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Overview of ITU work on inert matrix fuels

A.Fernandez, D. Haas, J.P. Hiernaut, R. Konings
C. Nästren, H. Ottmar ,J. Somers, D. Staicu

Institute for Transuranium Elements (ITU)
Karlsruhe, Germany
http://www.jrc.org/

http://itu.jrc.cec.eu.int/

Outline

1. Fuels for transmutation: state of the art
2. Fabrication process development at ITU
3. Fuel characterization and material properties
4. Fuels and targets irradiation programmes

Candidate fuels for transmutation

Fuel composition
Oxide
Metal
Nitride
Carbide

Fuel form
Solid Solution
Composite

Fuel state
Pellet
Particle

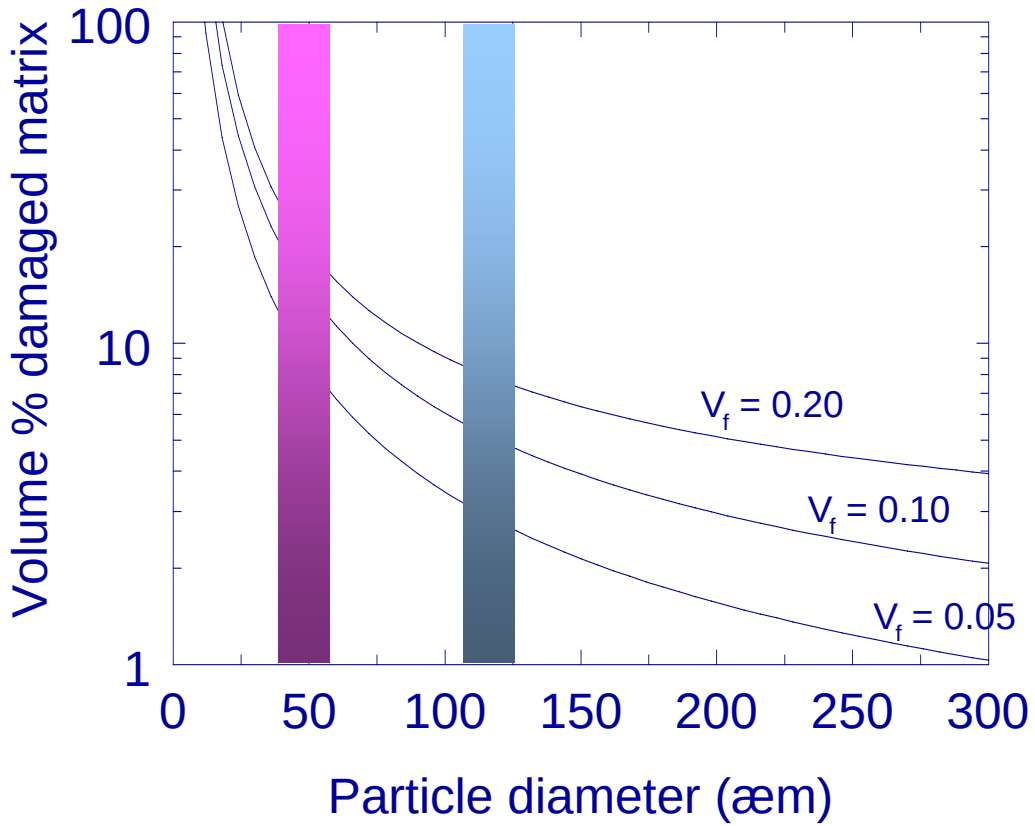
Solid solution:

- Simple fabrication
- Low thermal conductivity (oxides)
- Uniform effects

Composite (CERCER and CERMET):

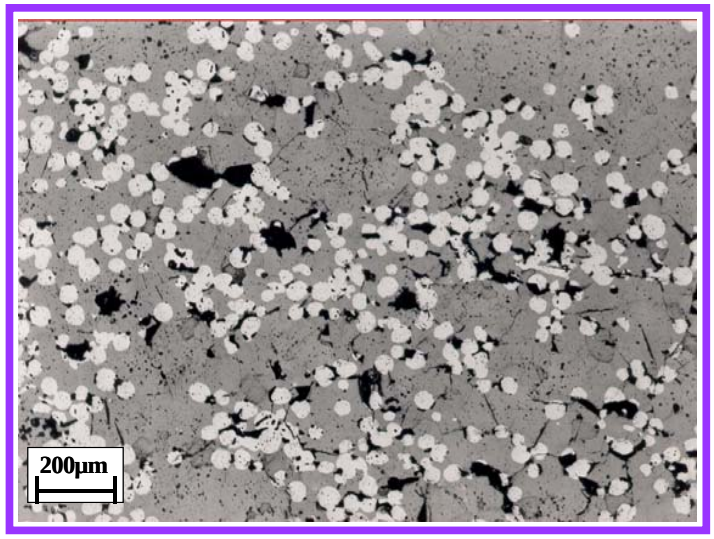
- Complex fabrication
- Material selection not evident
- 'Tailored' thermal conductivity
- Localised effects

CERCER and CERMET : Effect of particle size

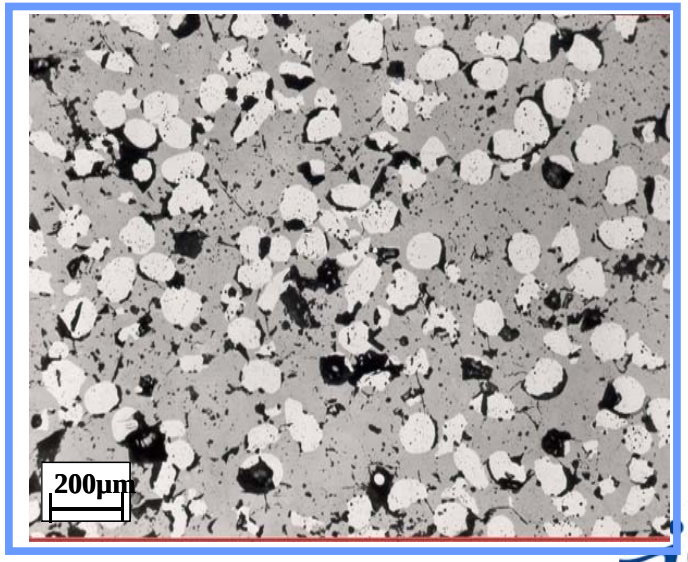


$(Pu_{0.20}Zr_{0.66}Y_{0.14})O_{2-x}$ in MgO

Microdispersed



Macrodispersed



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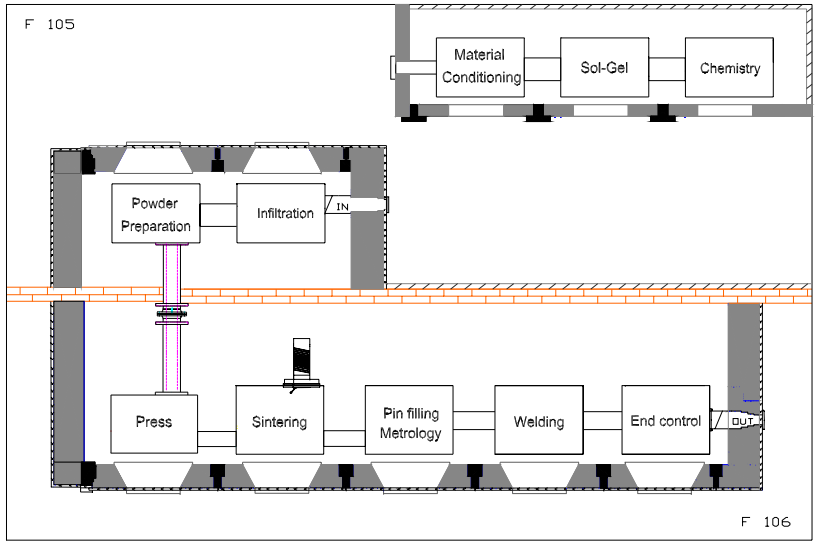
Fabrication process development

Criteria :

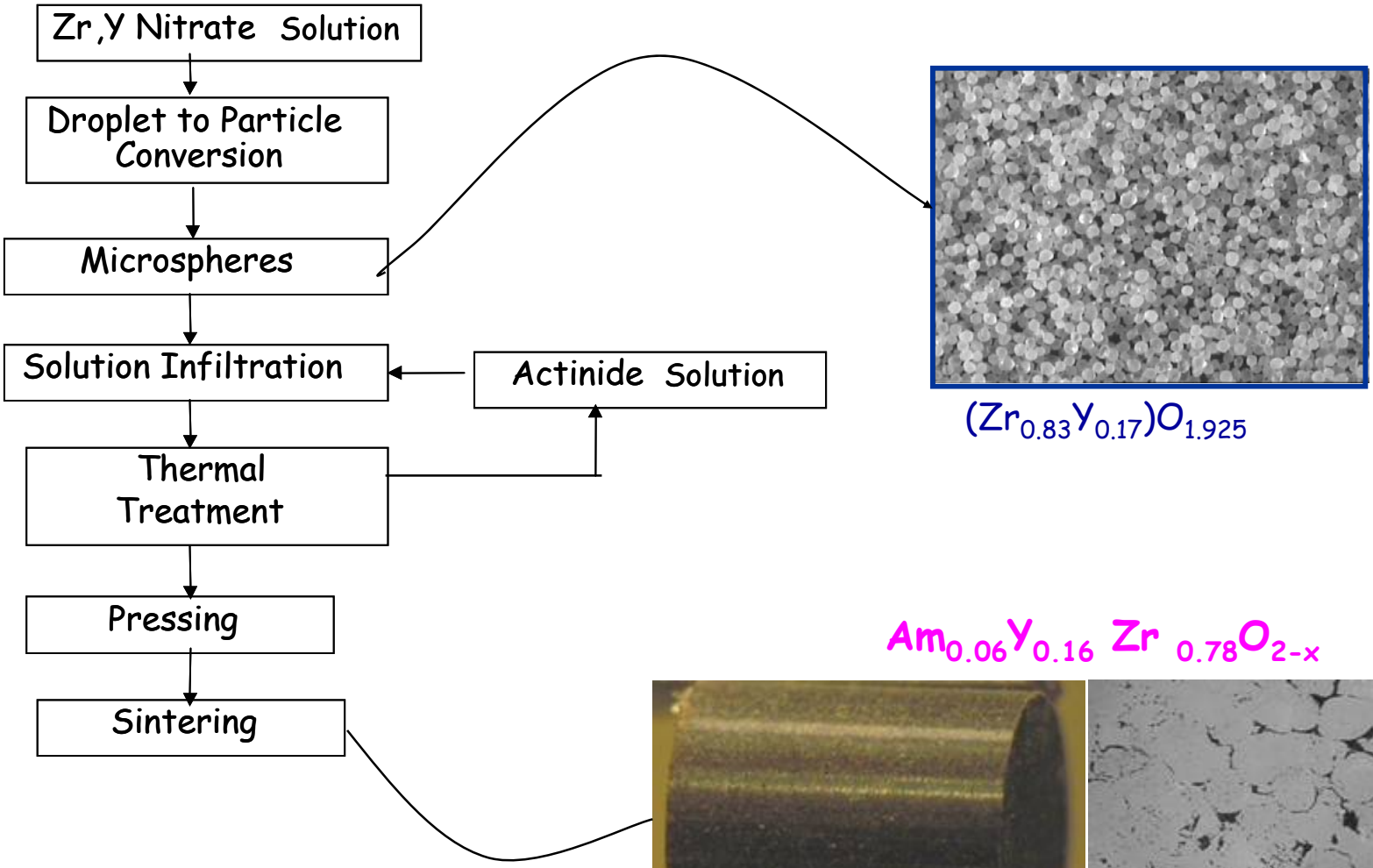
(a) Shielded installations → remote handling
(b) Automation → use of robots
(c) dust free
(c) process simplification : minimises the (active) fabrication steps

hybrid process consisting of a combination of **sol gel** and **infiltration** techniques



Minor Actinide Laboratory

HOMOGENEOUS fuels & targets



COMPOSITES : CERCER and CERMET

Zr,Y Nitrate Solution

Droplet to Particle Conversion

Microspheres

sieving

Solution Infiltration ← Actinide Solution

Thermal Treatment

MgO/Mo Powder

Granulation

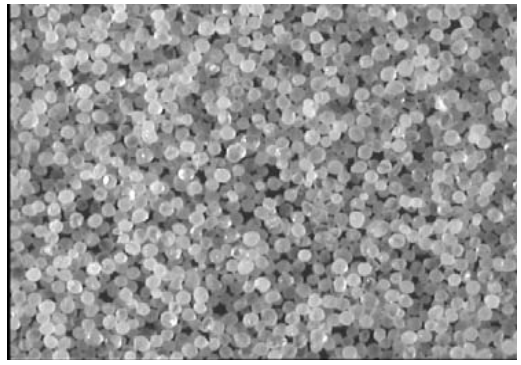
Mixing

Blending

Pressing

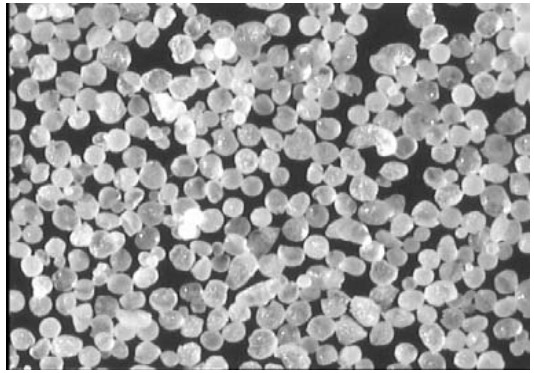
Sintering

microdispersion

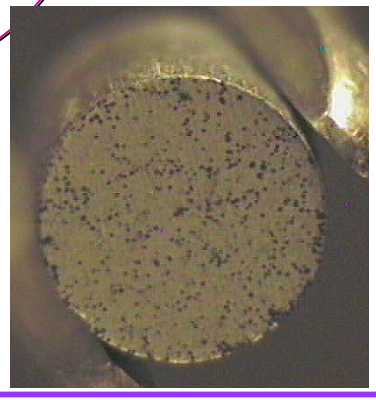


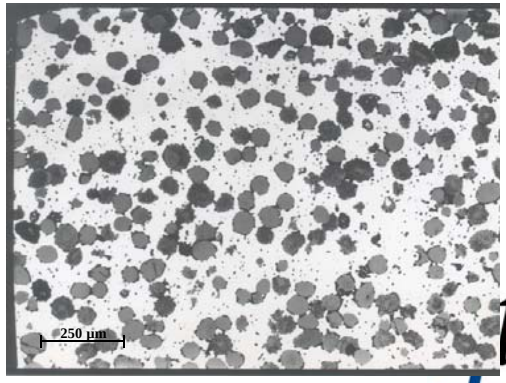
40-60μm

macrodispersion



80-100μm





Summary (I)

- Sucessful development of advanced fabrication processes, by a combination of
  - sol-gel
  - infiltration
  - and conventional blending techniques
- For composites, the process has high flexibilities
  - to select the size and
  - volume of the ceramic phase, and
  - the actinide content in the ceramic phase.
- Excellent homogeneous dispersion of the ceramic phase (fuel-bearing phase) in the metal

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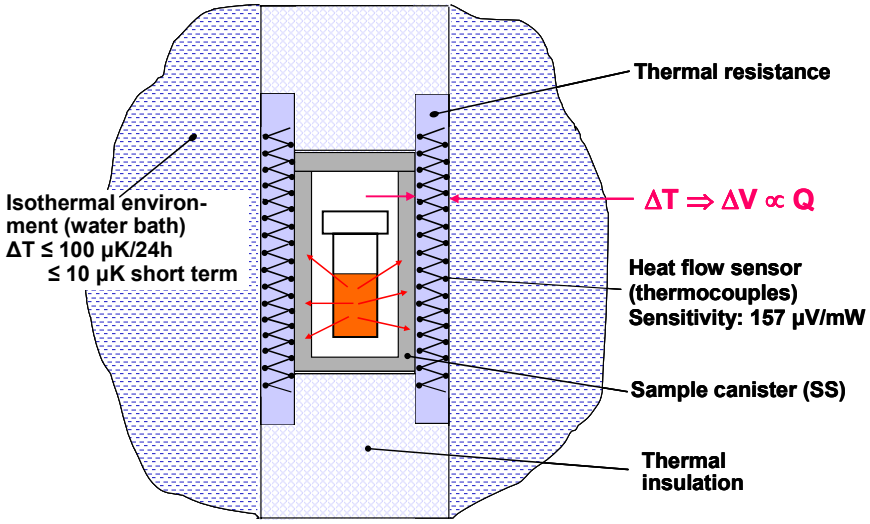
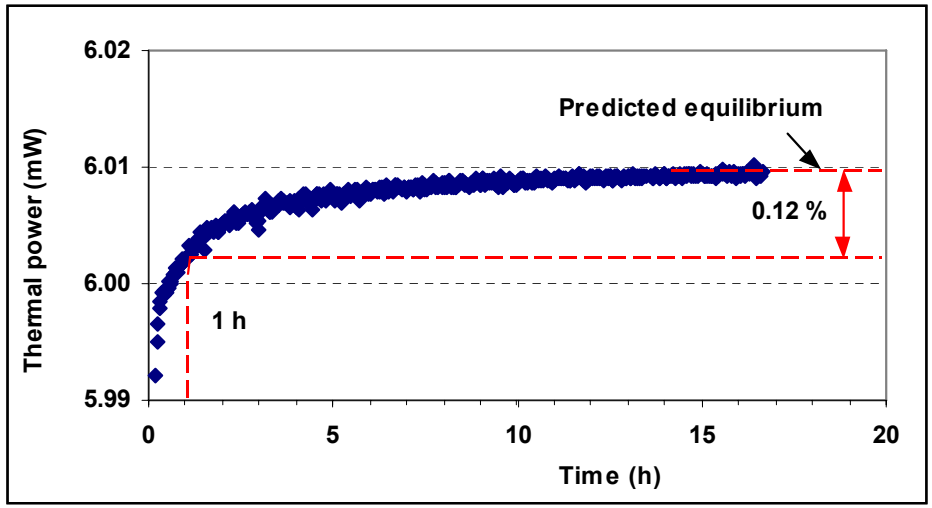
Calorimetry: Am content determination

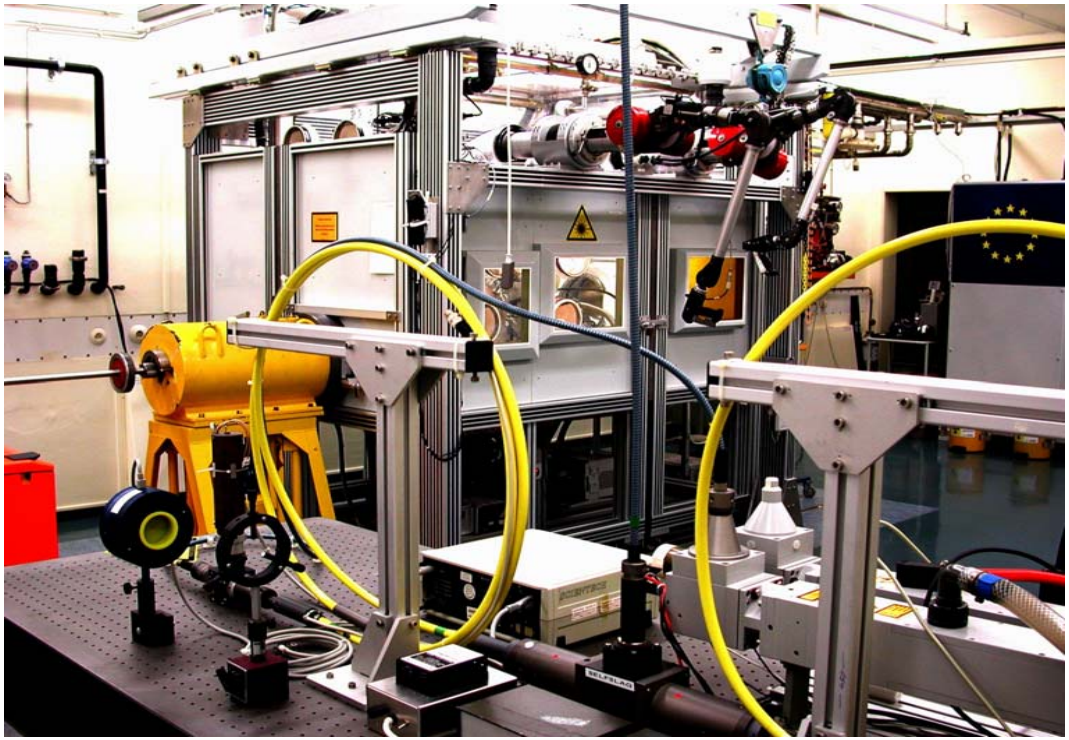


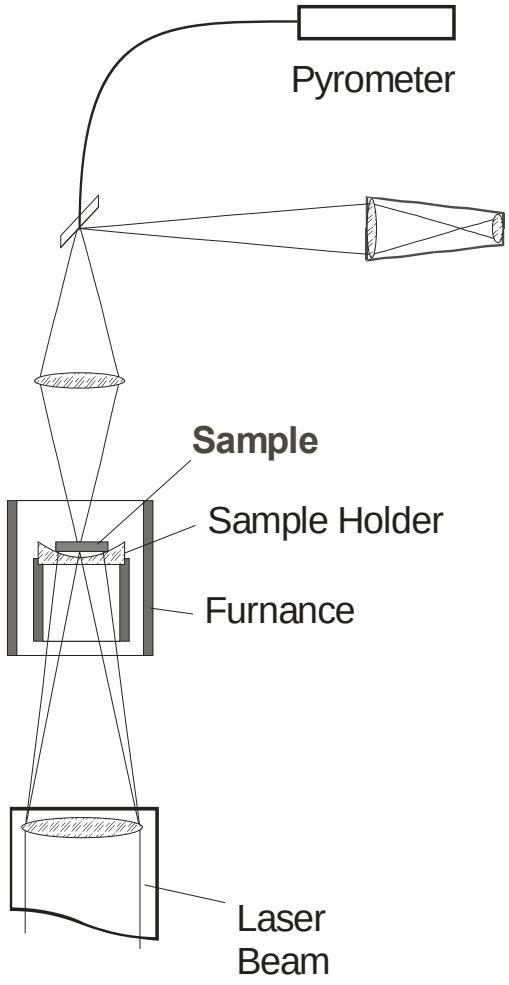


	%weight Americium (gravimetry)			%Am (calorimetry)
Infiltration	1st	2nd	3rd	
FUTURIX 5 PuO_2	12.56	**17.33**		**17.57**
FUTURIX 6 $Pu_{0.30}Zr_{0.70}O_2$	15.44	27.94	**30.69**	**30.07**

Excellent agreement between gravimetry and calorimetry!!

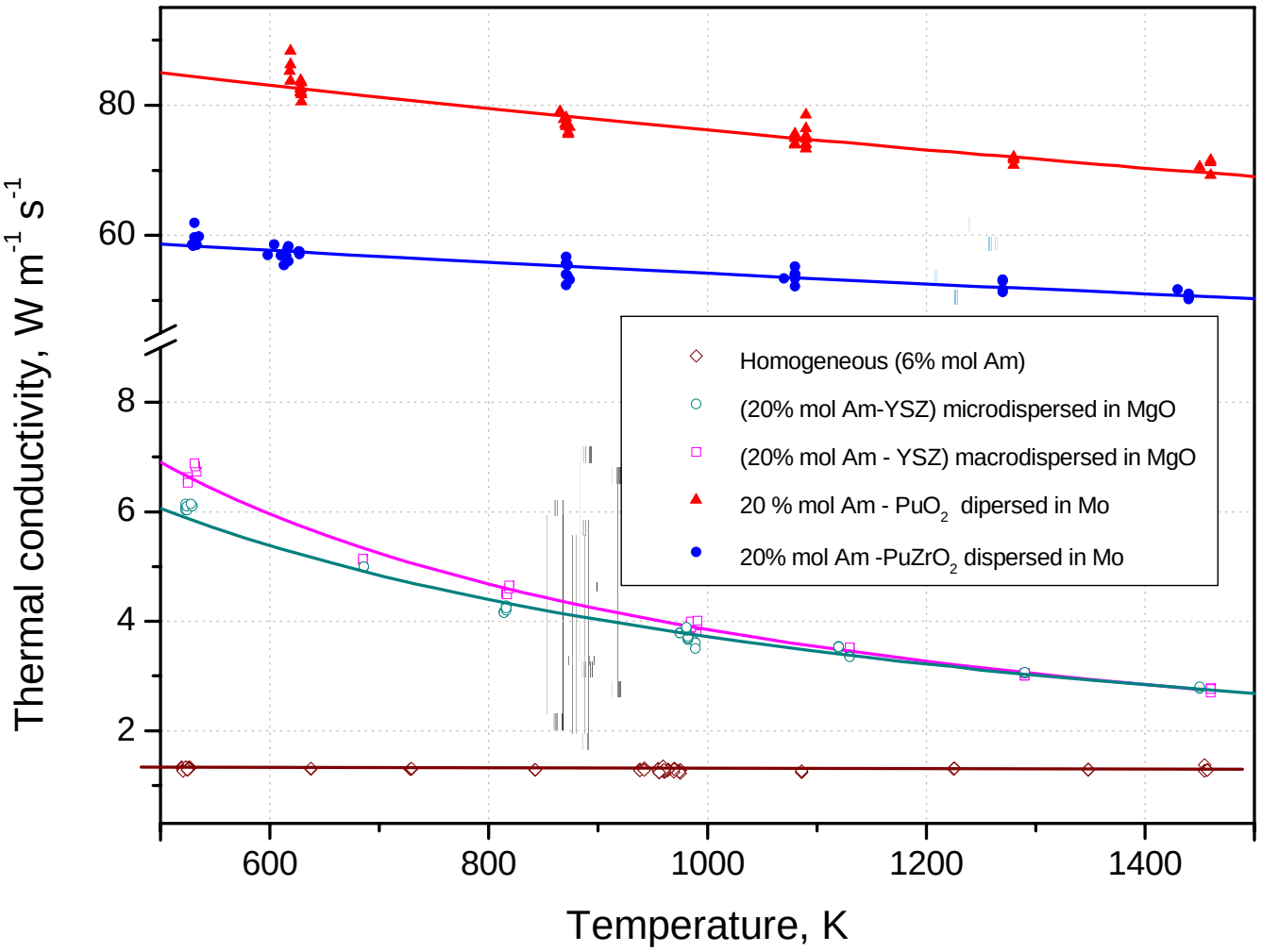
Laser flash for thermal properties



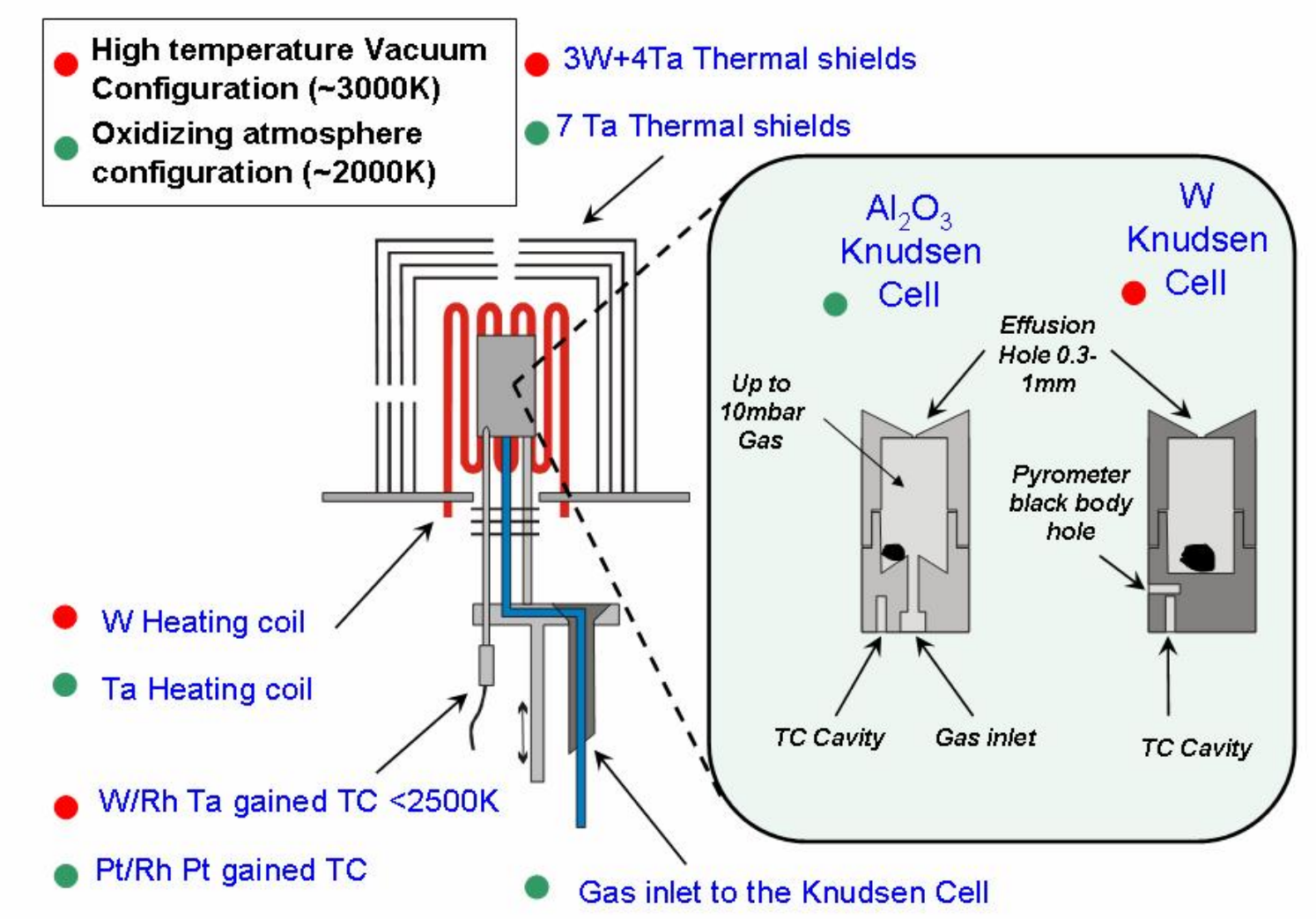


- high measurement precision for diffusivity (±1%)
- simultaneous measurement of α and C_p (±5%)
- highly localised measurements possible
- samples with irregular shapes can be used

Laser flash thermal conductivity measurements

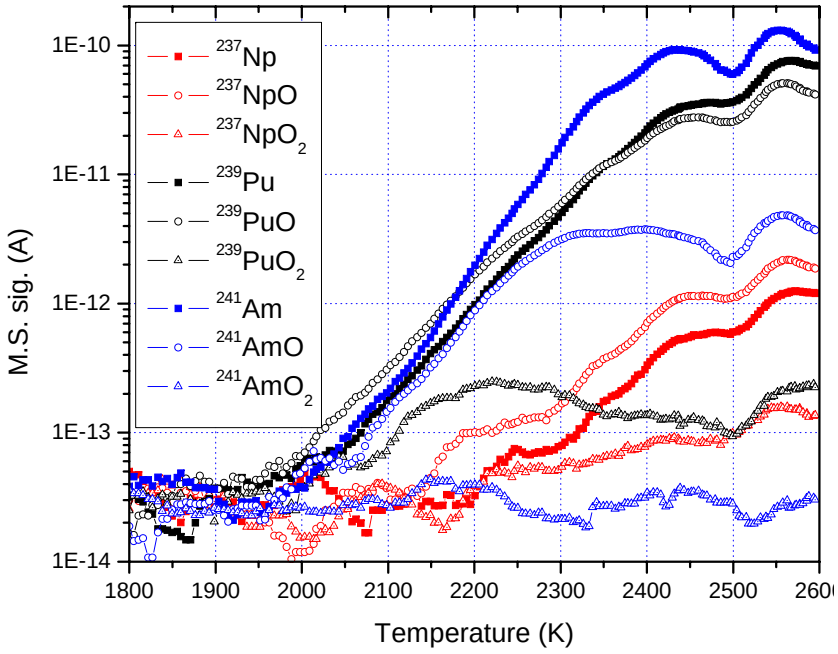


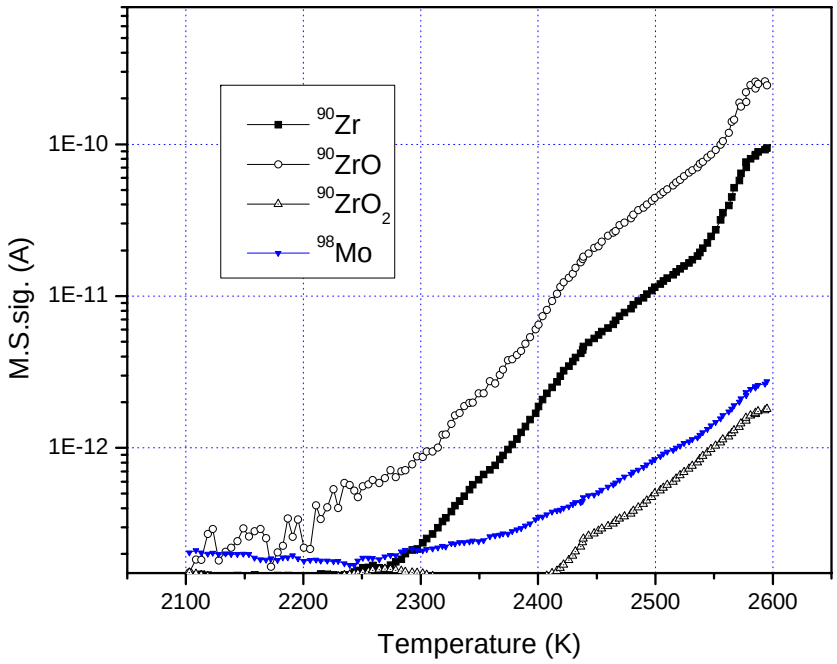
Vaporisation behaviour: Knudsen cell



Vaporisation behaviour

CERMET $(Pu_{0.225}Am_{0.240}Zr_{0.534})O_{2-x}$-Molybdenum





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SMART irradiation in HFR

SMART- 1 : $(Pu_{0.090}Zr_{0.757}Y_{0.153})O_{1.92}$ Solid Solution

SMART- 2 : SSL + $(Pu_{0.241}Zr_{0.631}Y_{0.128})O_{2-x}$ Composite, microdispersed (60-80μm)

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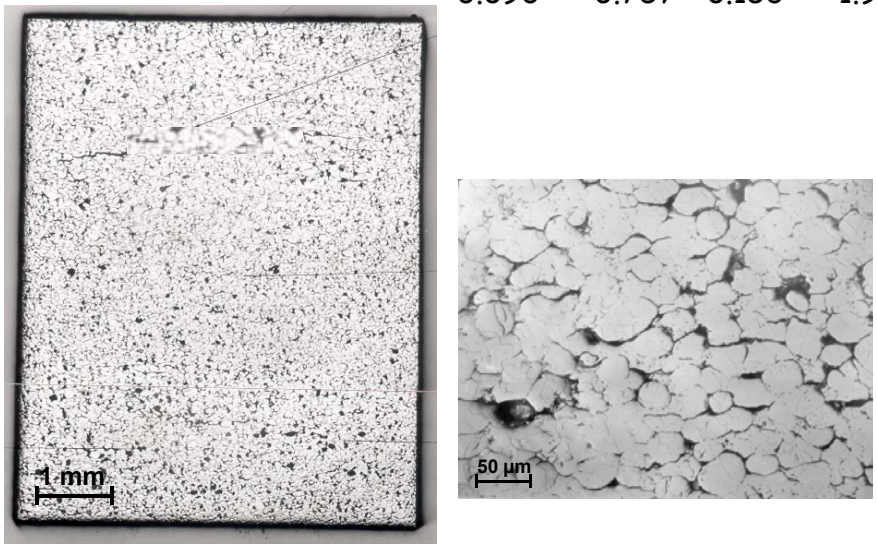
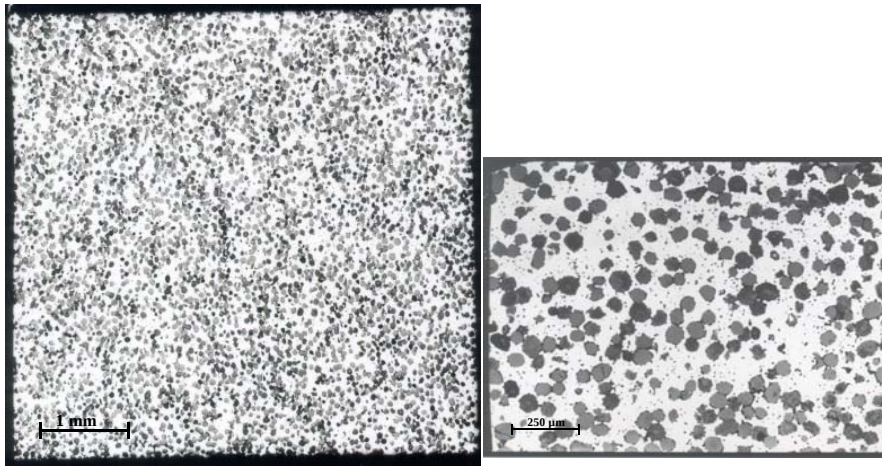
$(Pu_{0.090}Zr_{0.757}Y_{0.153})O_{1.92}$



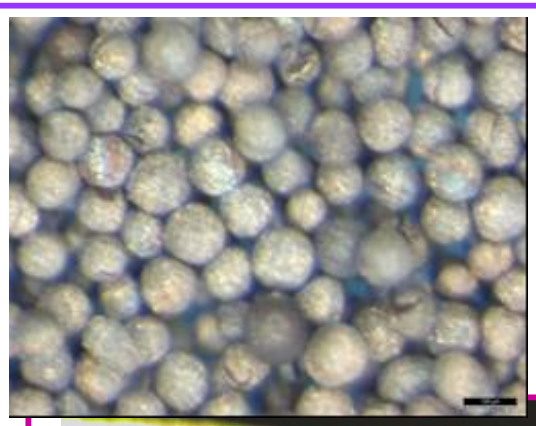
SS + $(Pu_{0.241}Zr_{0.631}Y_{0.128})O_{2-x}$

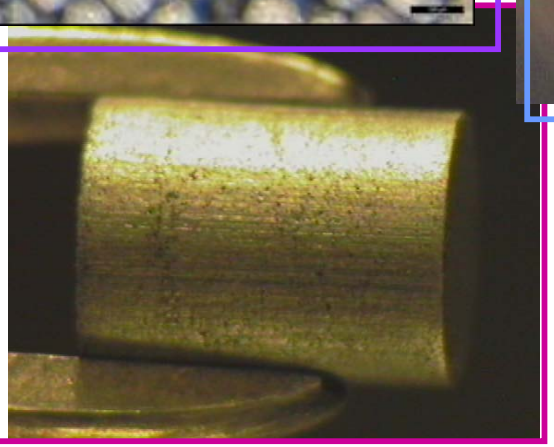


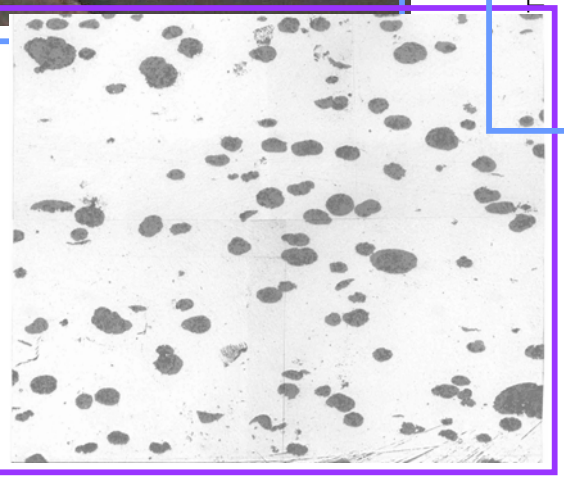
End of irradiation: mid 2007
PIE in ITU

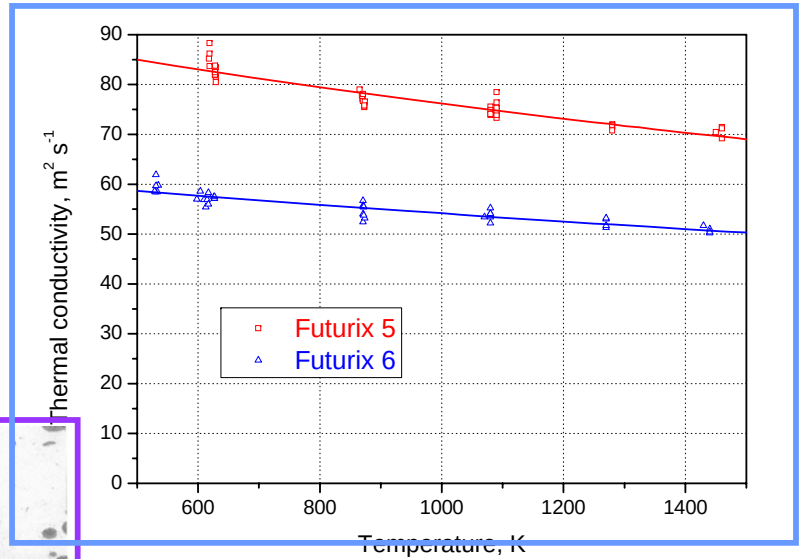
FUTURIX irradiation in Phenix
(within IP EUROTRANS, US DOE, CEA, JAEA)

- $Pu_{0.8}Am_{0.2}O_{2-x}$- Molybdenum and $(Pu_{0.225}Am_{0.240}Zr_{0.534})O_{2-x}$-Molybdenum
- **High quality pellets fabricated: meeting all specifications for Phenix**









HELIOS irradiation in HFR Petten
(within IP EUROTRANS, CEA, NRG)

Fabrication of four fuels and pins for irradiation in HFR-Petten

Fuel	Compound	Am content* $g \cdot cm^3$	Pu content* $g \cdot cm^3$	Particle size μm	Density %TD
HELIOS 2	$ZrYAmO_2$	0.76			90±5
HELIOS 3	$ZrYPuAmO_2$	0.76	0.42		
HELIOS 4	$ZrYAmO_2$ + Mo	0.76		80-100	
HELIOS 5	$PuAmO_2$+ Mo	0.32	1.28	20-150	

Homogeneous and CERMET pellets fabricated by a combination of sol-gel, infiltration and mechanical mixing

HELIOS 2 pretest

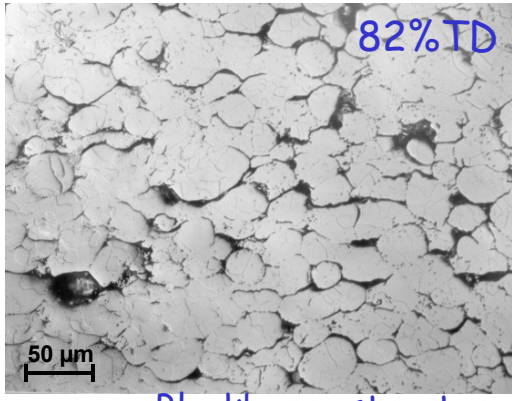
INNOVATION:
Addition of Carbon to the sol-gel feed solution

- improve pellet microstructure
- increase porosity (higher Am content by infiltration)

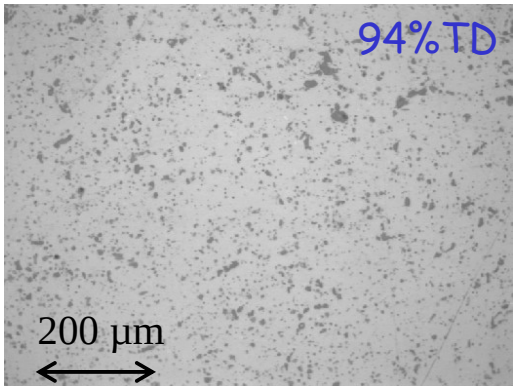
HELIOS irradiation in HFR Petten
(within IP EUROTRANS, CEA, NRG)

Addition of Carbon to the sol-gel feed solution

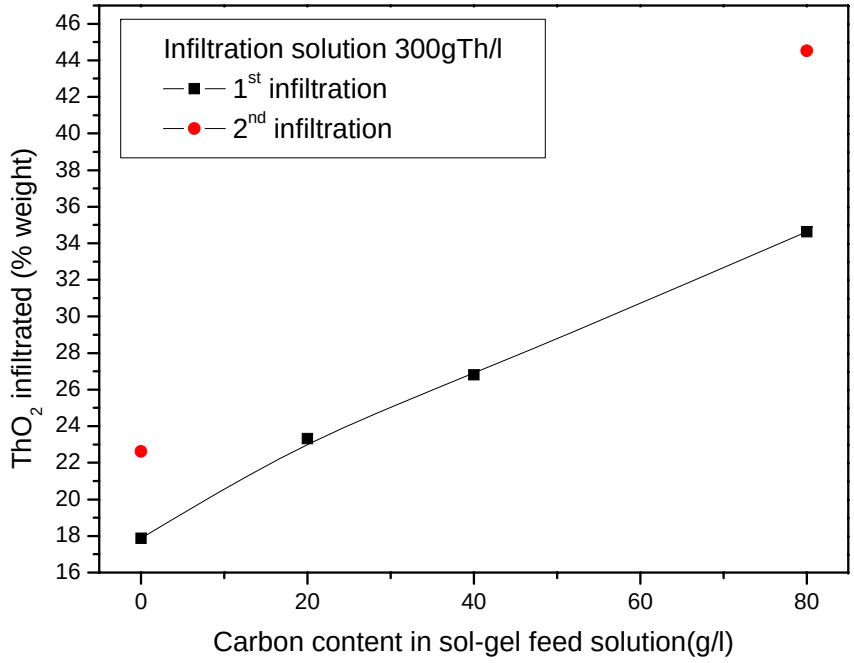
improve pellet microstructure **increase porosity (higher Am content by infiltration)**



Blackberry structure



PuO_2 infiltrated with Th



Collaborations