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

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Kosuke Tanaka, Shuhei Miwa, Isamu Sato, Masahiko Osaka, Takashi Hirosawa, Hiroshi Obayashi, Shin-ichi Koyama, Hiroshi Yoshimochi, Kenya Tanaka
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  - Microstructures
  - Radial distributions of U, Pu and Am

Summary
**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).
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.
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
- Concrete shield
- Manipulator
- Welding machine
- X-ray inspector
- He-leak detector
- Pin manufacturing and inspection

Concrete shielded-cells combined with inner air-tight box.
Fabrication flow of Am-MOX fuel pin

**UO₂**
Prepared by conventional ADU (Ammonium di-uranate) method

**PuO₂ with 9%Am**
Obtained by storing $^{241}$Pu included PuO₂ powder for a long time

**PuO₂ 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

- Inner Fuel
- Outer Fuel
- Reflector
- Control Rod
- Neutron Source
- MA-MOX test subassembly

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Power

- 43 kW/m for 10 min
- Manually shut down

Time

Power

- 43 kW/m for 24 h

Time
Ceramographs (1)

Formation of a central void

No apparent restructuring

Top

Bottom

3% Am-MOX  5% Am-MOX  3% Am-MOX

Mid plane

Insulator

No apparent restructuring
No sign of fuel melting was found in any of the specimens
Ceramographs(1)

- With lenticular pores
- Surrounded by high dense columnar grains
- Without lenticular pores

The central void had developed after the 24-h irradiation.
No sign of fuel melting was found in any of the specimens.

- 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)
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.