EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

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Progress in Am transmutation targets from EFTTRA

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The EFTTRA Collaboration: 15 years from 1992 to 2006

- Goal: transmutation of long-lived FP and MA
- Tc-99 and I- 129 irradiations performed and reported
- Inert matrices selection and irradiations in Phenix and HFR
- Pre-selection of $MgAl_2O_3$ for Am targets transmutation
- Irradiations (Am) in HFR: T4 and T4bis (2 burn-up levels)
- Results not conclusive > Selection of Zirconia (**once-through scenario**) or MgO, Mo (**multiple recycling scenario**)
- Preparation of HELIOS irradiation in HFR
- Further developments

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EFTTRA: a 15-years successful collaboration

- Agreement on experimental programmes, seminars, publications
- Financing by the partners (case by case)
- Financial (partial) support through EC Framework Programmes:
- FP5 (EFTTRA T4)
- FP6 (EUROTRANS IP: HELIOS, BODEX)

EFTTRA T4 and T4bis Objective

- $MgAl_2O_3$ spinel as IMF for **once-through transmutation**
- Development of Am spinel target fabrication
- First irradiation testing of Am spinel
- In-pile behaviour, transmutation demonstration
- Burn-up effect (two irradiation times)

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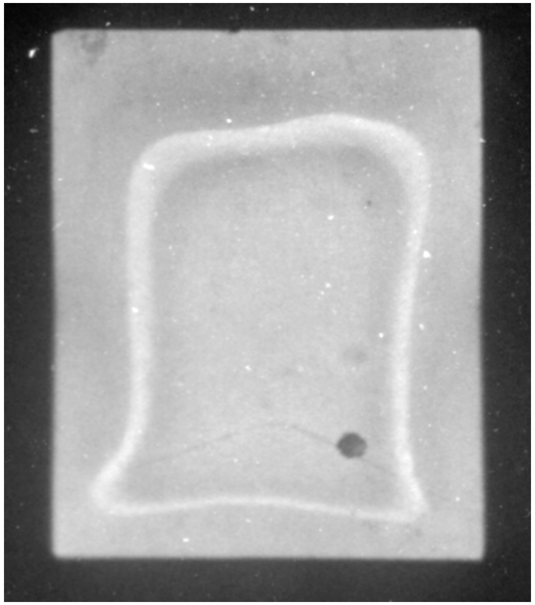
EFTTRA T4 and T4bis main conclusions

- Am spinel fabrication demonstrated, but improvements implemented (matrix powder infiltration instead of green pellet infiltration)
- Irradiation successful (up to 650 days): no failure, good pellet structure
- Very high gas production (mainly He), low release (low T°)
- Very large pellet swelling (gas bubbles)
- Am-Spinel chemical instability: formation of $AmAlO_3$

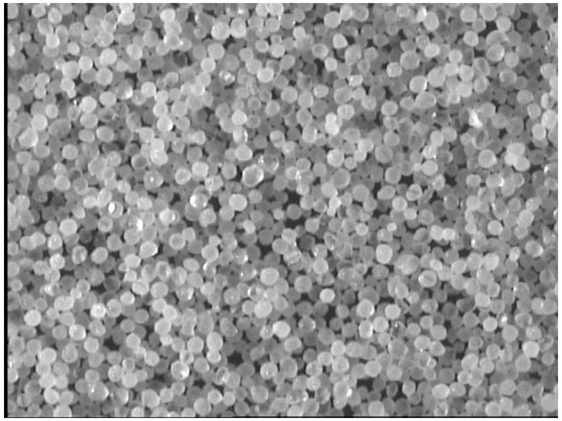
EFTTRA-T4(bis) pellets: green pellet infiltration

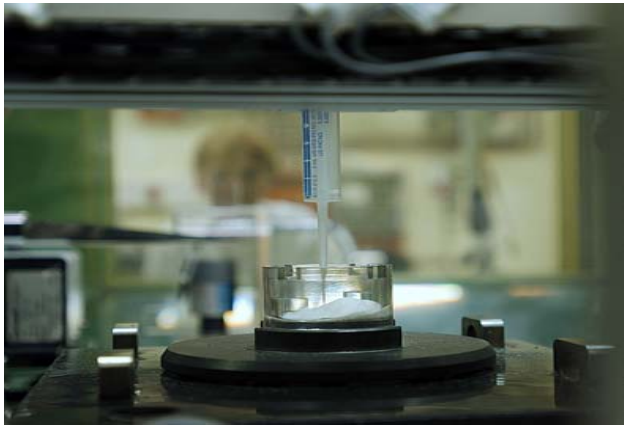
Inhomogeneous Am distribution in spinel



HELIOS: sol-gel beads infiltration

Solid-solution formation in the sintered pellet





MA-Laboratory

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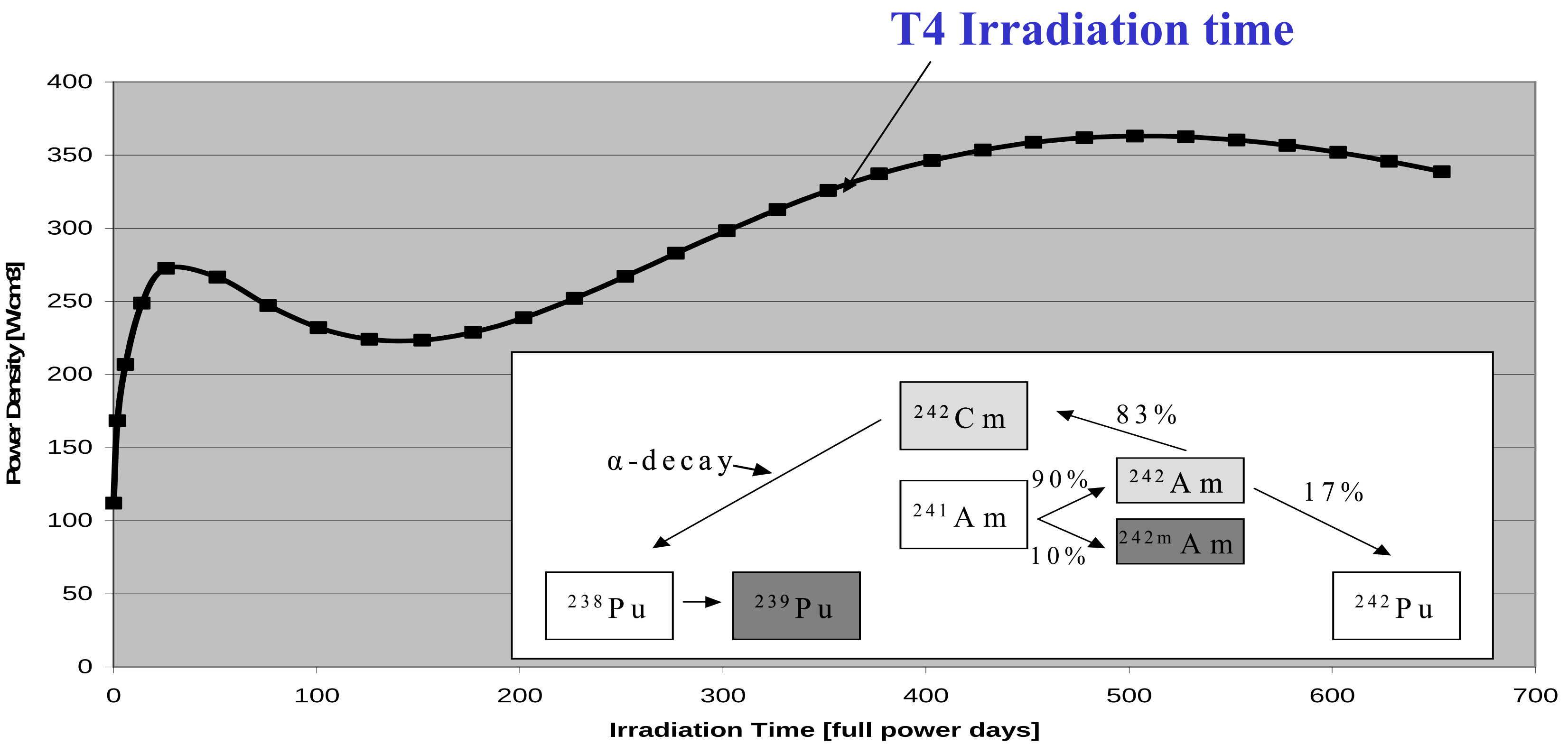
Power density in the EFTTRA T4bis irradiation

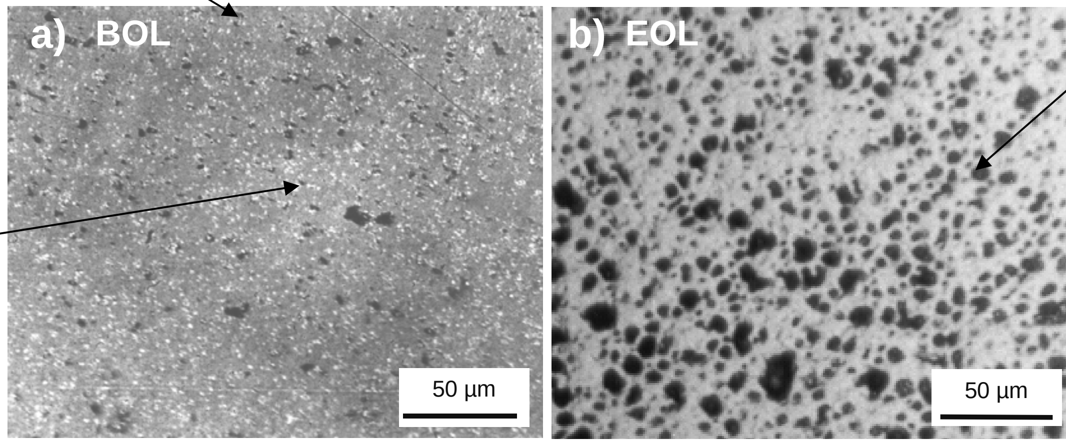


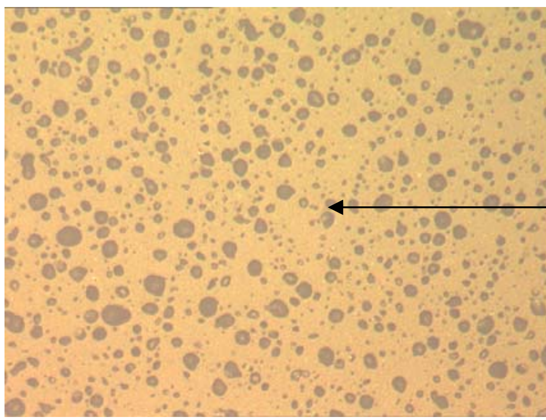
The two maxima are due to formation and fission of Am-242m and Pu-239, respectively. The EFTTRA T4 irradiation showed a similar power profile, but it did not reach the second maximum due to the shorter irradiation time.

As-fabricated T4 fuel

Irradiated T4: 17% porosity

AmAlO3

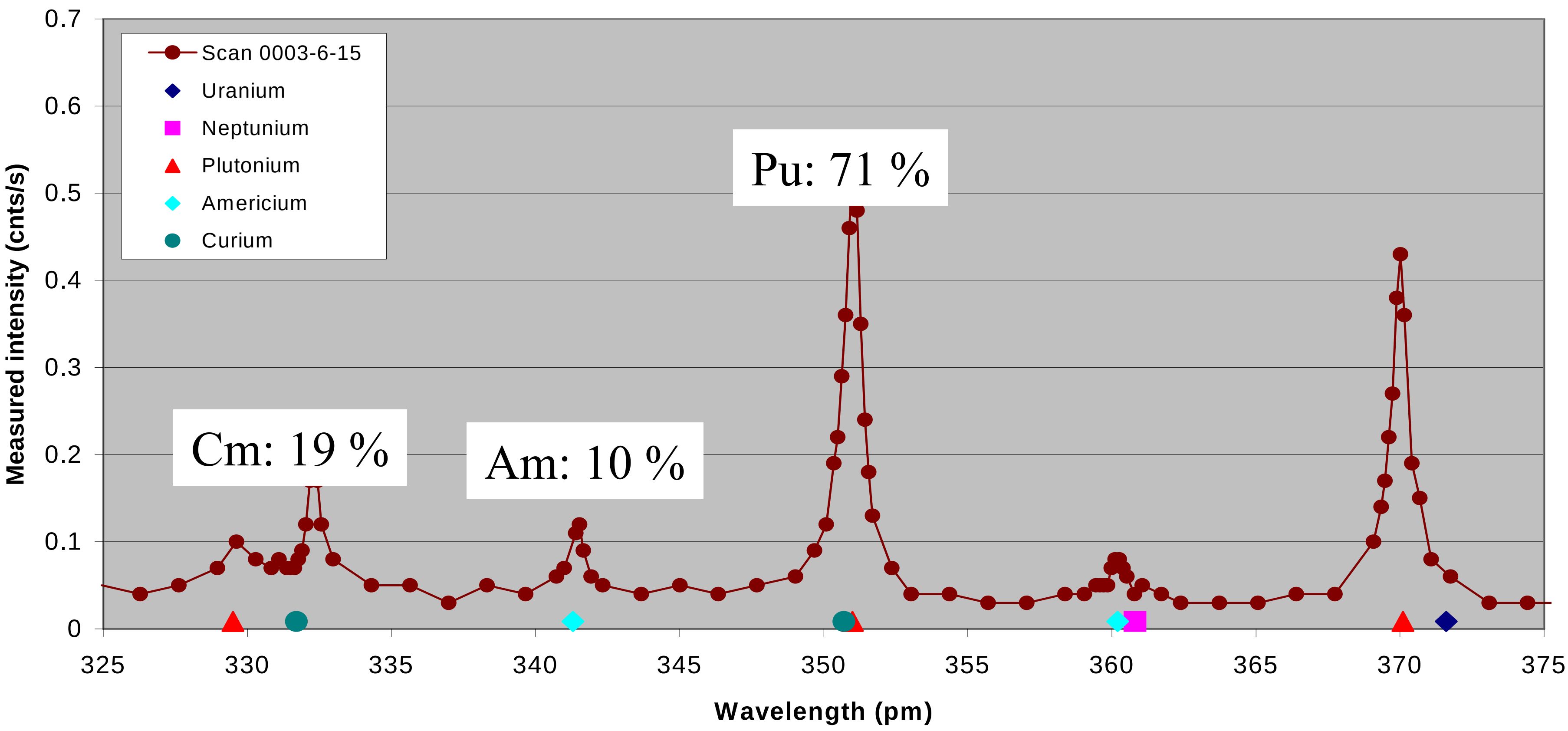




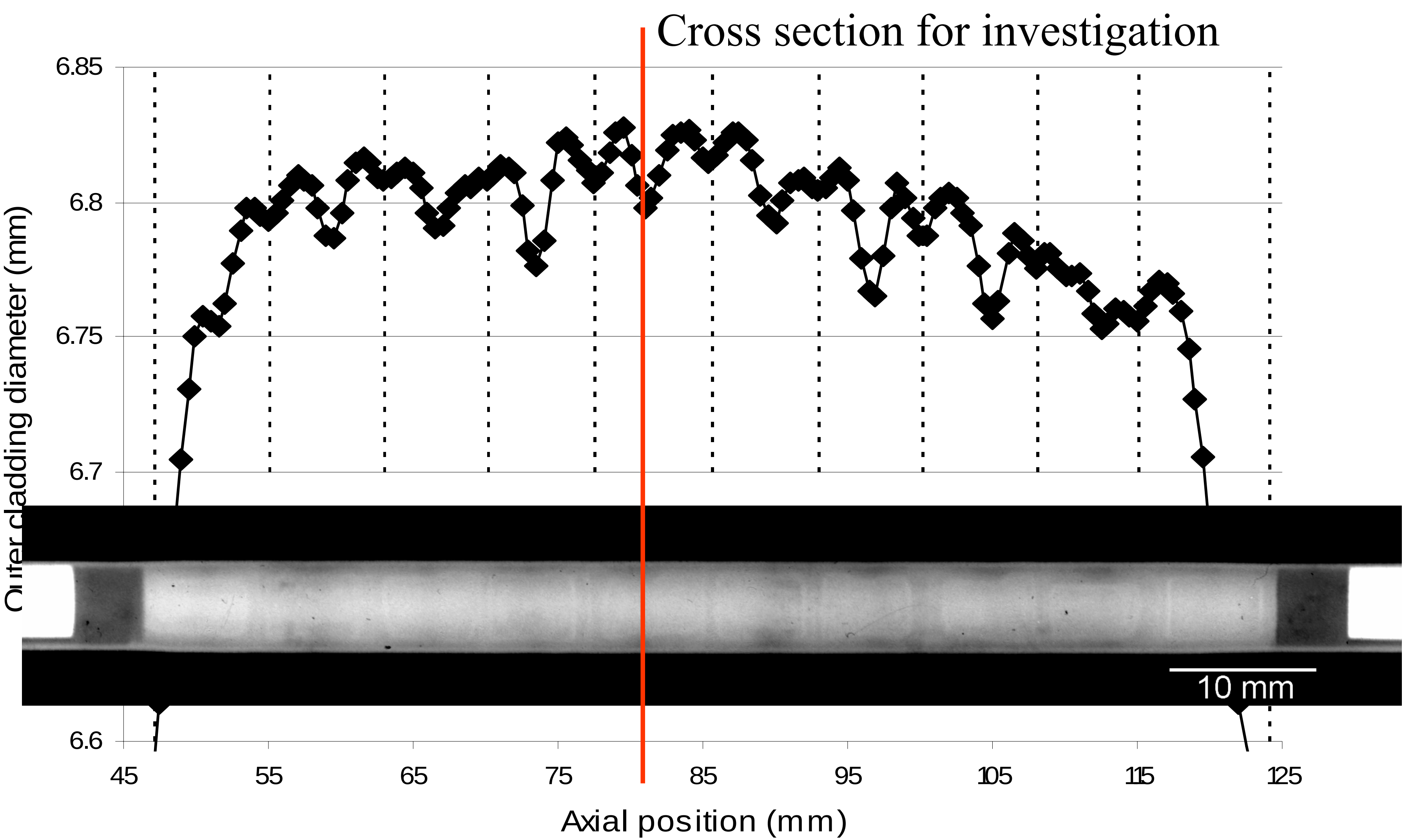
Irradiated T4bis: 25% porosity

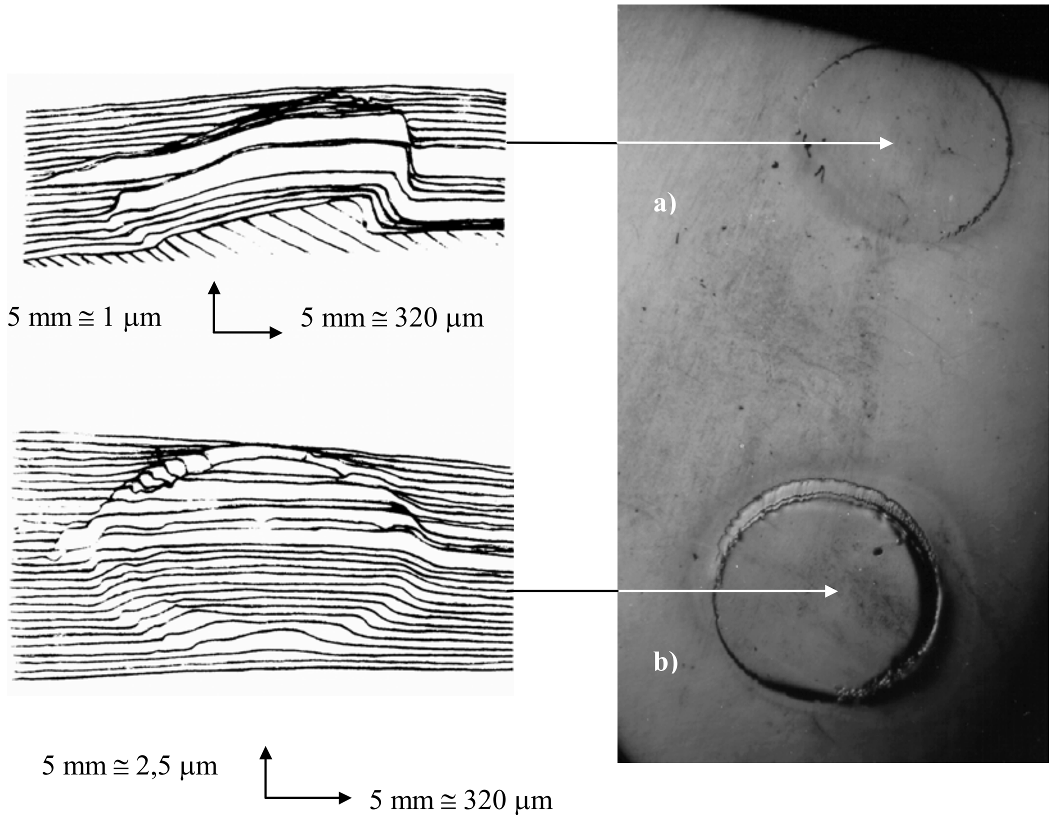
T4bis Electron Probe Micro-Analysis

Composition of the 50% actinides remaining in the fuel



EFTTRA T4bis Profilometry and X-ray image





Profilometry and optical micrograph of an MgAl2O4 single crystal <110> orientated irradiated with iodine ions of 72 MeV energy. The respective fluences are 1015 for a) and 1017 ions/cm2 for b). The optical micrograph shows clearly the irradiated area poping out from the original crystal surface.

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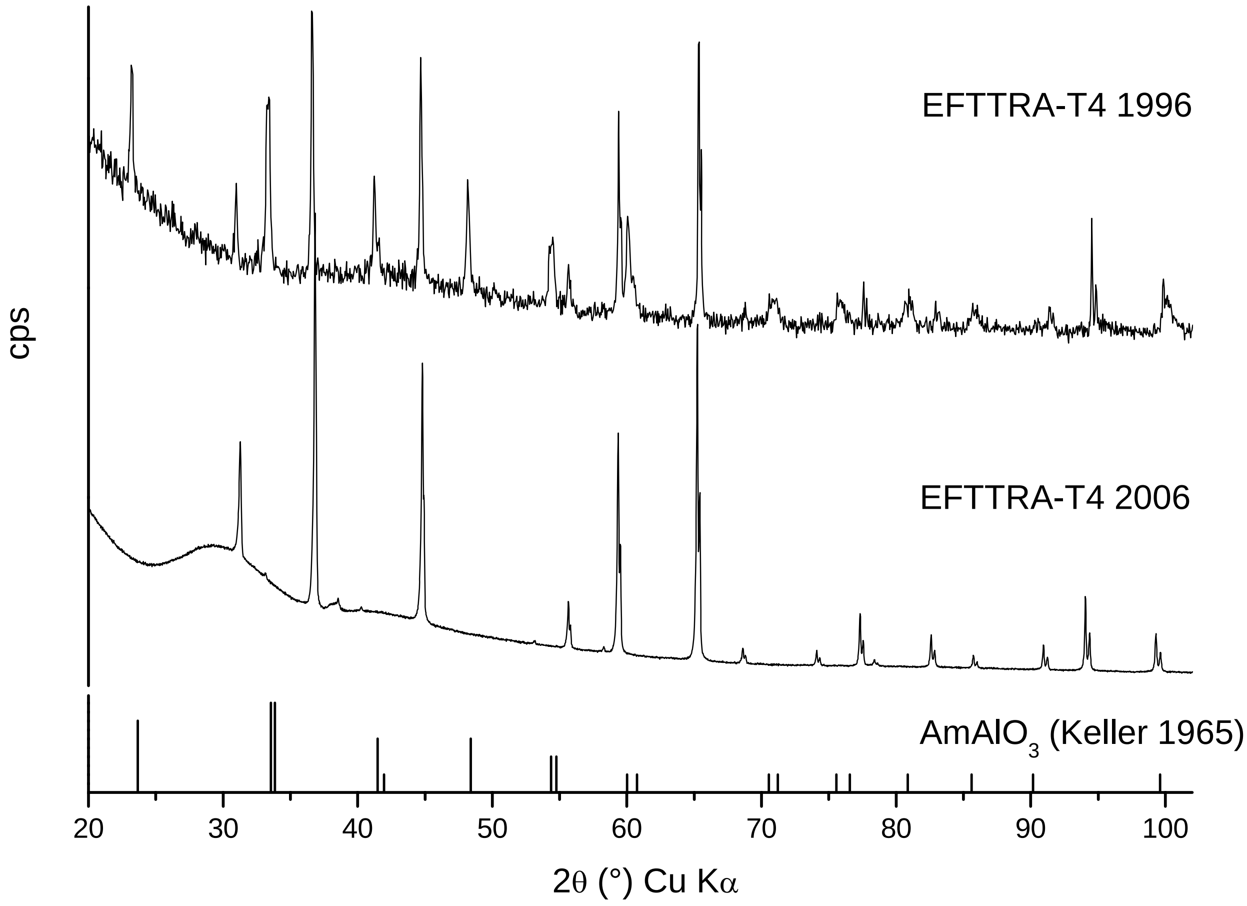
X-ray diffraction of EFTTRA-T4 fuel



spinel +

Am phase similar

to $AmAlO_3$

spinel (crystalline!)

no Am phase

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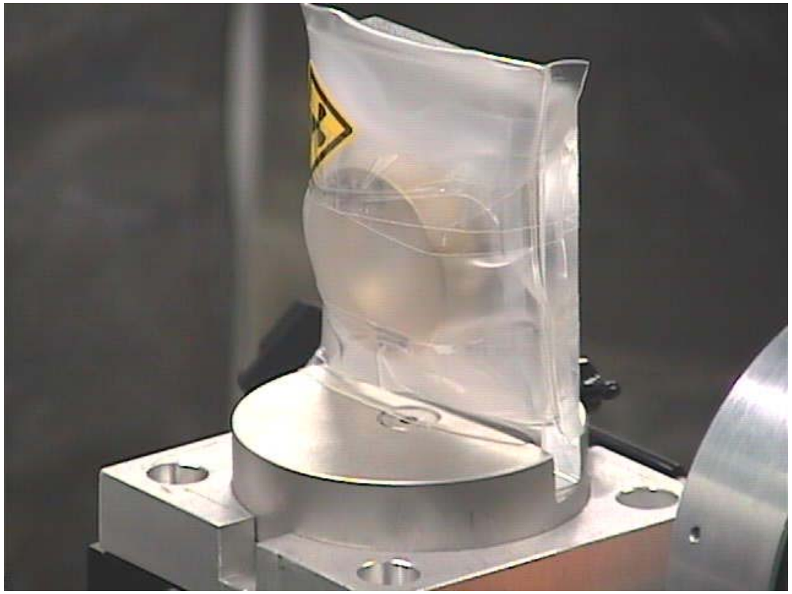
EXAFS measurement

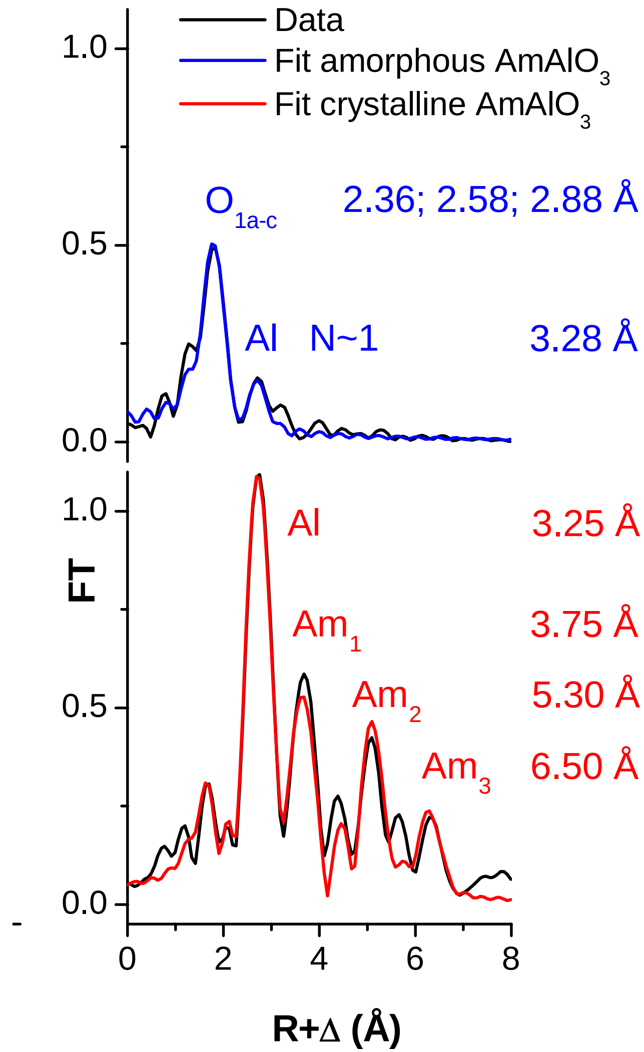
- annealing at 1600°C in Ar/H_2
  (as for production in 1996)
- about 60 mg Am-spinel powder in a steel shielded Plexiglass cuvette
- measurement at INE Beamline at the Ångströmquelle Karlsruhe, ANKA



→ EXAFS provides information of local atomic structure:

- interatomic distance
- coordination number
- type of atom in coordination shells
- disorder

Am L_{III}-edge EXAFS of aged and annealed EFTTRA-T4



10 years aged EFTTRA-T4 fuel shows no peaks corresponding to a periodic structure

Am L_3-edge EXAFS of annealed EFTTRA-T4 fuel can be fitted with $AmAlO_3$ structure

→ **$AmAlO_3$ is predominant in EFTTRA-T4 fuel**

General conclusion related to the use of spinel as IMF

- Conclusion based on T4+T4bis + other experiments in HFR and Phenix
- At low temperature, He retention leading to swelling
- At high temperature He release, but chemical instability
- Study started of a more stable IMF (once-through): Y-stabilised Zirconia
- Additional investigation of MgO and Mo for recycle strategies
- Need of irradiation experiments: HELIOS in HFR

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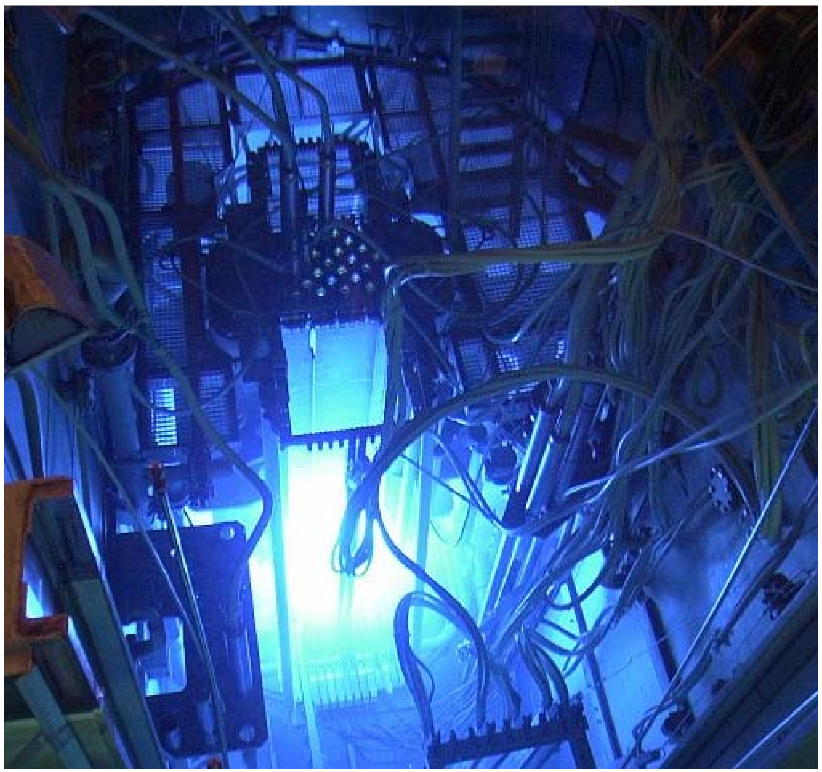
EUROTRANS IP (FP6) Irradiation Tests

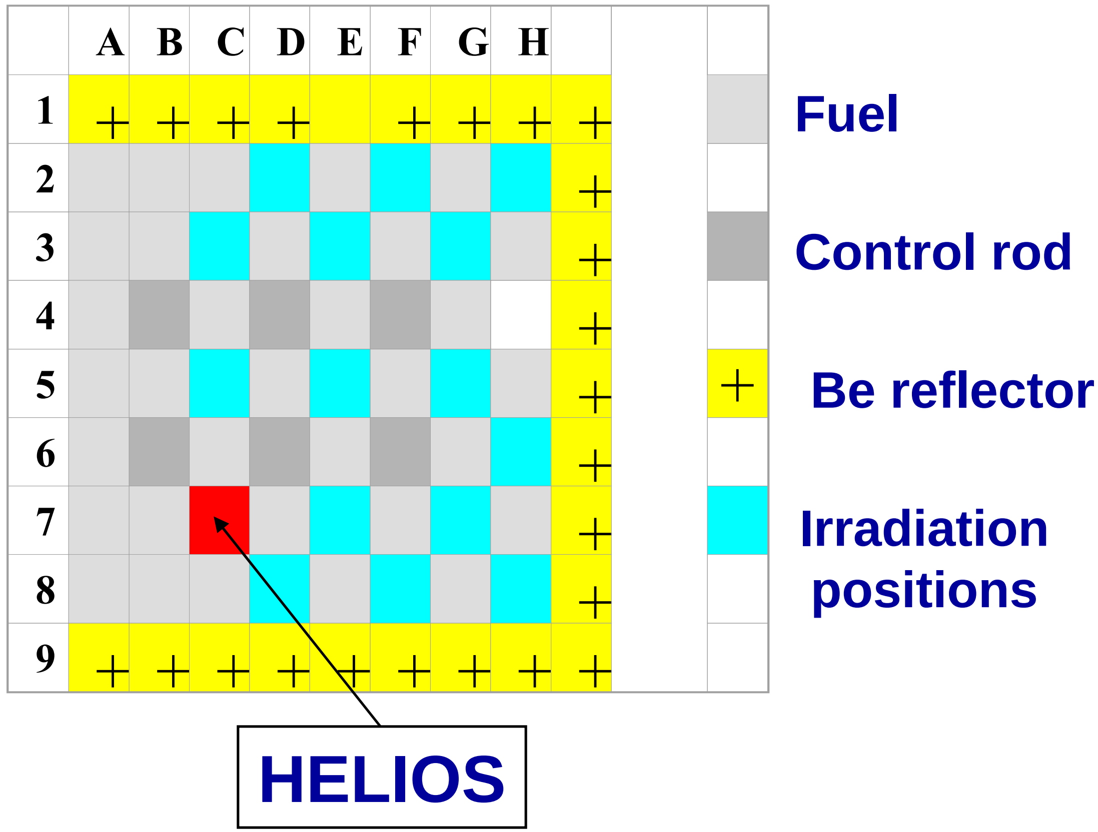
- **FUTURIX: irradiation test in Phénix of TRU-fuels under EFIT relevant conditions**

- **BODEX: irradiation test in HFR to study the helium buildup and release from inert matrixes for IMF's**

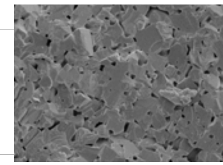
- **HELIOS: irradiation test in HFR to study the in-pile behaviour vs temperature of U-free Am targets**

HFR-Petten

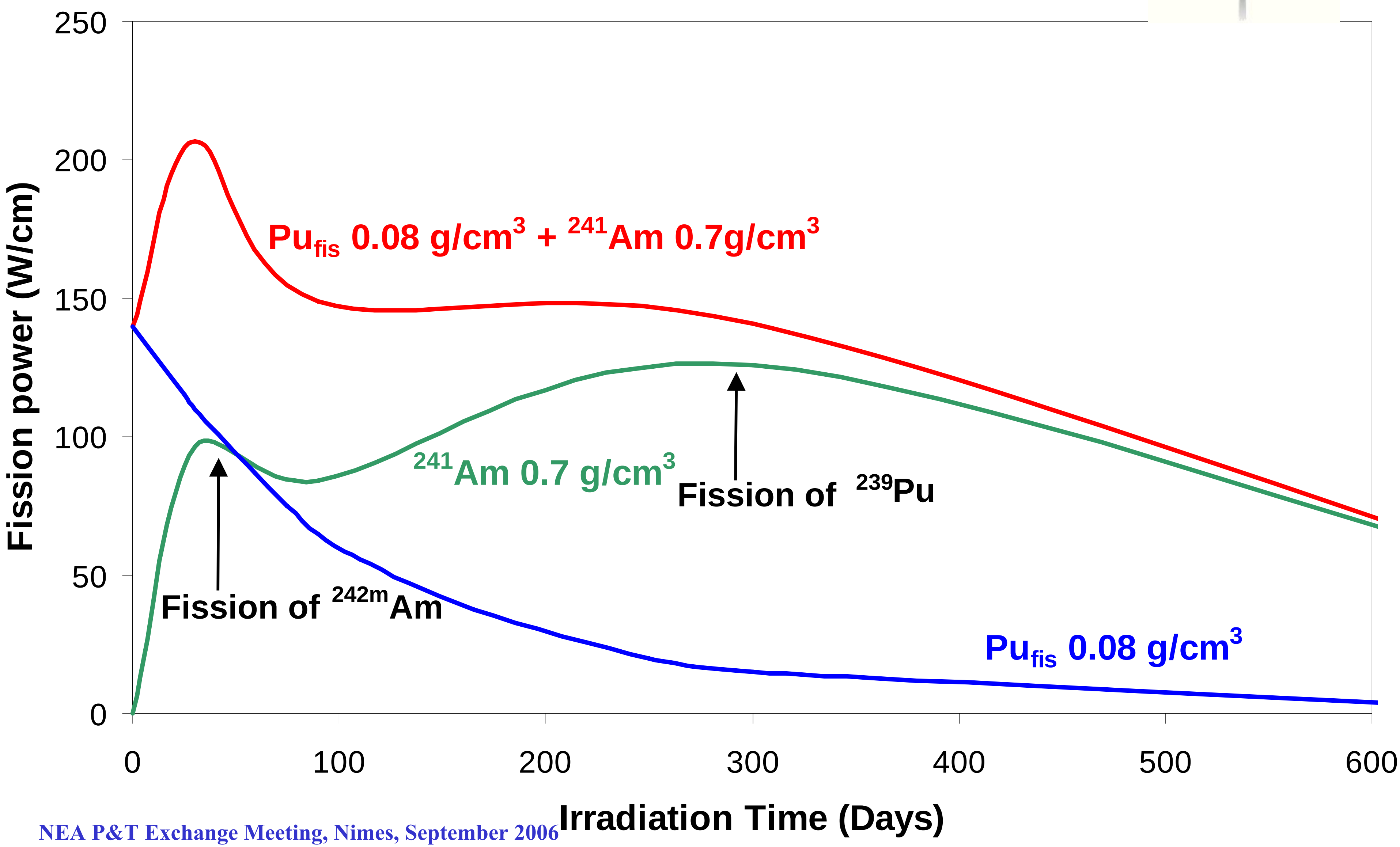



A B C D E F G H
1
2
3
4
5
6
7
8
9
Fuel
Control rod
Be reflector
Irradiation positions
HELIOS

HELIOS test matrix

Pin Nr	Composition	Microstructure	As-fabricated density [g/cm³]		Fuel Manufacturer	Fuel Type	Remarks
			^{241}Am	Pu_{tot}			
1	$Am_2Zr_2O_7$+MgO	10-50 μm	0.7	0	CEA	Cer Cer	
2	$(Am,Zr,Y)O_2$	Solid solution	0.7	0	JRC-ITU		Instrumented with Central TC
3	$(Am,Pu,Zr,Y)O_2$	Solid solution	0.7	0.39	JRC-ITU		Instrumented with Central TC
4	$(Zr,Am,Y)O_2$+Mo	60-120 μm max 30 vol%	0.7	0	JRC-ITU	Cer Met	
5	$(Pu,Am)O_2$+Mo	40-150 μm max 30 vol%	0.3	1.2	JRC-ITU	Cer Met	

Power calculations



Estimated temperatures

Pin	Composition	Pu-content [g/cm³]	Am-content [g/cm³]	Max Power [W/cm³]	Linear Power [W/cm]	$T_{central}$ [°C]	Calculated with power [W/cm³]
1	$Am_2Zr_2O_7$ + MgO	0	0.7	240	56	741	300
2	$(Am,Zr,Y)O_2$	0	0.7	170	40	811	230
3	$(Pu,Am,Zr,Y)O_2$	0.39	0.7	740	170	1439	787
4	$(Am,Zr,Y)O_2$ + Mo	0	0.7	250	58	687	300
5	$(Pu,Am)O_2$ + Mo	1.2	0.3	1600	370	1477	2020

- Onset of He release: ≈ about 550 °C
- Complete He release: ≈ about 1350 °C

$(Am,Zr,Y)O_2$ pre-fabrication tests

Sintered density > 90%TD

HELIOS Status

- HELIOS irradiation shall start in 2007 in the HFR and last for about 1 year (i.e. 10 HFR cycles)
- Fuel production and hardware procurement & manufacturing underway
- Predicted temperatures in the fuels are acceptable (slightly lower than aimed)
- Destructive PIE's results shall be available in 2009

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Future EFTTRA plans

- Complete HELIOS experiment within EUROTRANS IP
- Integrate the results within other experiments: BODEX
- Demonstrate the high Am transmutation capability of Zirconia IMF with a 5-years irradiation in HFR: HELIOSbis (not decided – funding dependent
- Looking at the feasibility of Cm transmutation in once-through mode