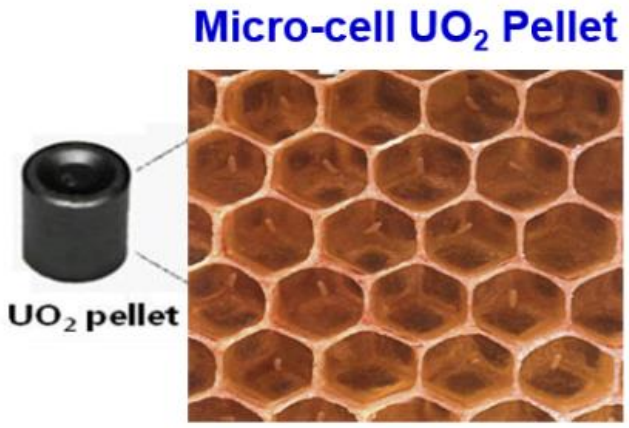
Recent progress on micro-cell UO_2 pellets



3rd meeting of the EGATFL, 3-5 March 2015 NEA HQ

Korea Atomic Energy Research Institute (KAERI)

YANG Jae-Ho, KIM Dong-Joo, Kim Keon-Sik, KOO Yang-Hyun

ATF Pellet Program in KAERI

❑ Mid-term technology: Micro-cell UO_2 pellets

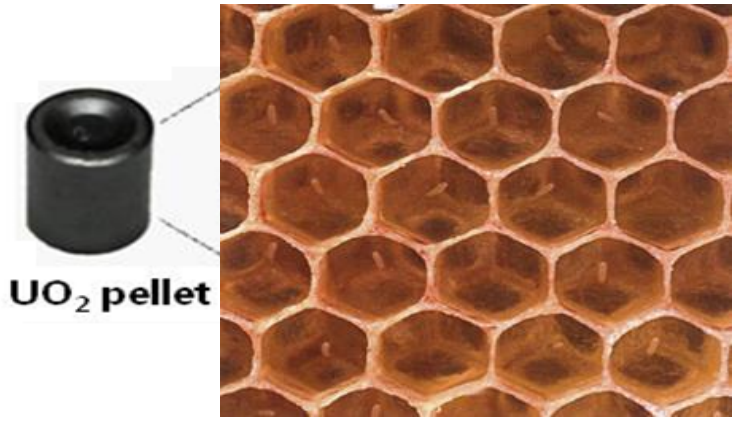
- **Enhance retention capability** of volatile fission products (Cs, I) → Reduced radioactivity release to the environment
- **Use existing infrastructure**, experience and expertise to the maximum extent possible

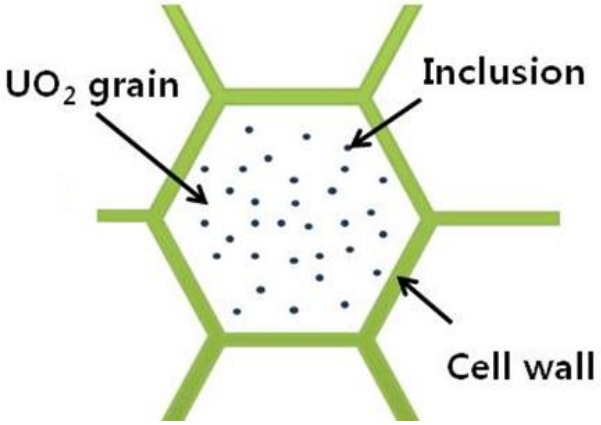
❑ Long-term technology: High uranium density pellets

- Develop innovative fuel pellets with **uranium nitride (UN) composite**
- **Increase uranium density & thermal conductivity** → Increased discharge burnup (economy) and lower fuel temperature (safety)

Micro-cell UO_2 Pellet

- Objective: To **enhance the retention capability** of volatile fission products (Cs, I) during **accident** and normal conditions
- How: To provide many **chemical and/or physical barriers (micro-cells)** within UO_2 pellet that prevents volatile fission products being released to pellet outside
- Cell wall: Ceramic or metallic material

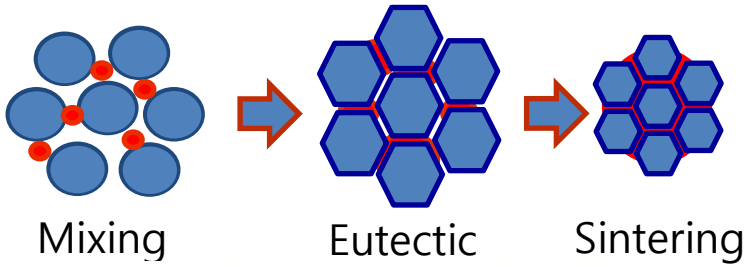


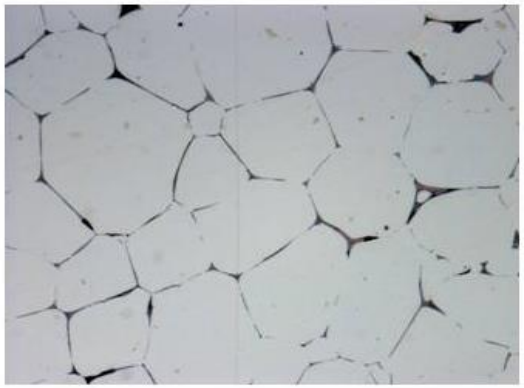


Micro-cell pellets: Fabrication Feasibility

- Ceramic wall : Si-based oxides, 1~2vol%
- Metallic wall : Refractory metals (Cr, Mo, Nb, alloys), ~5vol%

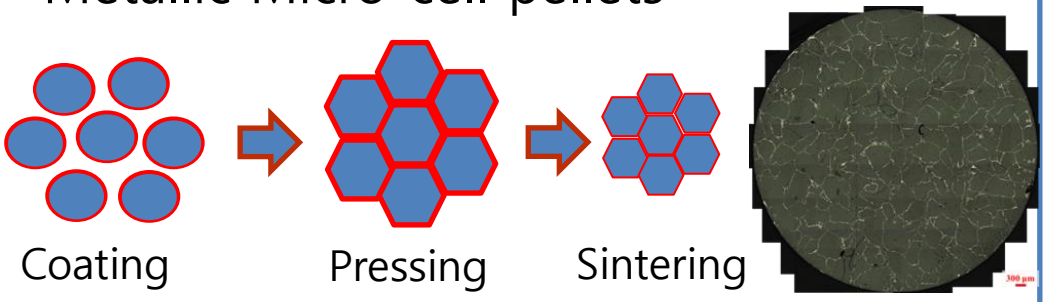
Ceramic Micro-cell pellets

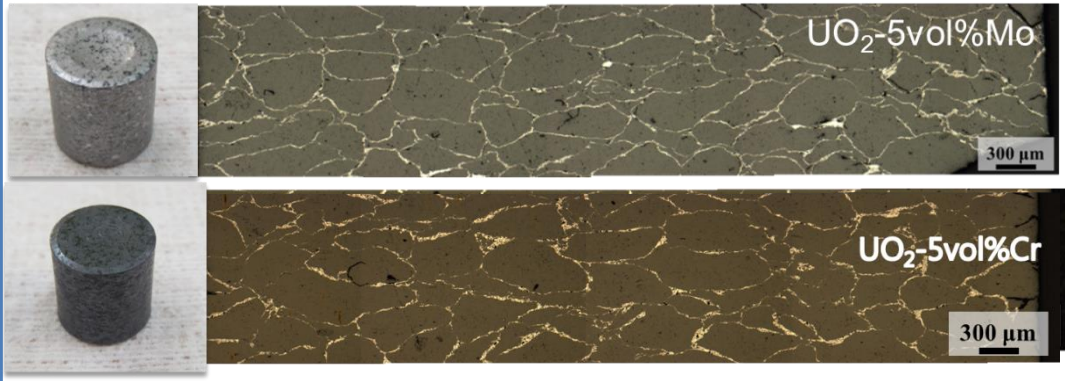




Grain size: ~100μm
Density: ~97%TD

Metallic Micro-cell pellets

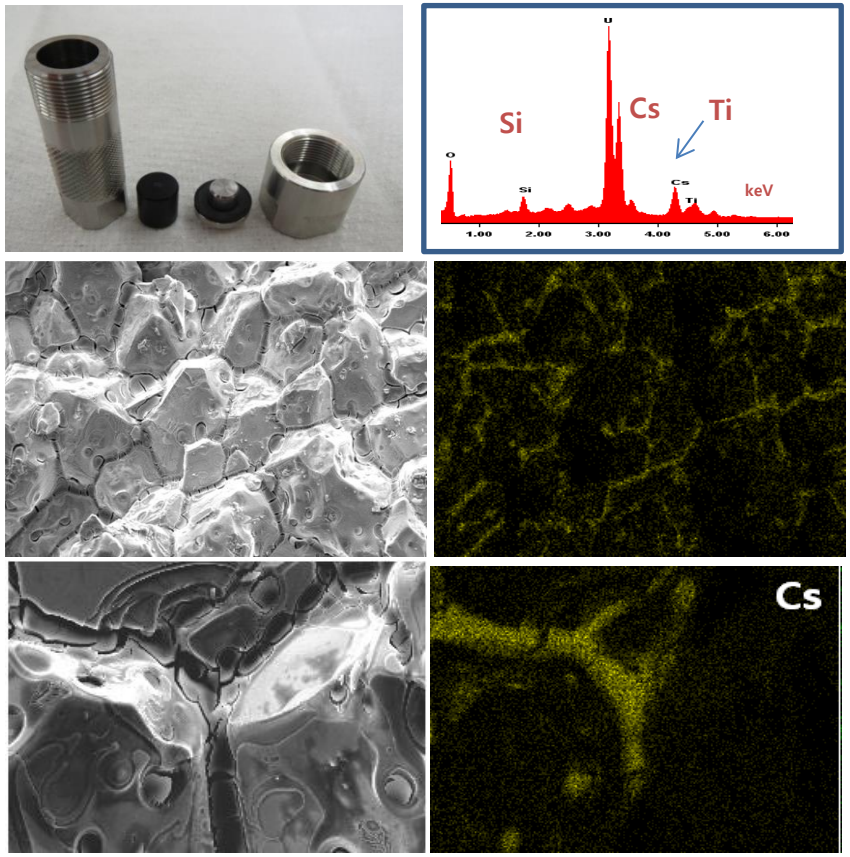




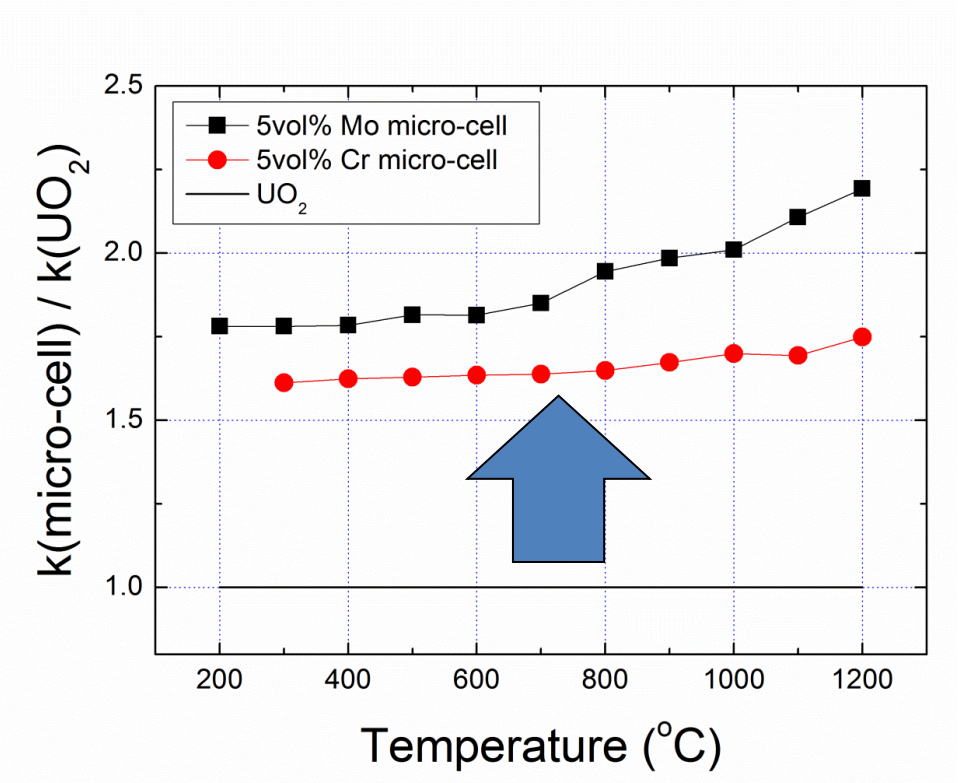
Granule size: ~350μm
Density: ~96.5%TD

Micro-cell pellets: Performance Feasibility

❑ Cs capture test
(ceramic micro-cell)



❑ Thermal conductivity
(metallic micro-cell)



Thermal conductivity of metallic micro-cell pellets increased by ~100%

Micro-cell pellets: Performance Feasibility

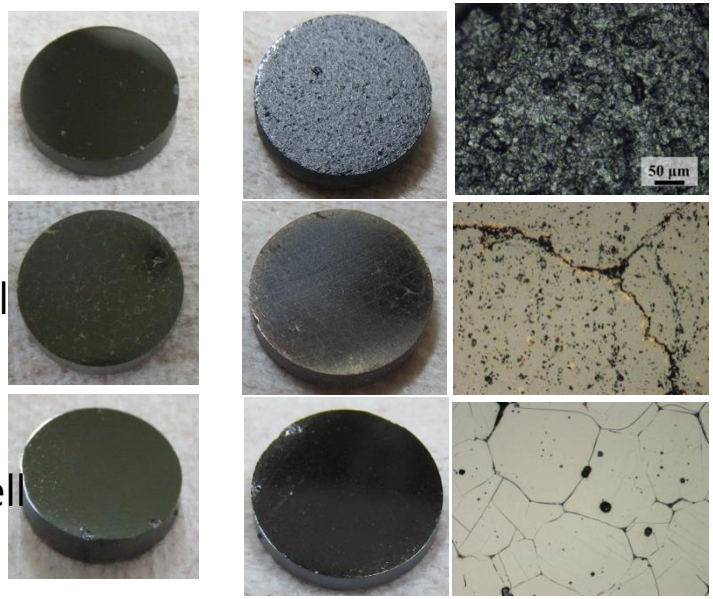
❑ Steam oxidation test

As polished After 72h oxidation

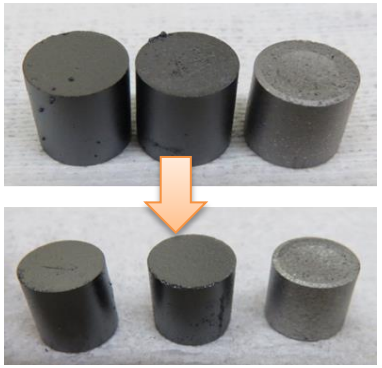
UO_2

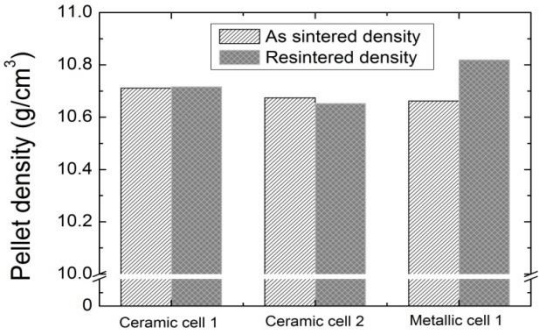
Metallic Micro-cell

Ceramic Micro-cell

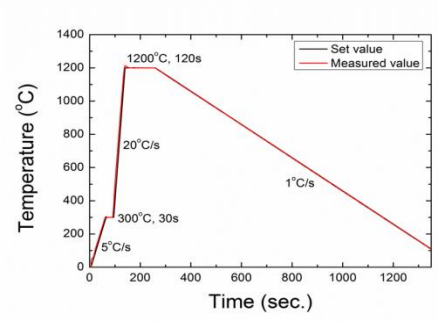


❑ Resintering test

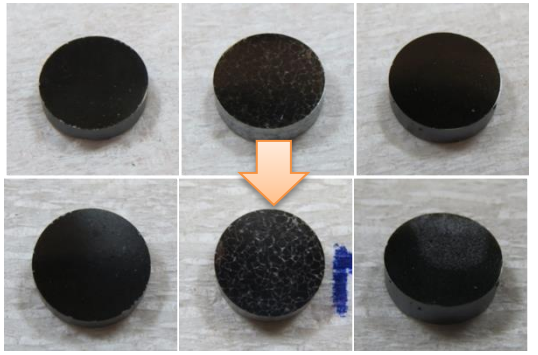




❑ Thermal shock test



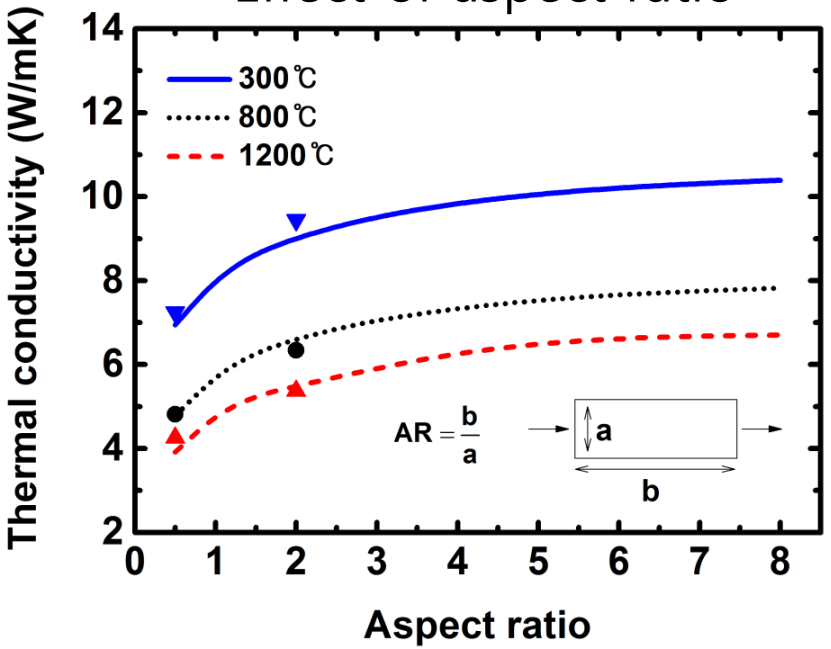
UO_2 Metallic Ceramic

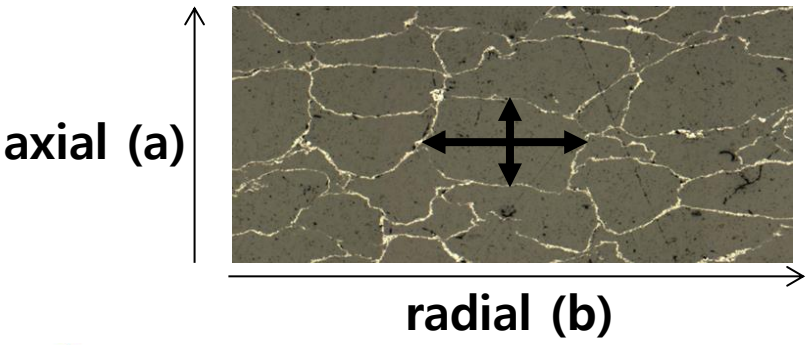


Metallic-cell: Cell geometry optimizing

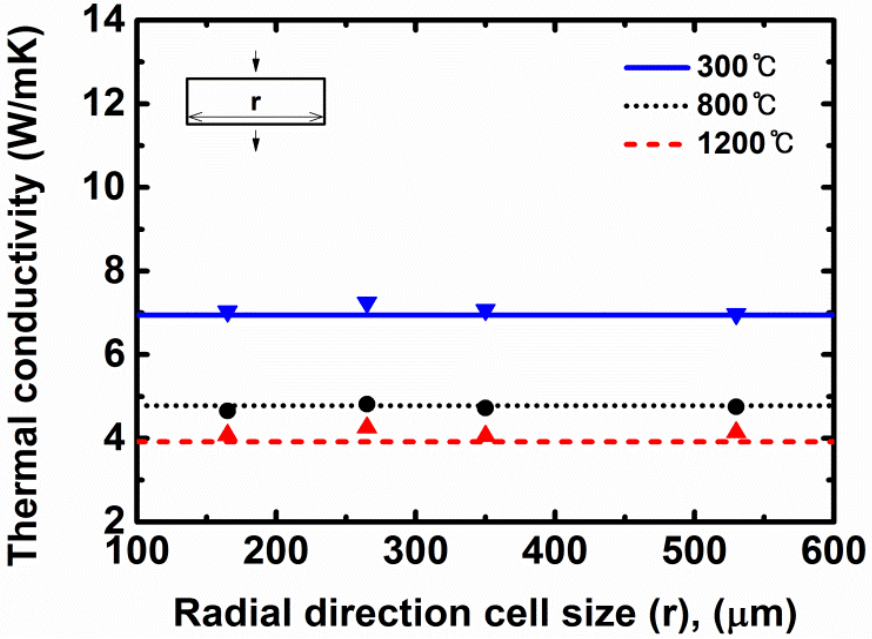
❑ Cell geometry on thermal conductivity

• Effect of aspect ratio





• Effect of cell size



- Fixed metal volume
- Fixed aspect ratio

Analysis tool

COMSOL ANSYS

Nano-e Lab
NANOTECHNOLOGY FOR ENERGY CONVERSION LAB
Department of Mechanical Engineering
Hanyang University

Performance Assessment Plans

- Properties under normal operating condition
  - Thermal & mechanical properties: Thermal conductivity, Melting Temperature, Creep, Toughness, Heat capacity,… etc.
  - Chemical properties: Water corrosion, oxidation, FPs retention, Cladding reaction, long-term stability
- Behavior under accident condition
  - Oxidation behavior under high temperature high pressure steam
  - Dimensional integrity at accident conditions
  - Compatibility with ATF claddings
  - Etc.
- Manufacturability, Reproducibility of pellets, …
- Several test apparatuses are being equipped.
- Neutronics, Fuel cycle economy,…

Fuel Cycle Economy

- Fuel cycle economy would be reduced
  - Wall volume ⇨ Low U loading, Neutron absorption by metallic wall

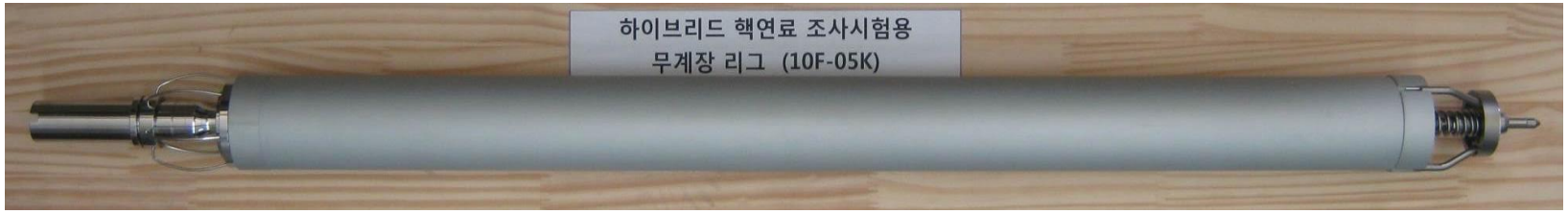
Property	Cell Volume (additives)	U density (g/cm^3) (4% porosity)	U density (g/cm^3) (2% porosity)
UO_2	0	9.27	9.46
Ceramic micro-cell UO_2	1~2%	9.08	9.27~9.37
Metallic micro-cell UO_2	5%	8.81	8.99
			9.17 (reduced gap size 80⇨40μm)

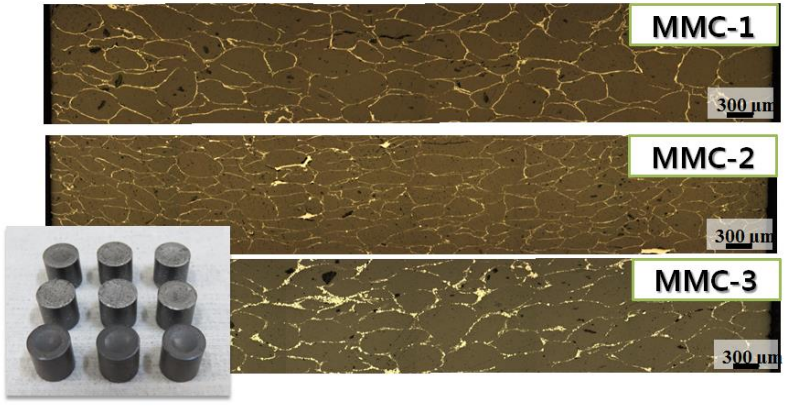
- Partly compensable
  - Ceramic microcell UO_2 (soft pellets, reduced PCI)
    ⇨ Increasing the pellet density or decreasing the gap distance.
  - Metallic microcell UO_2 (cold pellets, reduced thermal expansion)
    ⇨ Increasing the pellet density & decreasing the gap distance
    ⇨ Metal alloy with reduced neutron capture cross-section

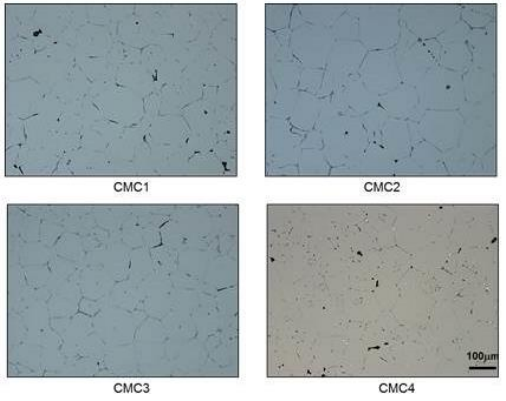
Irradiation Test Plan (1/2)

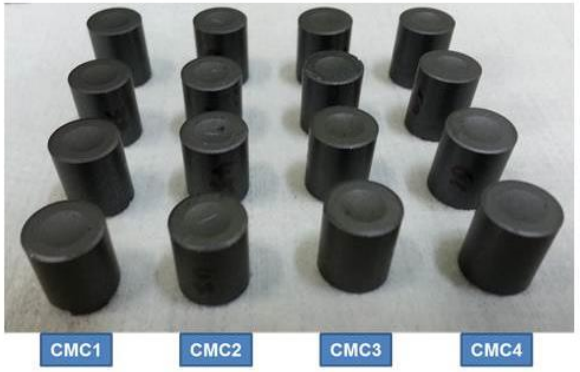
❑ HANARO program

- 4 kinds ceramic + 2 kinds metallic micro-cell pellets
- Target burnup : 20 GWd/MTU
- Stability of wall and pellet, Cs capture ability
- Irradiation period : two years
- Pending due to overhaul









Irradiation Test Plan (2/2)

❑ Halden reactor test: Cooperation with "Thor energy"

- Two ATF rods with instrumentation.
- **Rod 1**: Metallic microcell pellet + Surface modified Zr cladding
- **Rod 2**: Ceramic microcell pellet + Surface modified Zr cladding
- Irradiation period : 2015.06 ~ 2017.05 (Estimated burnup: 25GWd/MTU)

❑ Halden reactor test: Halden Reactor Project (HRP)

- ATF Pellets were proposed as candidates for test
- Ceramic & Metallic microcell pellets are proposed
- Irradiation period : 2017 ~

Thank you for your kind attention!