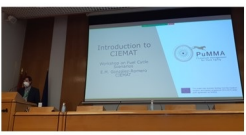
WPs: EDUCATION AND TRAINING, DISSEMINATION AND COMMUNICATION




11/04/2022

5 topics covered:


- National Fuel Cycles and International Activities
- Simulation codes
- Modelling
- Uncertainties + Optimization
- Machine learning



- 2 days
- 7 sessions
- 27 presentations
- 20 speakers
- 42 attendants
- Dedicated session for students



Contributions from BME, CEA, CIEMAT, CNRS, EK, Framatome, IAEA, Jacobs, LGI, NNL, OECD/NEA, Polytechnique Montréal, SCK-CEN, UJV, UPM, VTT



Successful mixed on site/remote Workshop

Milestone MS13 accomplished!

Next Workshop on *Fuel behaviour and fuel modelling for nominal and accidental conditions – Validation base for code reliability.*

Coordinated by JRC in Petten

The first workshop of PuMMA on Fuel Cycle Scenarios took place in Madrid.

PROJECT RESOURCES

Related events



- [Uranium Raw Material for the Nuclear Fuel Cycle \(URAM-2023\)](#) May 8-12, Vienna
- [World Nuclear Symposium](#), September 6-8, London
- [29th IAEA Fusion Energy Conference \(FEC 2023\)](#), October 16-21, London

- [World Nuclear Exhibition](#), November 28-30, Paris



PuMMA on SNETP Platform

PuMMA is featured within SNETP portfolio's page which provides access to a factsheet describing the project.

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Project Partners

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