GEN IV International Forum[SM]
Expertise | Collaboration | Excellence

MOX Fuel for Advanced Reactors

Summary / Objectives:

Today, **knowledge on MOX fuel behavior in fast neutron reactors comes mainly from feedback on SFRs that have operated in the past in Europe, USA, Japan and are still in service in Russia, India and China**. The GENERATION-IV systems (SFR, GFR, LFR, FSMR...) with the associated fuel cycle strategy have been chosen to face the requirements of safety, non-proliferation, sustainability and waste minimization. This completion is possible thanks to the flexibility of fast neutron systems: they offer the possibility of using plutonium and uranium coming from spent fuel, making the best use of resources while reducing waste. Thus (U,Pu)O2 has proved to be the most ready candidate to achieve these performances in reactor and during the fuel cycle. **Mox fuel is suitable for example for multirecycling, isogeneration, burning or breeding plutonium through adjustment of Pu concentration.** Taking into account a wide range of fuel composition (Pu content: 20 to 45%), irradiation conditions and applying the safety criteria, we will present the state of the art on MOX fuel for GENIV systems with respect to knowledge and qualification.

The knowledge on (U,Pu)O2 will be presented under the aspects of material properties and fuel behavior under irradiation with post irradiation examinations and modelling. The methodology of MOX qualification will be will be detailed with TRL (Technological Readiness Level) scale evaluation and the need to extend the qualification area in order to cover all design, composition and situations described above.

The support of the international organizations (GIF, OECD/NEA, IAEA, EURATOM) to scientific and technological issues will be assessed.

Meet the Presenter:

Dr. Nathalie Chauvin is working at **CEA Cadarache IRESNE in the fuel Studies Department** as an International Expert on fuels for fast reactors. She worked for a long time on the minor Actinides transmutation program, participating to the optimization of the fuel design, the irradiation experiments and the synthesis reports. Then she was project manager for the development of very innovative fuels for the Gas cooled Fast Reactor with oxide/carbide fuels, refractory cladding including ceramic composites one for pin or plate type fuel element. She is now in charge of international cooperations devoted to fast reactor fuels.

Main Features of Mixed Oxide Fuel for Advanced Reactors

Comparison of fuel properties during irradiation

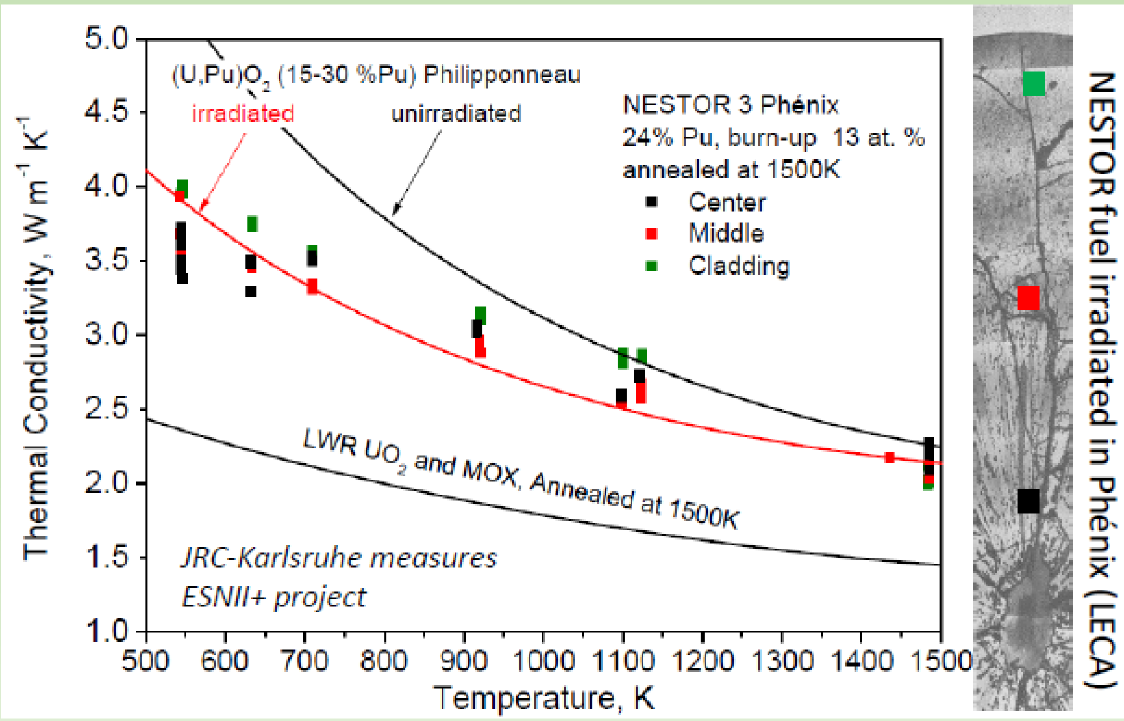
MOX fuel has features, such as high melting temperature, low thermal conductivity, high margin to melt, high thermal creep(low mechanical interaction with clad), lows welling: pin design easier.

Properties	(U0.8Pu0.2)O2	(U0.8 Pu0.2)C	(U0.8Pu0.2)N	U-19Pu-10Zr
Theoretical density, g·cc	11.04	13.58	14.32	15.73
Melting point, K	3083	2750	3070	1400
Thermal conductivity, ($W \cdot m^{-1} \cdot K^{-1}$) at 1000–2000 K	2.6–2.4	18.8–21.2	15.8–20.1	40–40
Crystal structure	Fluoride	Nacl	Nacl	Alfa
Breeding ratio	1.1–1.15	1.2–1.25	1.2–1.25	1.35–1.4
Swelling	Moderate	High	Moderate	High
Handling	Easy	Pyrophoric	Inert	Inert
Compatibility: clad	Average	Carburisation	Good	Eutectics
Compatibility: coolant	Average	Good	Good	Good
Dissolution and reprocessing	Good	Demonstrated	Risk of C14	Amenable for pyro reprocessing
Fabrication/irradiation experience	Large and good	Limited	Very little	Limited

GIF – "Advanced Sodium Fast Reactor (SFR) Fuel Comparison », March 2009.

Physical characteristics of (U, Pu)O_2

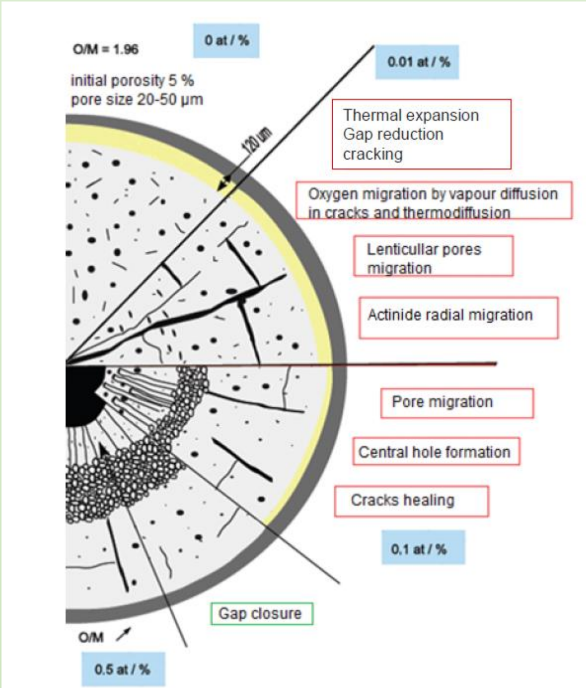
- As for melting point, discrepancy of measurements above 60% of Pu
- Thermal conductivity is influenced strongly by temperature, O/M, Pu content, density, and irradiation.
- Intensive European experimental programme new measurements (PUMMA etc.) is continued.

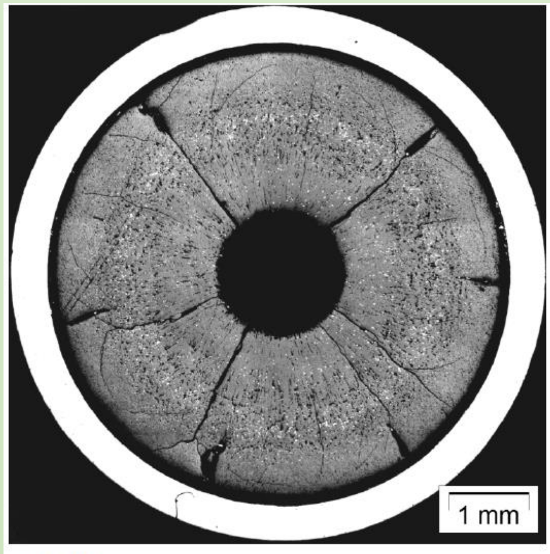


Main Features of Mixed Oxide Fuel for Advanced Reactors (continue)

MOX behaviour: microstructure & composition evolution

Microstructure & composition are evolved as increase of burnup.





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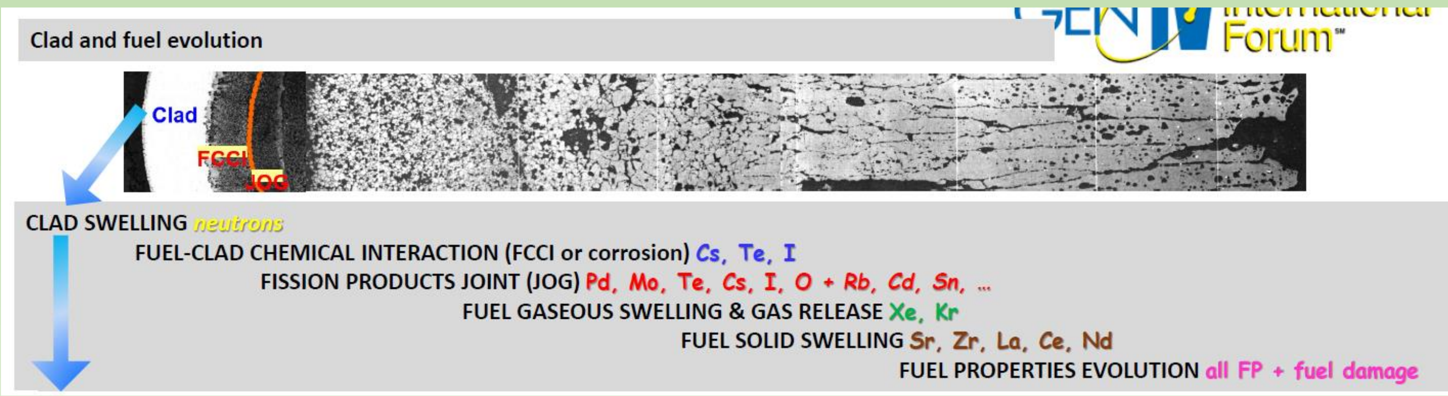
MOX behaviour: effects of the irradiation

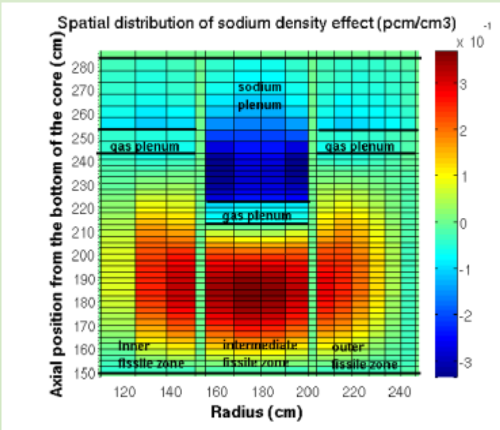
- Chemical state of the fuel depends strongly of the oxygen chemical potential of $(U_{1-y}Pu_y)O_{2-x}$ that increases during irradiation. Fission is oxidizing.
- Modification of physical and chemical properties of the irradiated fuel **(FP in solution, oxides precipitates, metallic precipitates)**
- Formation of : JOG(oxide/clad joint) : Cs_2MoO_4+ others compounds
- FCCI(Fuel Clad Chemical Interaction) or corrosion: **Te**, **I**, **Cs** reacts with clad(Fe, Ni, Cr): Cs_2CrO4, $FeTe_{0.9}$, $NiTe_{0.6}$.

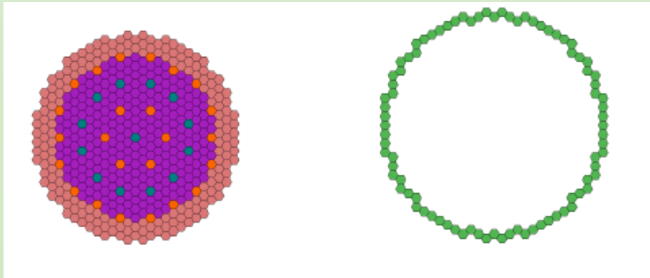


Main Features of Mixed Oxide Fuel for Advanced Reactors (continue)

Improvements in the Fuel Element Design

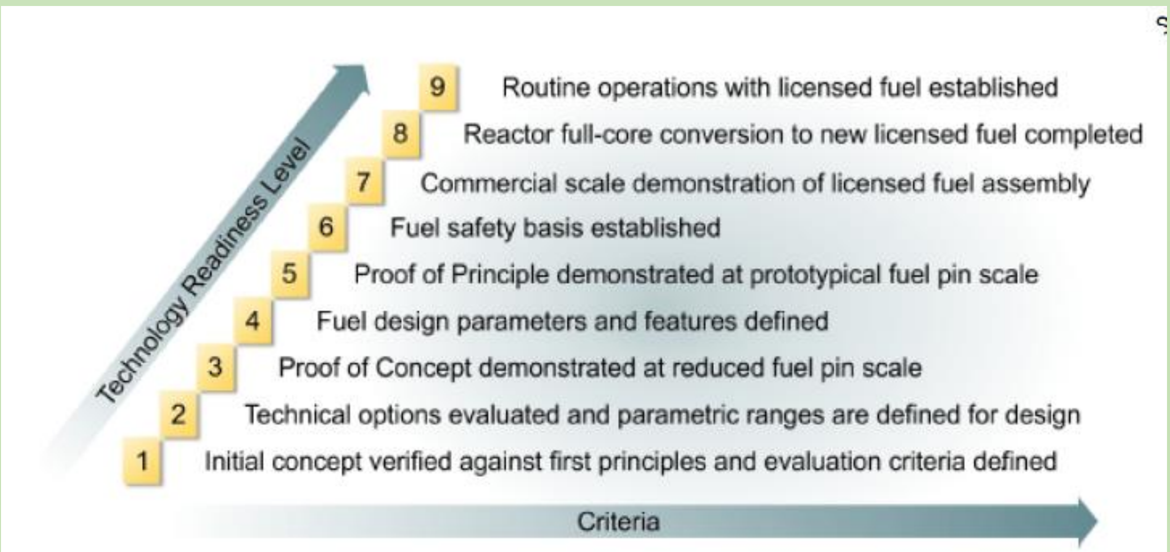
Improvements on the geometry, range of components, and specifications will be carried out in fuel element design.





Fuel Element Qualification

An essential part of fuel qualification is to define a test envelope to cover expected operating, transient, and accident conditions to assess fuel performance and validate fuel performance codes.



TRL 9 for Phenix type pins (Phenix, SNR300, Joyo) & same geometry with central hole (EBR2, PFR, BN800), SPX type
TRL 6-7 for others concepts