Microstructural evolution and Am migration behavior in Am-containing MOX fuels at the initial stage of irradiation

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Background(1)

- A closed nuclear cycle based on the fast reactor is one of the most promising ways to achieve a sustainable energy supply.
- Management of MAs such as Am, Np, Cm is important from the viewpoint of
  - Reduction of environmental burden
  - Effective use of natural resources
  - Enhancement of nuclear nonproliferation
- MOX fuels containing several percents of MAs and fission products are promising candidates for the JSFR (JAEA Sodium Cooled Fast Reactor) system of FaCT (Fast Reactor Cycle Technology Development Project).

Background(2)

- Am, which represents the MAs, should be considered important in view of its having
  - High generation yield in the spent fuel,
  - High and lasting radioactivity / radiotoxicity
  - Expected impacts on various properties of MOX fuels.

  ⇨ Am-MOX fuel having up to 5%Am have been studied as a first step to promote R&D of the MA-MOX fuels in AGF of JAEA.

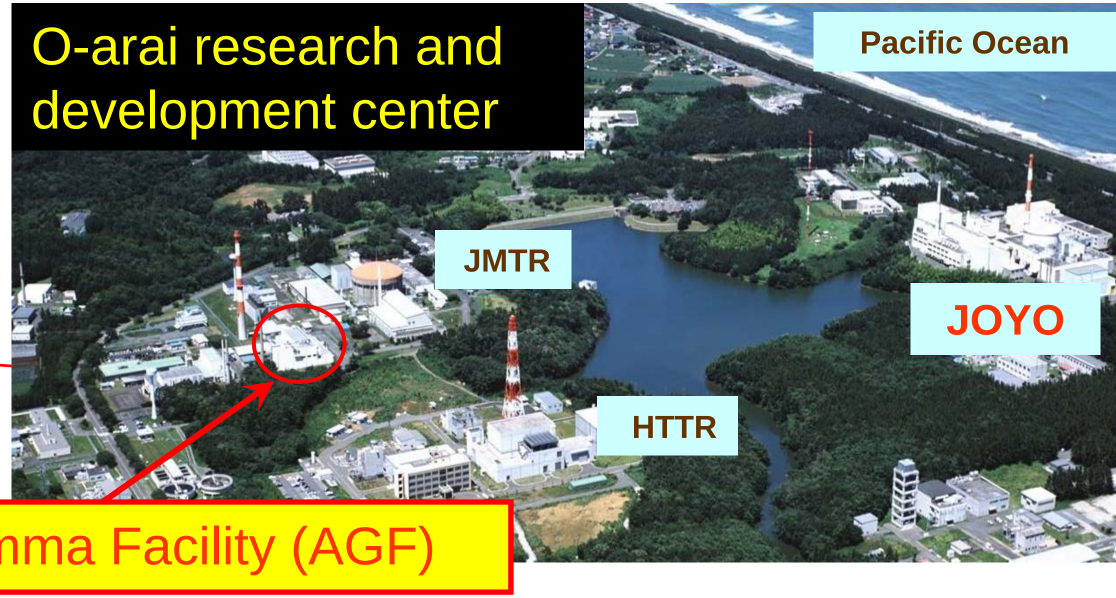
- By adding Am to MOX….. What will happen to the irradiation behavior of MOX fuel ?

  ⇨ Irradiation test named "Am-1" program has been conducted in JAEA.

Outline and objectives of Am-1 program

- The fuels for Am-1 program
  - 3% or 5%Am-containing MOX fuels (Am-MOX)
  - 2%Np and 2%Am-containing MOX fuels (Np/Am-MOX)
- Short-term irradiation tests (10 min and 24 h test)
  - To confirm whether or not fuel melting occurred at a high linear heating rate.
  - To evaluate the redistribution behavior of Am during the initial burn-up.
- Steady state irradiation test
  - To evaluate the fuel behavior such as fuel cladding chemical interaction (FCCI) up to middle or high burn-up.
  - To evaluate the Helium (He) release behavior.

Laboratory
- Alpha Gamma Facility (AGF) -

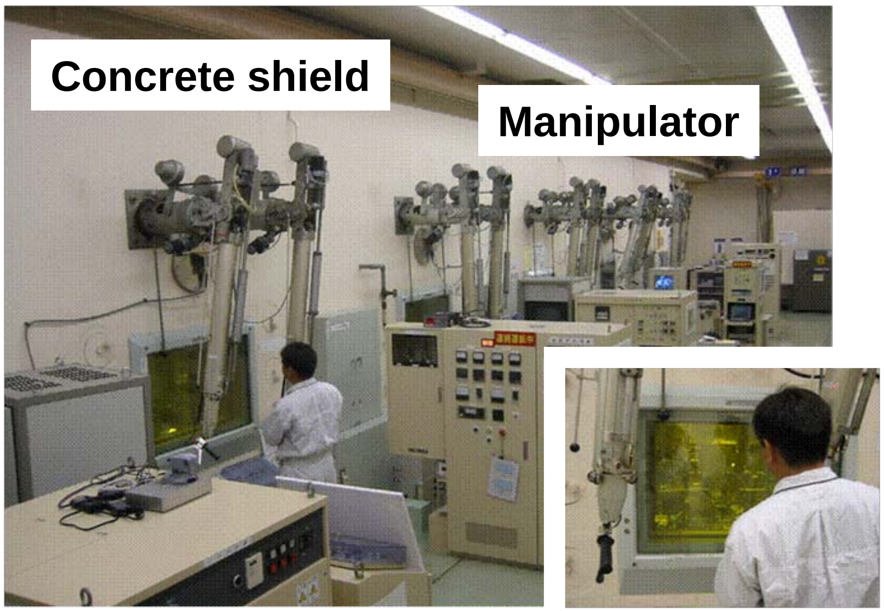


AGF was

- originally constructed as the PIE facility of the irradiated fuels.
- later equipped with a small-scale fuel fabrication unit in the hot cell.

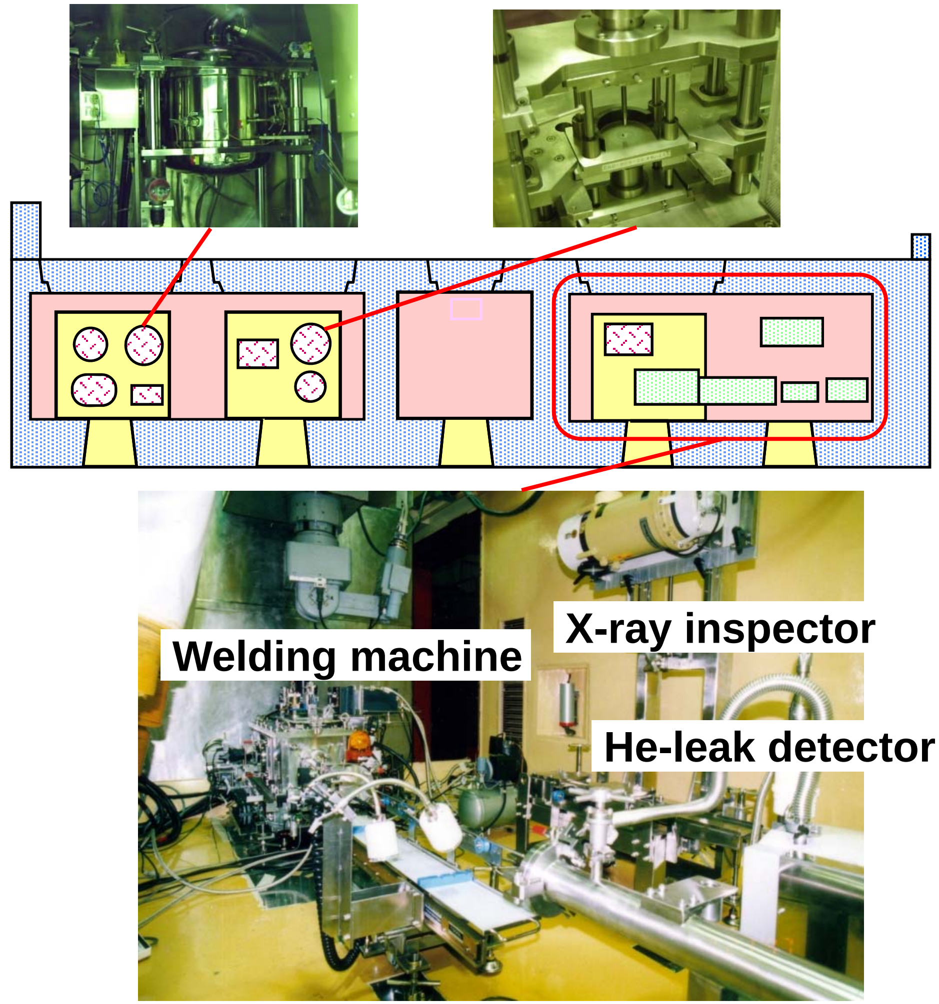
Remote fabrication apparatuses

Operation area



Sintering Furnace

Pressing unit



Pin manufacturing and inspection

- Concrete shielded-cells combined with inner air-tight box.

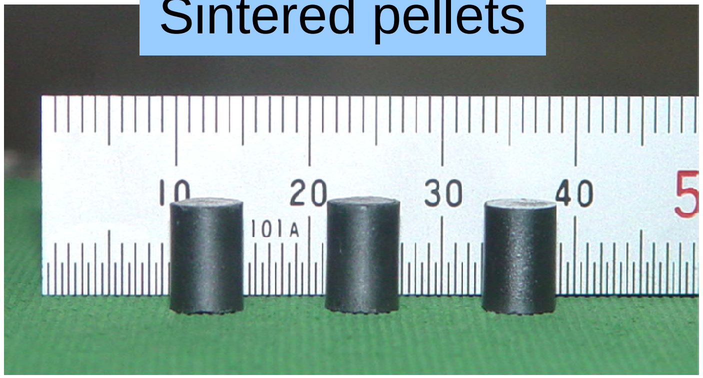
Fabrication flow of Am-MOX fuel pin

UO_2	Prepared by conventional ADU (Ammonium di-uranate) method
PuO_2 with 9%Am	Obtained by storing ^{241}Pu included PuO_2 powder for a long time
PuO_2 with 50%Am	Prepared by carrying out co-precipitation in the mixture of Pu and Am nitrite solutions and calcination

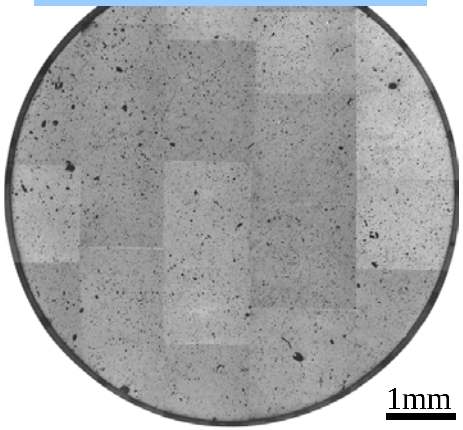
Heat treatment → Weighing → Ball milling → Binder addition (Zinc stearate) → Pressing → Pre-sintering → Sintering → Inspection → Loading into cladding → Welding → Inspection → Am-MOX fuel pin

Fabricated Am-MOX fuel pellets

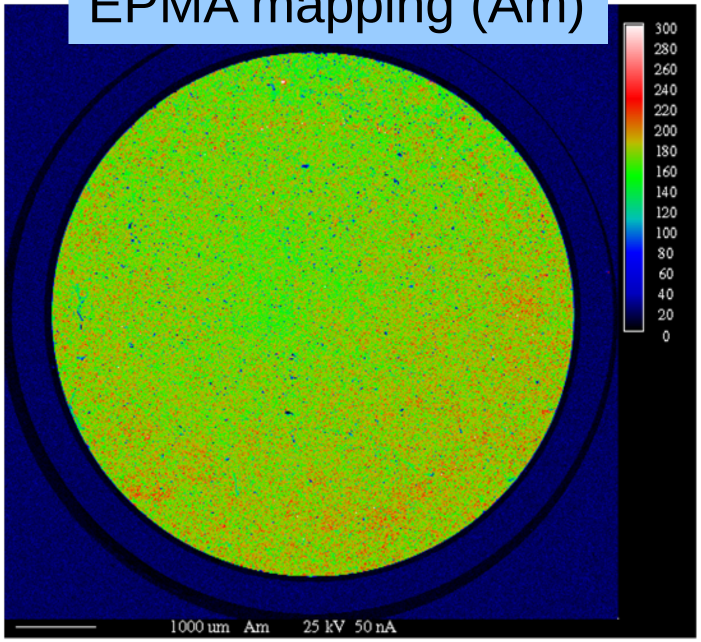
Sintered pellets



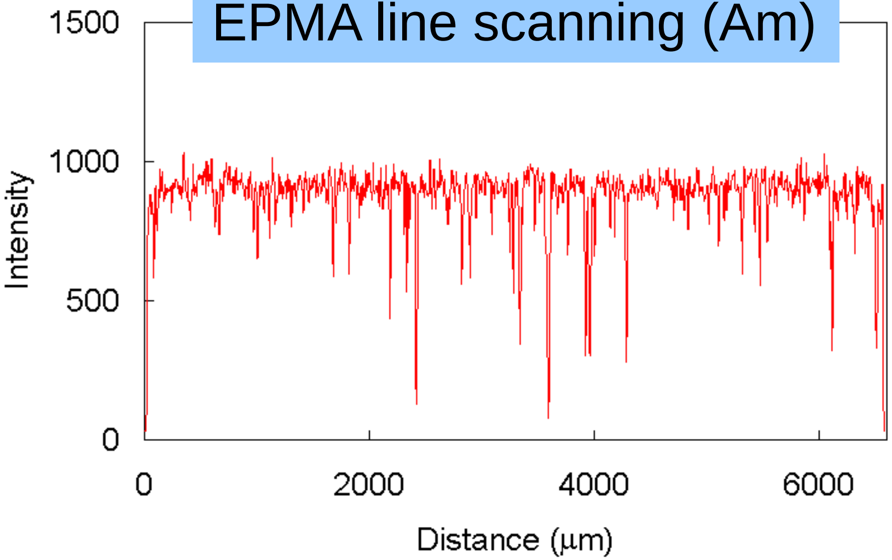
Ceramograph



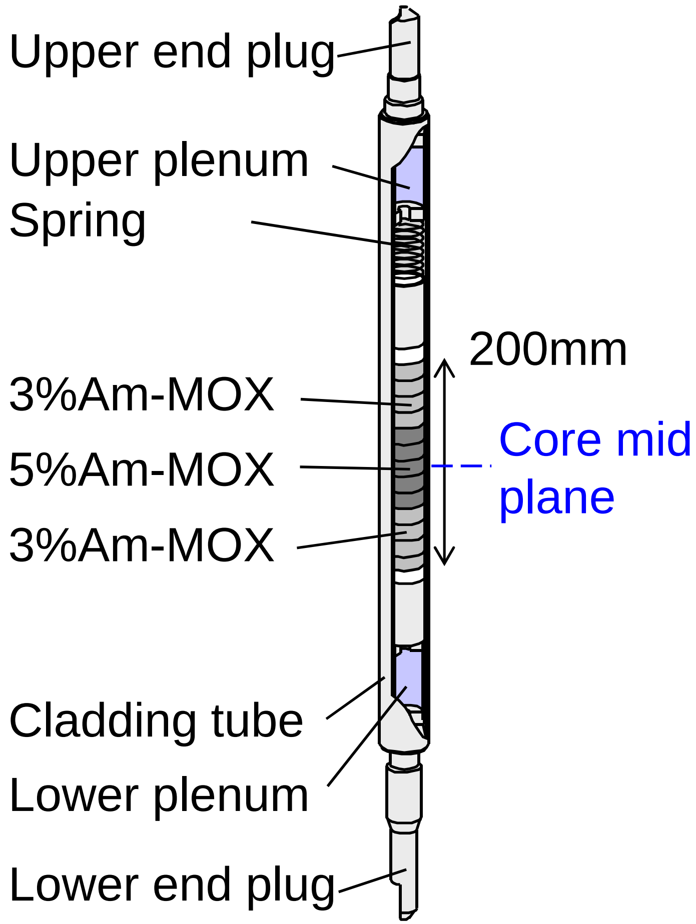
EPMA mapping (Am)



EPMA line scanning (Am)



Configuration and main specifications of the Am-MOX fuel pin



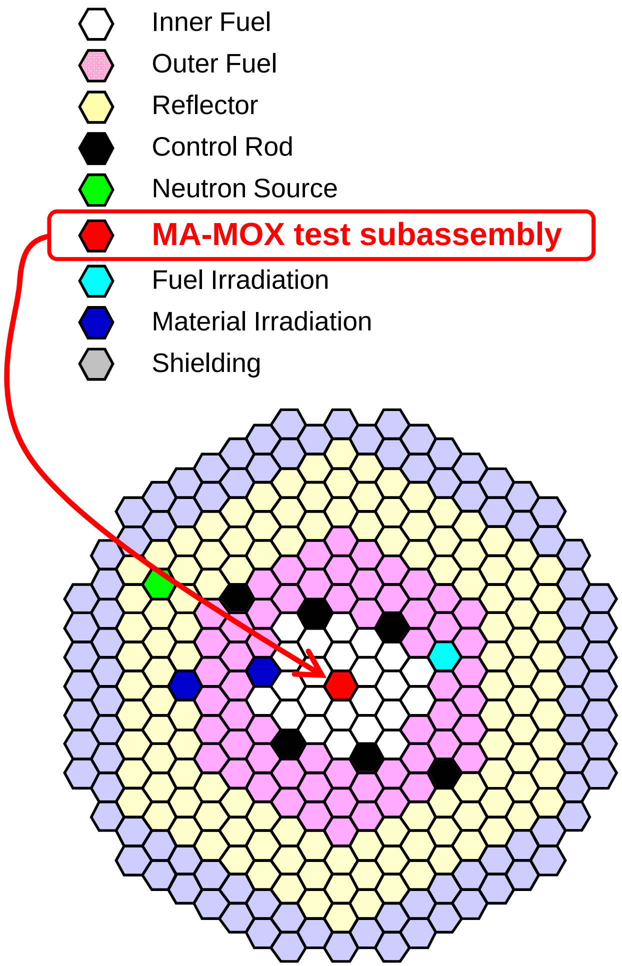
Fuel pellet

Diameter : 6.52 mm
O/M ratio : 1.98
Density : 93 % T.D.
Pu content : 30 wt. %
Am content : 3 and 5 wt. %

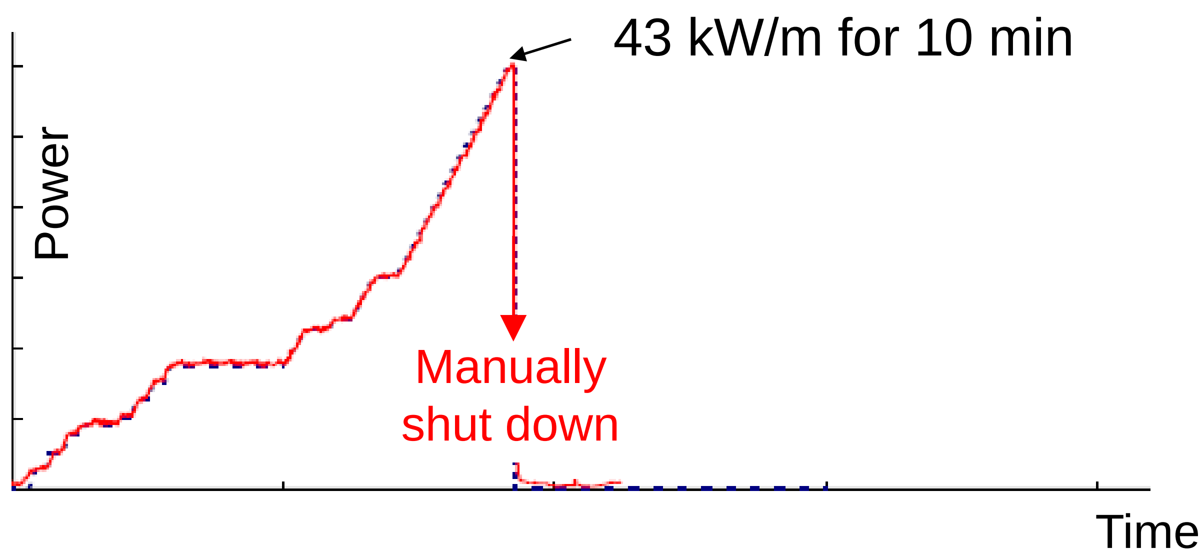
Cladding

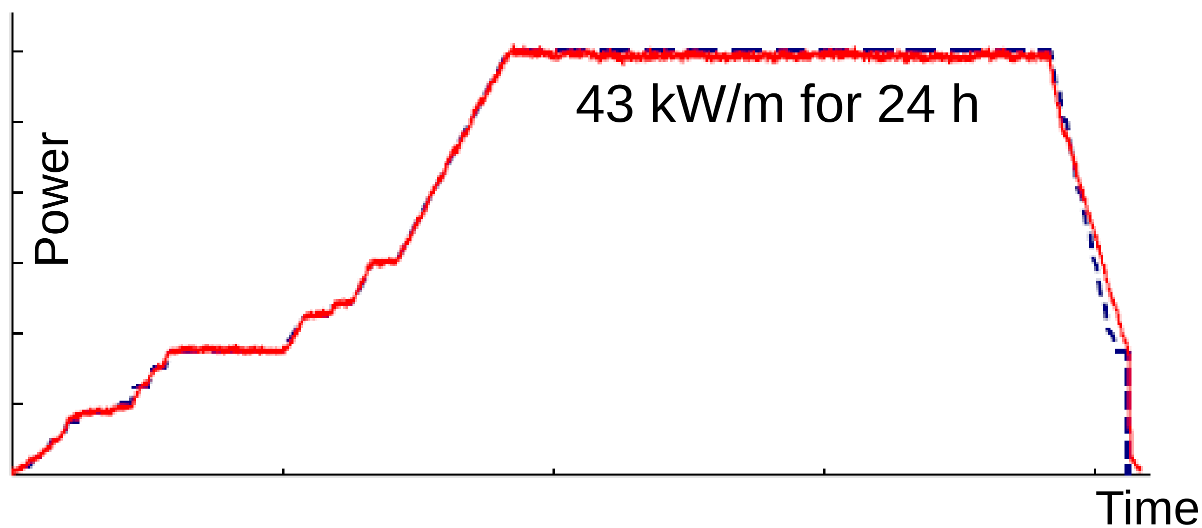
Outer diameter : 7.5 mm
Thickness : 0.4 mm

Irradiation conditions

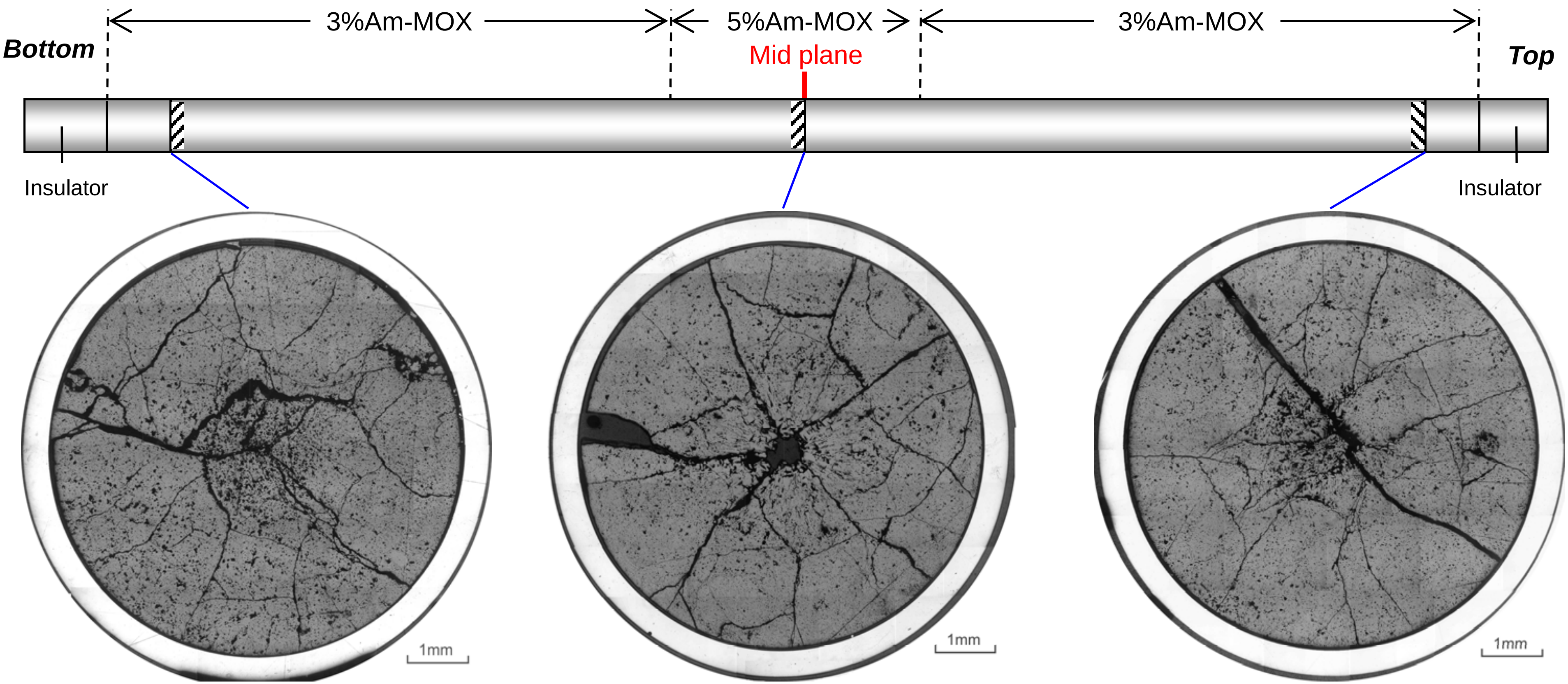


Configuration of the Joyo MK-III core



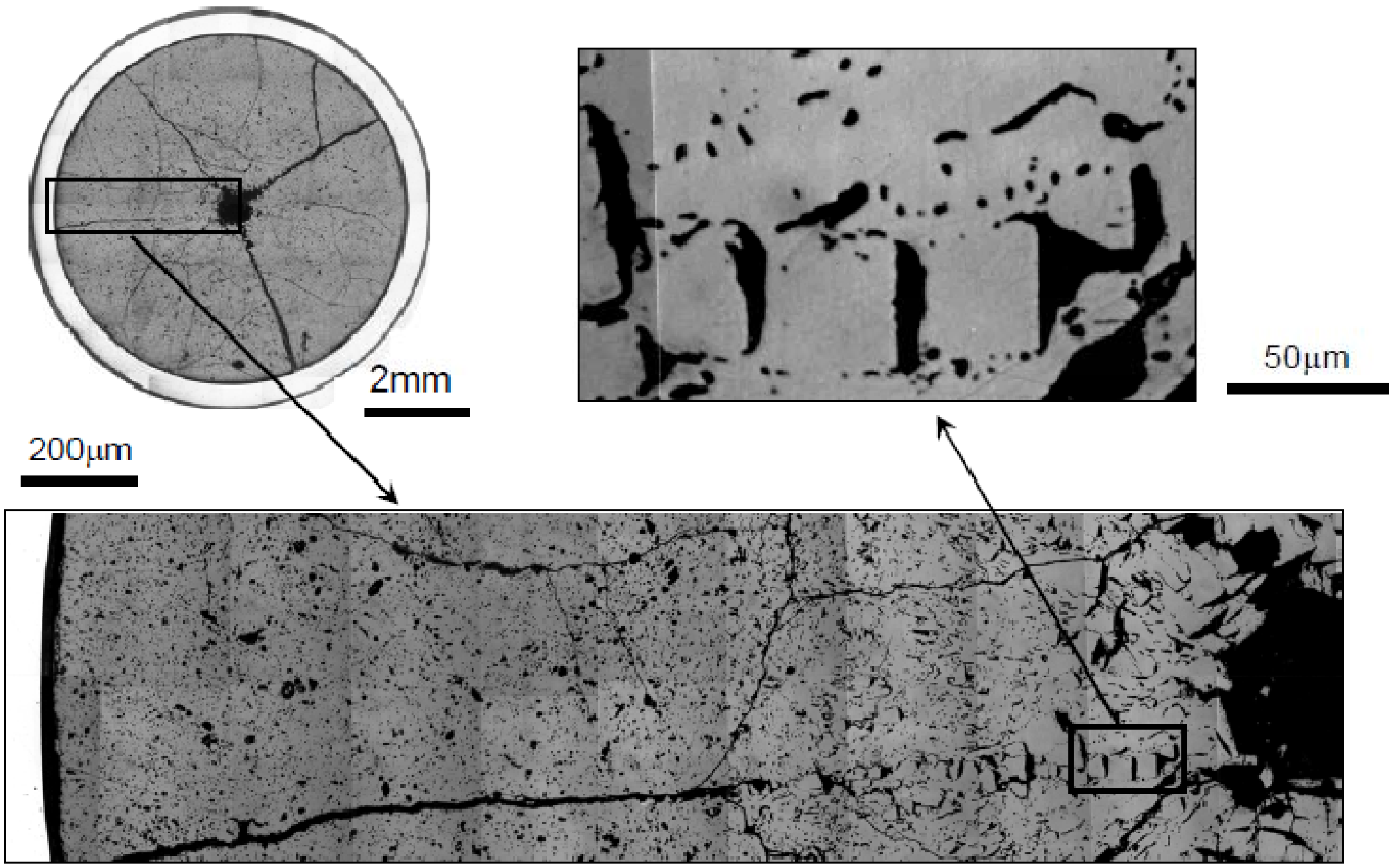


Ceramographs(1)



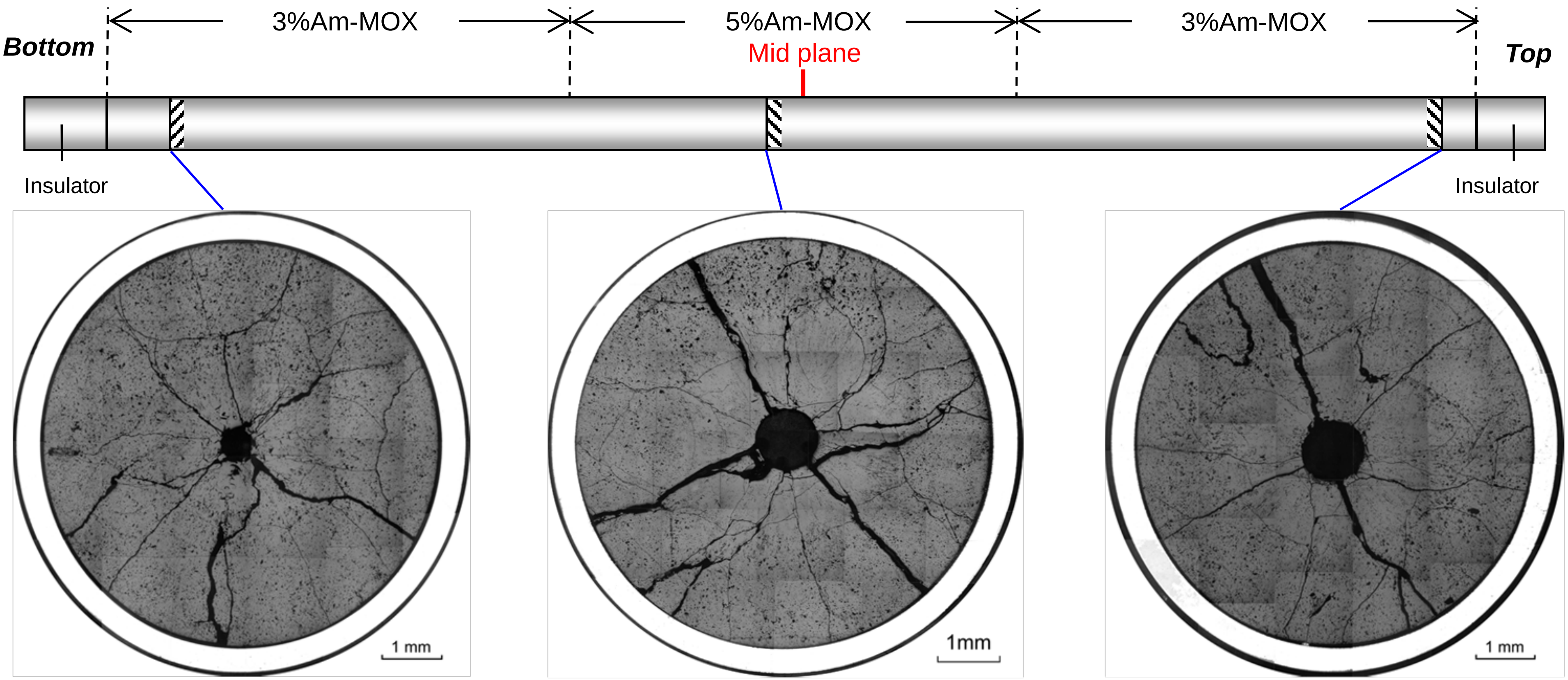
No apparent restructuring	Formation of a central void	No apparent restructuring

Ceramographs(2)



No sign of fuel melting was found in any of the specimens

Ceramographs(1)



-Witl The central voi

No sign of fuel

-Surrounded by high dense columnar grains

-Without lenticular pores

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-Surrounded by high dense columnar grains

-With lenticular pores

Redistribution of Am

- If local accumulation of Am by migration during irradiation occurs, thermal properties could be degraded.

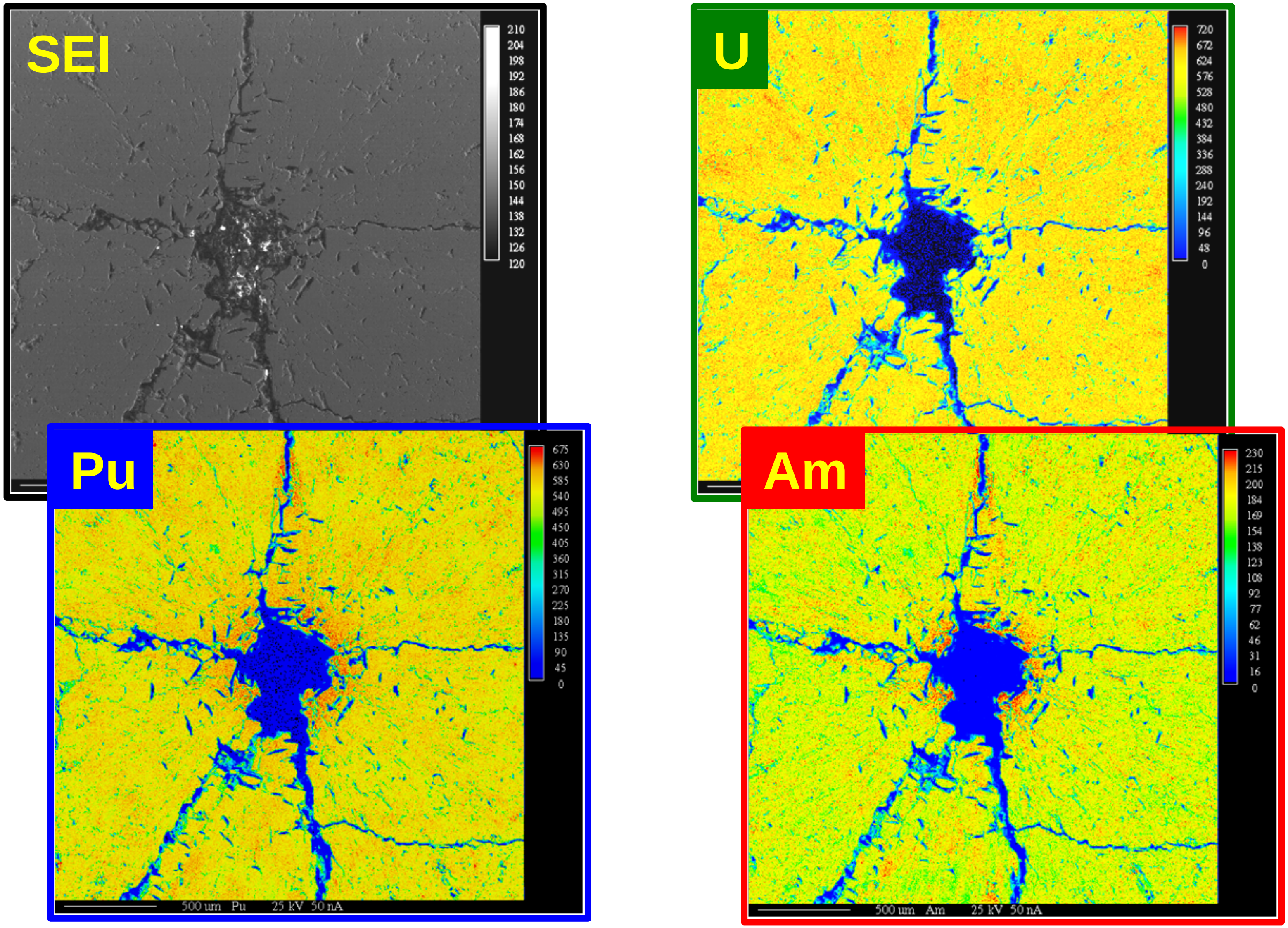
  ⇒ Am redistribution : Important behavior

- Pu tends to migrate up the temperature gradient, which results in accumulation in the pellet center.
  (MOX pellets with around O/M=1.98 for fast reactor)

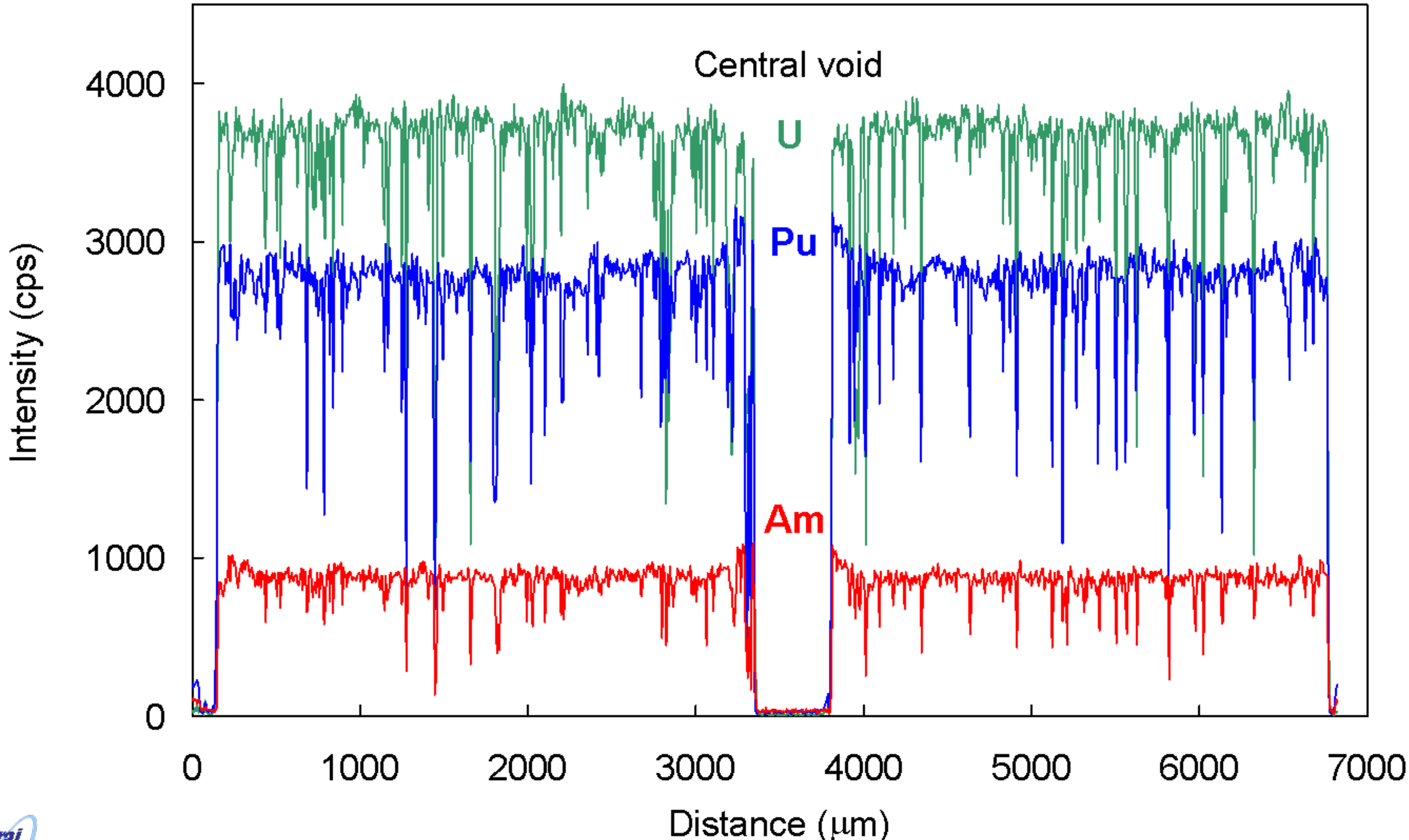
- How about Am ? Similar to Pu or not ?

  ⇒ Electron Probe Micro Analysis (EPMA) was conducted

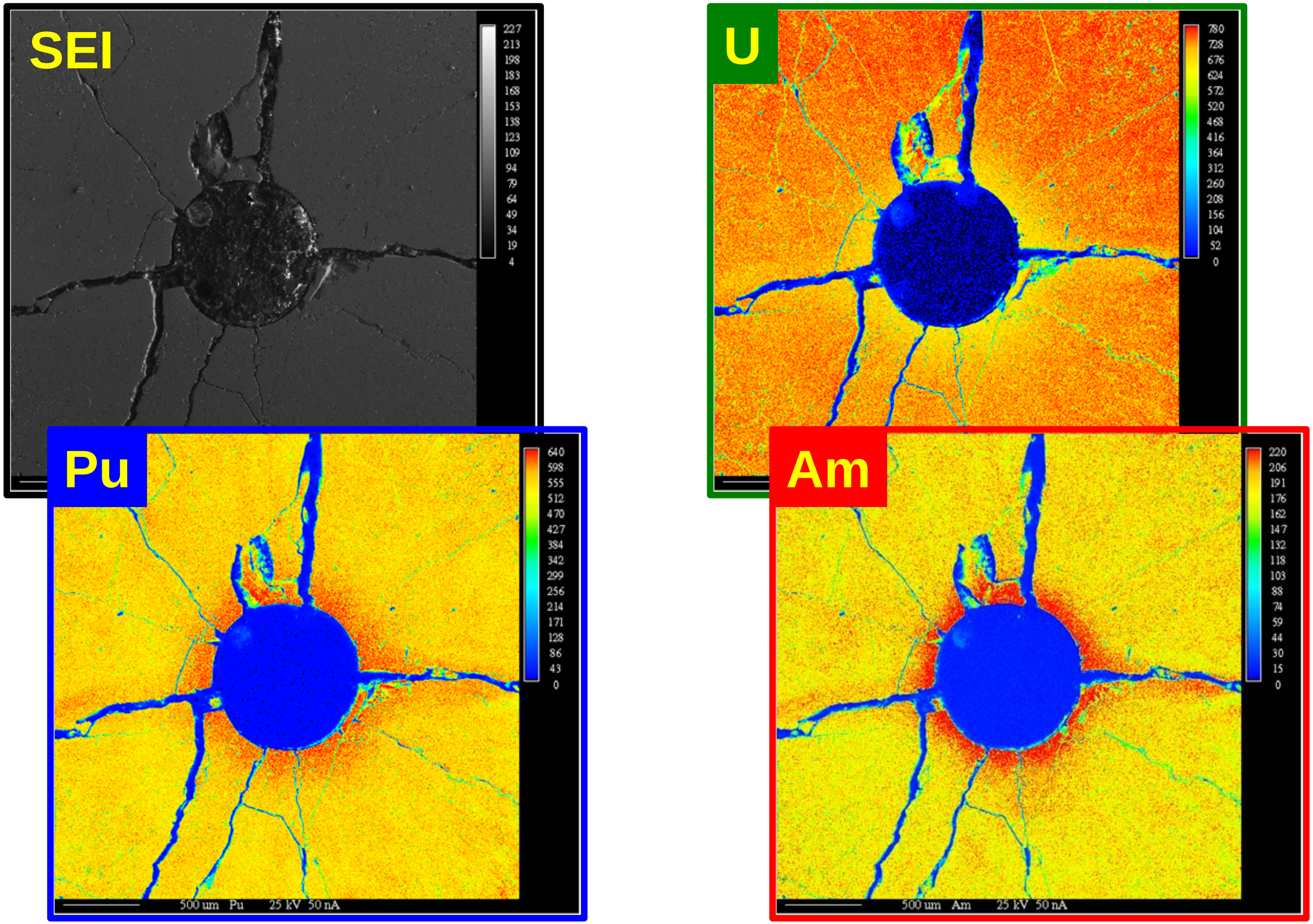
EPMA mapping of U, Pu and Am (10-min)



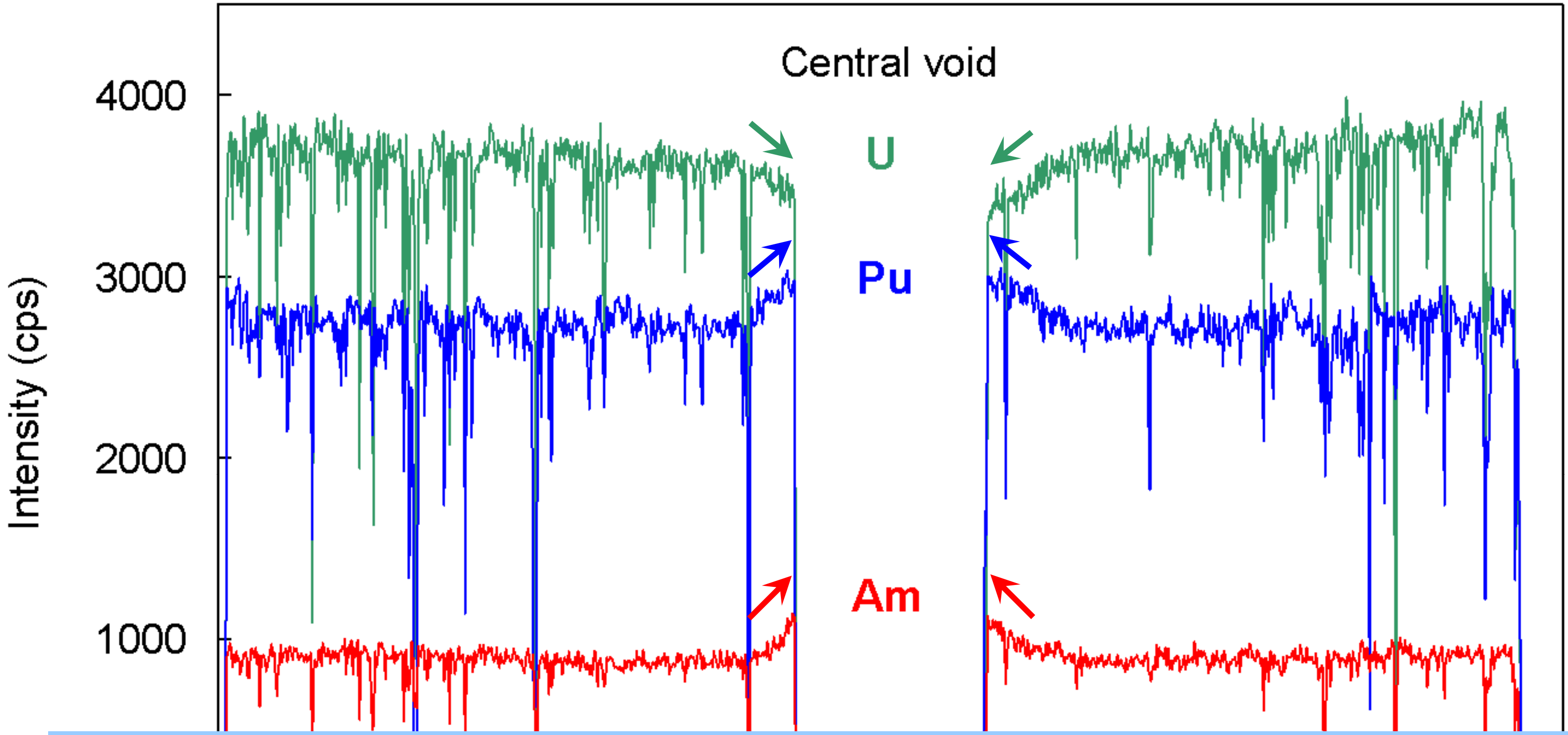
EPMA results of U, Pu and Am distributions (10-min irradiation)



EPMA mapping of U, Pu and Am (24-h)



EPMA results of U, Pu and Am distributions (24-h irradiation)



Careful consideration must be given to the redistribution behavior of Am as well as that of Pu for evaluating the impact on the thermal performance of Am-MOX fuels.

Summary

- The Am-MOX fuel pins containing 5% or 3%Am, which were fabricated by remote handling technique in AGF, were irradiated at about 43 kW/m for 10-min and 24-h in Joyo.
- The ceramography results showed that structural changes such as formation of the lenticular pores and the central void occurred quickly and early within 10-min irradiation.
- No sign of fuel melting was found in any of the fuel pellet specimens.
- The EPMA results revealed that the concentrations of Pu and Am increased whereas that of U decreased in the vicinity of the central void.
- The present EPMA results indicated that careful consideration must be given to the redistribution behavior of Am as well as that of Pu for evaluating the impact on the thermal performance of Am-MOX fuels.