Collaborations on nuclear fuel safety

JRC.G.5 unit and High Level Waste Unit (CIEMAT)

Marco Cologna, Unit G.5 - Nuclear Science and Innovation for Energy and Health (JRC-KA)

Jone M Elorrieta, High Level Waste Unit (CIEMAT)

Bilateral meeting between the JRC and CIEMAT

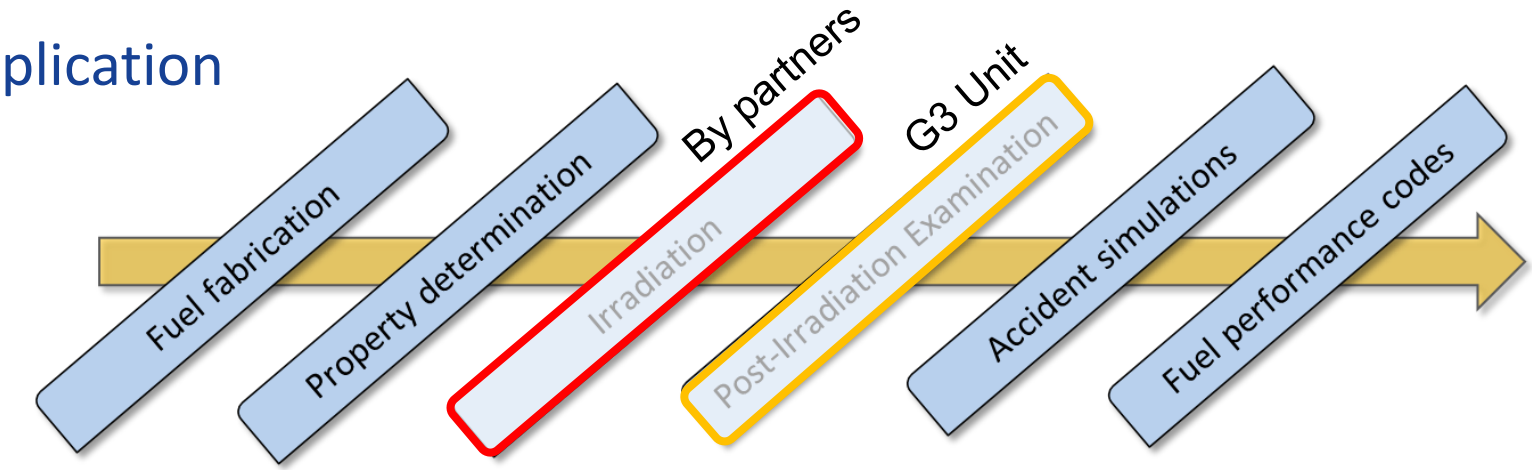
Madrid, 4th March 2026 (Online)

European Commission

Nuclear materials synthesis and characterization at JRC Karlsruhe

Contribute to the **safe operation** of nuclear energy systems in Europe by **providing knowledge and scientific/technological data** on nuclear fuels

- Current generation LWRs (Oxide fuels)
- Potential future reactors (Oxide, Nitride, Carbide, Liquid fuels)
- Radio-isotope Power Sources (Am-241 and Pu-238 for space applications)
- Re-use and recycling of nuclear materials (Critical Raw Materials)
- Targets for medical application



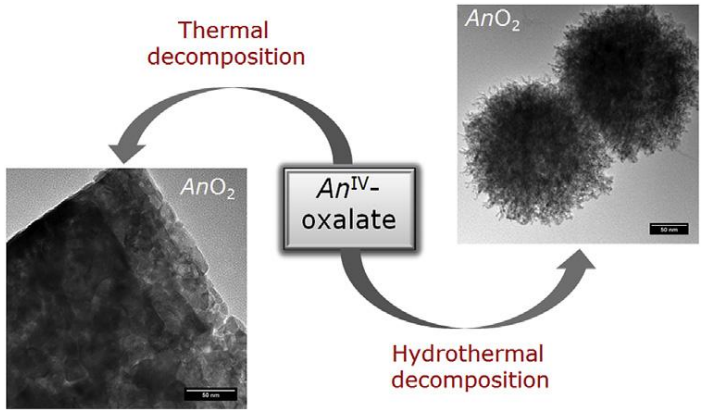
Nuclear ceramics synthesis

3 independent lines for fuel synthesis, with gloveboxes, shielded & remote operations

(i) **U and Th**, (ii) **Pu** and enriched U, (iii) **Minor Actinides Lab**

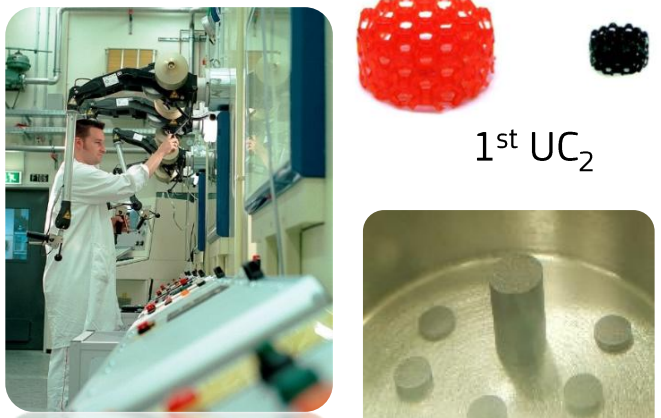
Powder synthesis

- Liquid routes: sol-gel, oxalate or hydroxide precipitaton, infiltration
- Solid routes: blending, milling
- Thermal or hydrothermal conversion, carbothermal reduction



Forming

- Uniaxial pressing
- 3-D printing, electro-dropping, electro-spinning (U, Th)

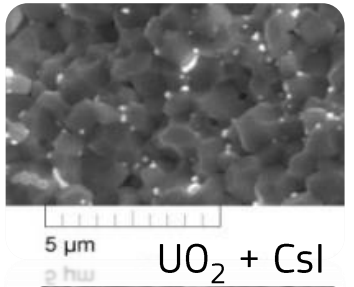


1^{st} UC_2

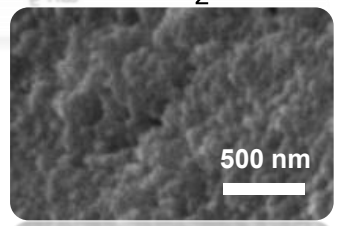
$(Am_{0.80}U_{0.12}Np_{0.06}Pu_{0.02})O_{1.8}$

Sintering

- Metallic and tubular furnaces in different atmospheres up to ~1700°C
- Conventional sintering
- Spark Plasma Sintering (U, Th)



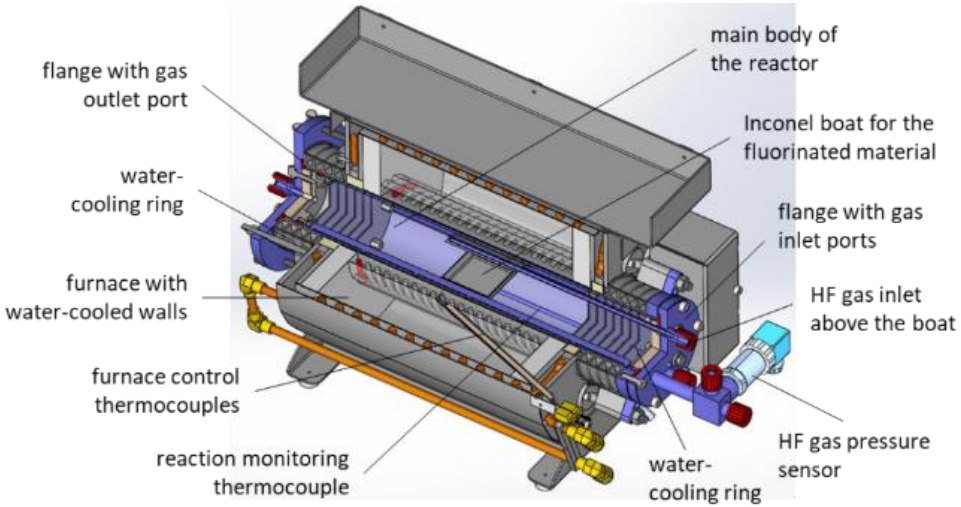
UO_2 + CsI



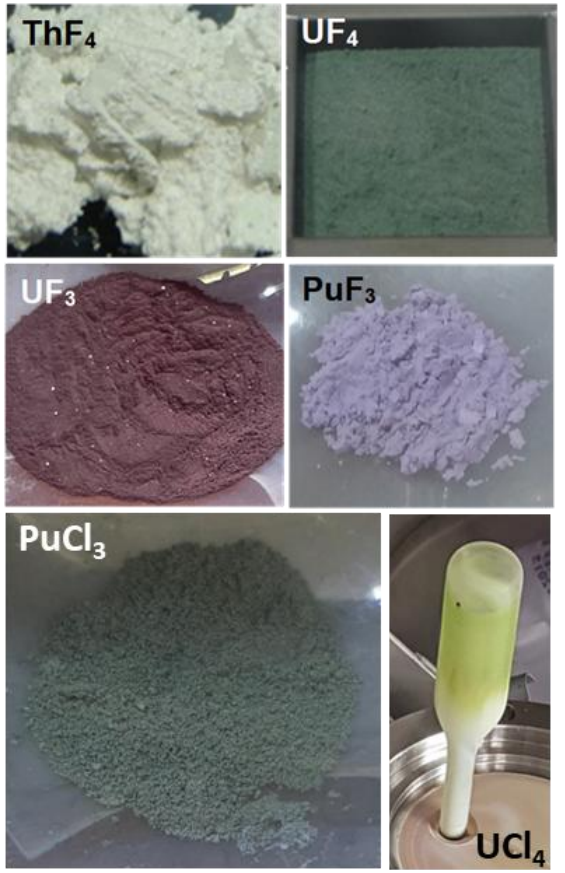
Nanostructured U, ThO_2

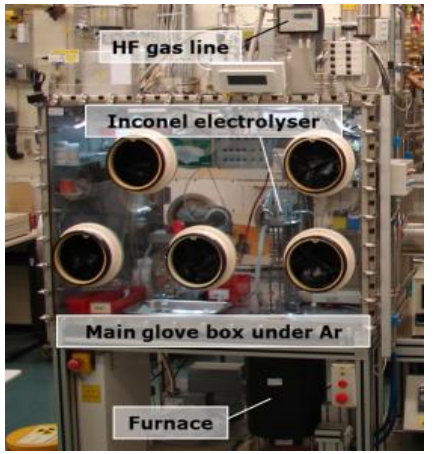
Actinide Halide Synthesis Laboratory

Fluorination and chlorination lines designed and installed at JRC Karlsruhe



Europe-unique installation possibility to handle gram scale of higher actinides + HF / Cl_2 / HCl gases





Milestones: Established synthesis of **pure actinide fluorides and chlorides**

Material for **reference data** **on Molten Salt Reactor fuel properties**

Material for MSR related **irradiation experiments**

Recent outcome:

Souček, P., et al., "***Synthesis, Purification, and Characterization of Molten Salt Fuel for the SALIENT-03 Irradiation Experiment***" Materials **17**(24) p. 6215 (2024)

Nuclear Fuels and Materials Characterisation

Structure and defects

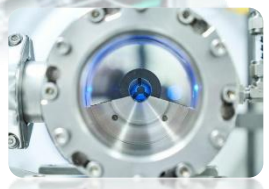
- Powder X-ray diffraction (Room T, high T) and single crystal
- Positron Annihilation Lifetime Spectroscopy (PALS)
- Raman Spectroscopy
- IR and UV/VIS

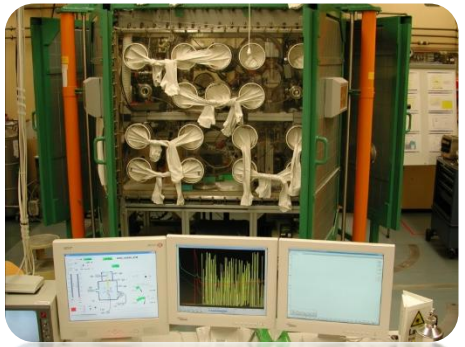
Physical properties

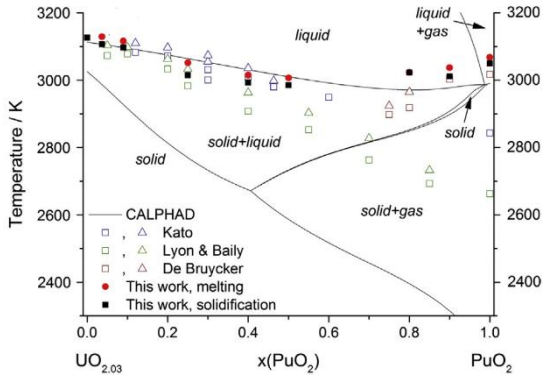
- Specific surface area (BET)
- Hardness (nano- and micro indentation)
- X-ray Tomography
- Electron and optical microscopy
- Thermobalance (TG-DTA)

Thermodynamycs

- Differential Scanning Calorimetry (DSC), Drop calorimetry, Knudsen Cell Effusion Mass Spectr. (KEMS), Laser Flash (LAF), Laser Melting for T_m > 4000°C
- Phase diagrams (experiments + modeling)

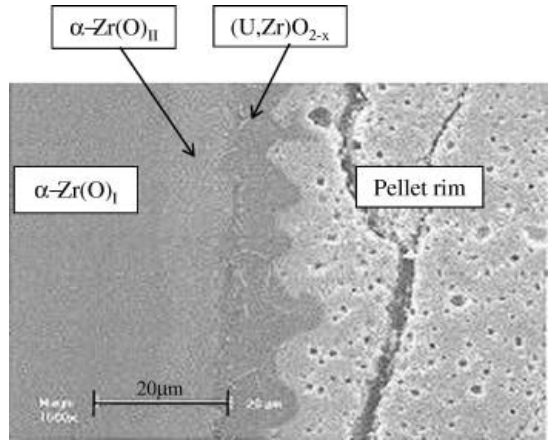




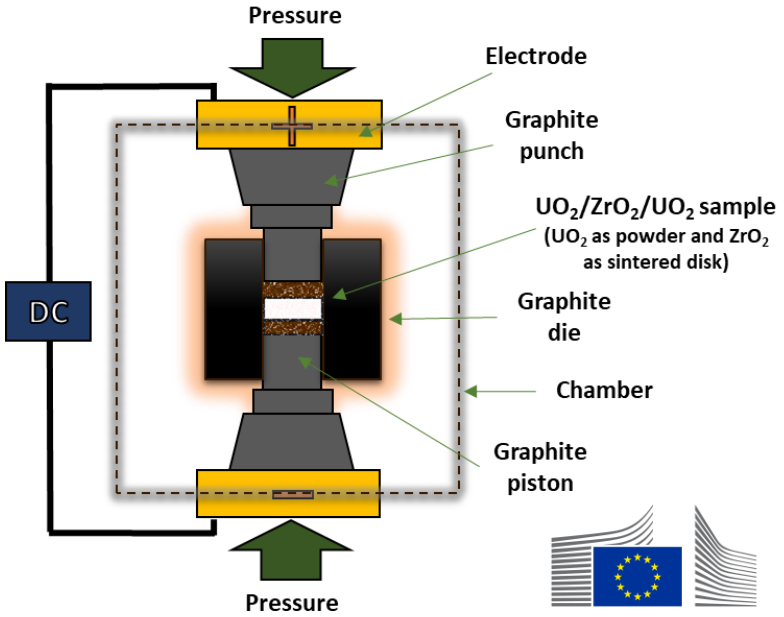


“**O**btention & **C**haracterisation of a **R**eliable **A**nalogue for **P**ellet-**C**ladding **I**nteraction” project

- Project: ***OCRAPCI*** *via ActUsLab, Fuel Material Research Laboratory, JRC Karlsruhe*
- Duration: July-October 2024; Jone M Elorrieta
- Objective: fabricate a reliable analogue for the pellet-cladding interaction (PCI) occurring in Light Water Reactor (LWR) spent fuel rods, by interdiffusion of UO_2 and ZrO_2 via spark plasma sintering (SPS)
  - Reliable: morphologically (grain sizes) and structurally (crystallographic phases)



Kim, *J. of Nucl. Mater.*, 404 (2), 2010



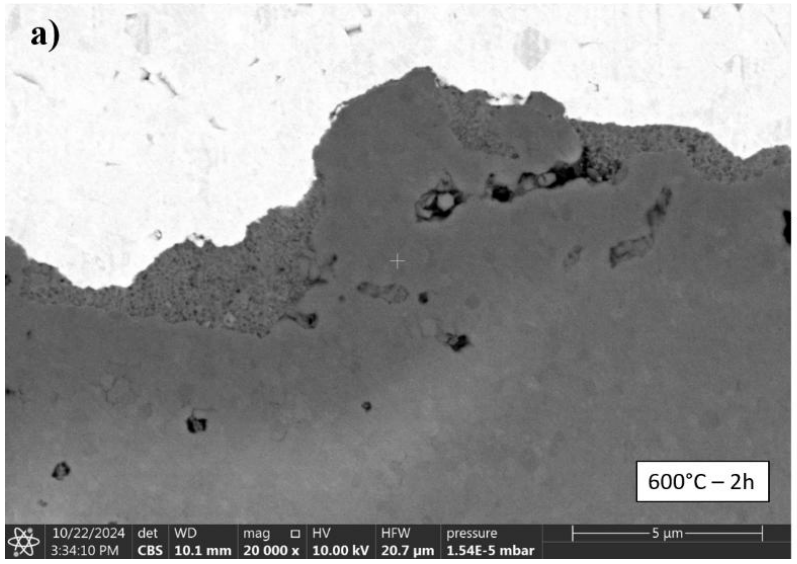
Elorrieta et al., *JRC*, 2026 (Technical report)

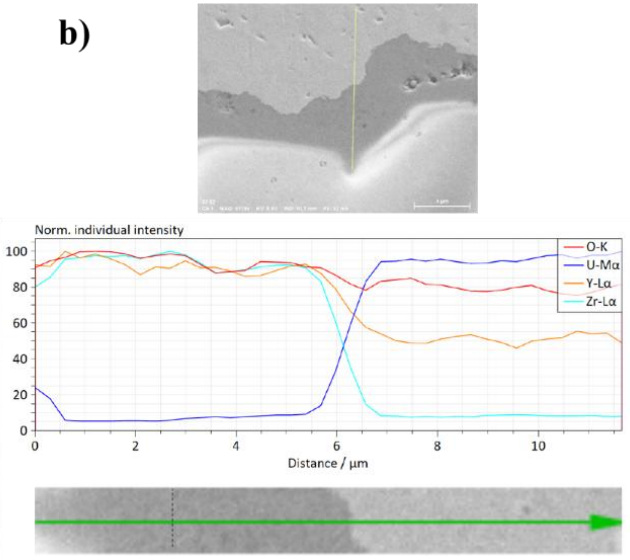
“**O**btention & **C**haracterisation of a **R**eliable **A**nalogue for **P**ellet-**C**ladding **I**nteraction” project

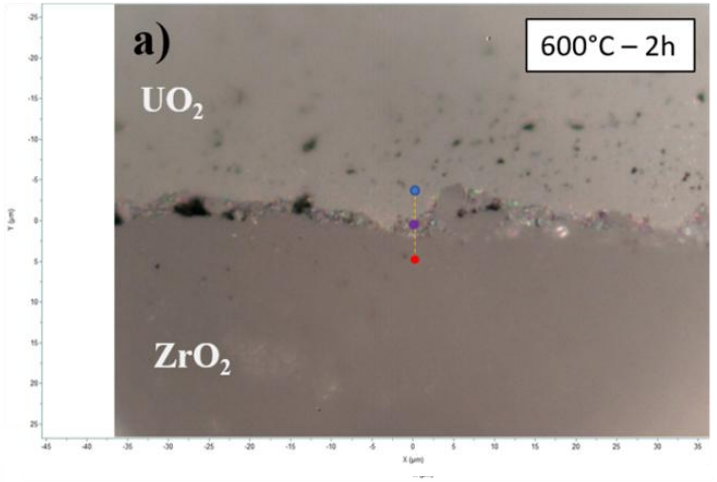
Results (i)

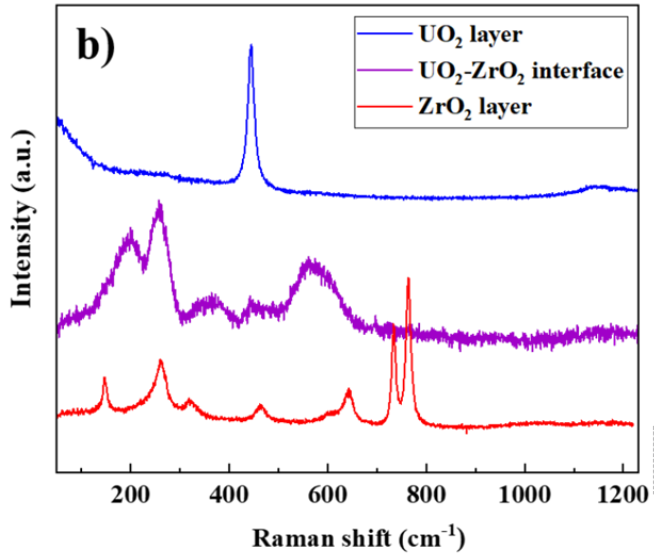
Elorrieta et al., *JRC,* 2026 (Technical report)

Raman spectroscopy analysis + **SEM/EDS examination**









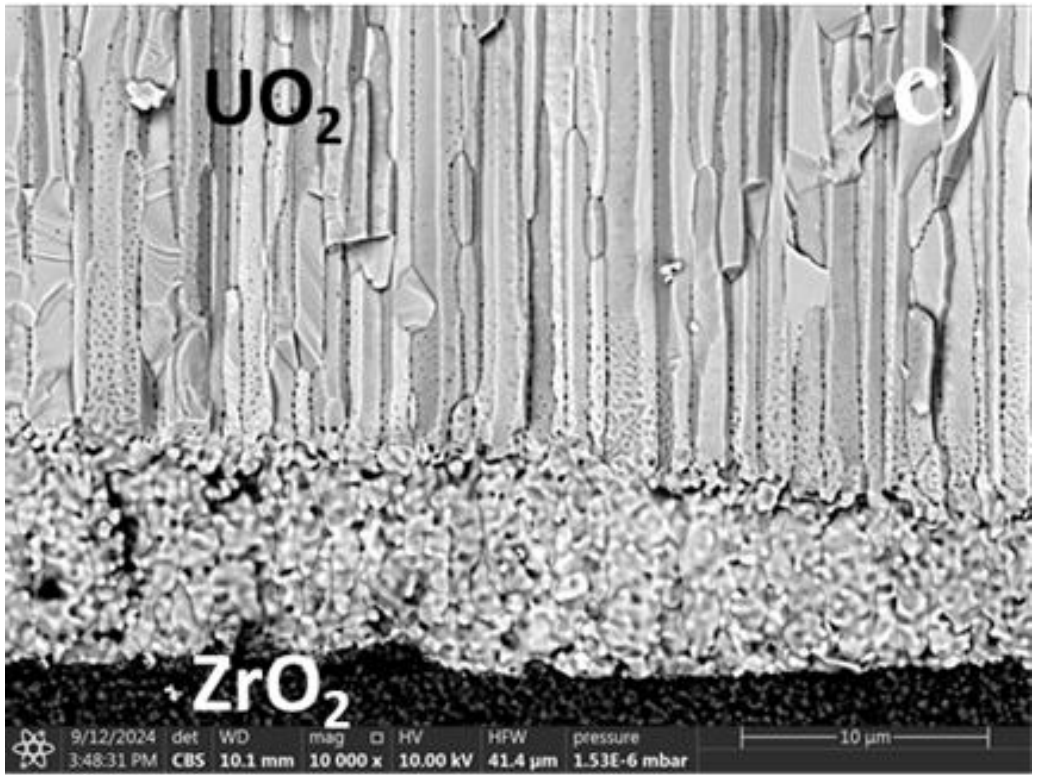
The detected bright interface zones revealed not only a peculiar morphology (very small grains), but also Raman features that match the main contributions corresponding to a mixed $(U,Zr)O_2$ phase with Zr content equal or higher than 20 mol%.

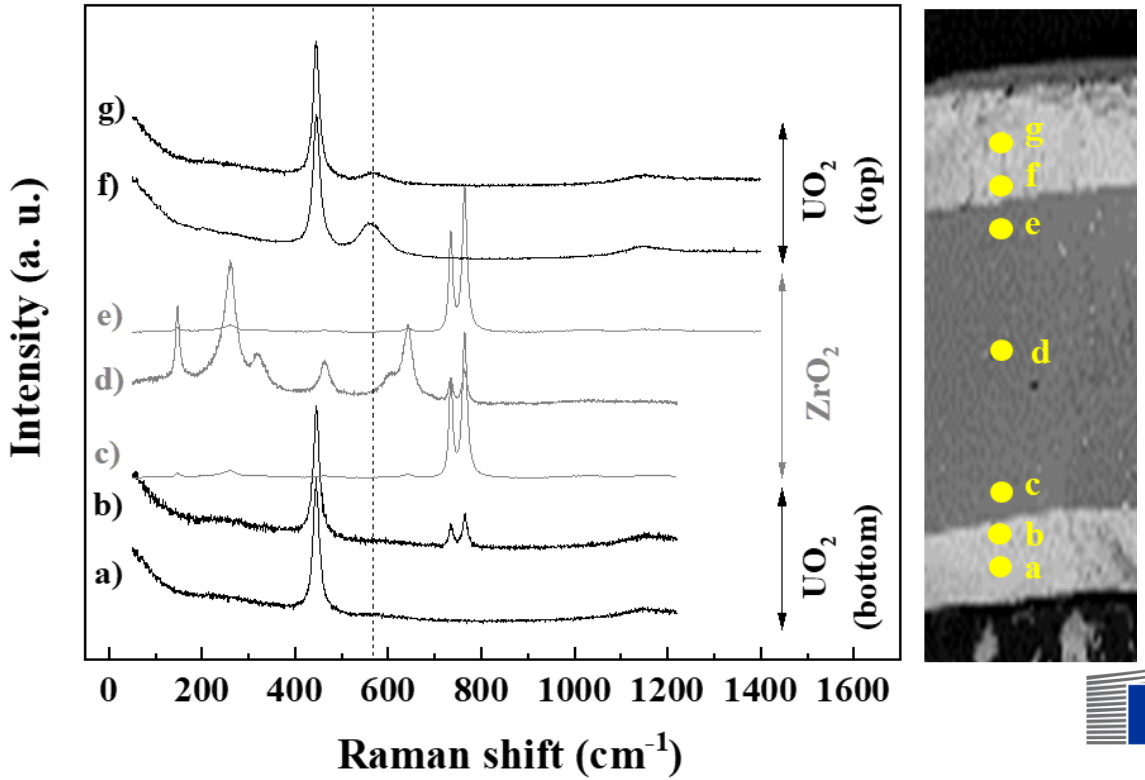
"**O**btention & **C**haracterisation of a **R**eliable **A**nalogue for **P**ellet-**C**ladding **I**nteraction" project

Results (ii)

Elorrieta et al., *manuscript in preparation*

- ZrO_2-UO_2 samples shipped from JRC to CIEMAT to continue analysis
- Unexpected columnar formation at interface (resembling fast reactor fuel restructuring) induced by SPS electrical field





"Impact of **NO**vel fuels with **GR**aphenic **A**dditives on the nuclear **B**ack-end" Project, 2025 - 2028

- Project: **INOGRAB**.
  - Spanish Ministry of Science, Innovation and Universities; 2024 Call
- Duration: September 2025 - August 2028
- P.I.: JM Elorietta, I. Sánchez-García
- Objective: Effect of carbon-based additives on the oxidation (dry interim storage) and reprocessing (PUREX) of potential ATFs of UO_2 incorporating these additives

MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

Cofinanciado por la Unión Europea

AGENCIA ESTATAL DE INVESTIGACIÓN

Fabrication of ATFs of UO_2 with graphenic additives

- ✓ C**onventional (CIEMAT)** and **spark plasma sintering (JRC)** methods will be used
- ✓ Charachterisation **Raman, XRD, TG-DTA.**

Spark Plasma Sintering at JRC