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The Summary of UO_2 ATF Fuel Development

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Contents

Background

Accident Tolerant Fuel (ATF) is the new concept fuel appeared after Fukushima nuclear disaster, it can improve fuel performance and resistance in DBA and BDBA.

ATF has became the focus area of nuclear power industry recently years.

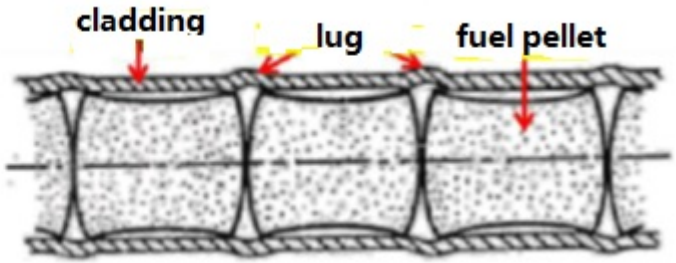
Background

Fuel pellet is the main component of Accident Tolerant Fuel system. The ATF pellets should be:

1. **High thermal conductivity**
2. **High Uranium density**
3. **High compatibility with cladding and coolant**
4. **High chemical stability with high temperature steam**
5. **Manufacturing cost acceptable**

Background

UO_2 pellet is the dominant fuel of NPPs. UO_2 has many advantages but very low thermal conductivity, so the pellet has a high center temperature and fission product release rate in reactor.



Background

The near-term purpose of ATF pellet is enhancing UO_2 pellet performance by additives and new manufacture technology.

Usually, high thermal conductivity additive such as metal or oxidation, and larger UO_2 grain size could increasing the UO_2 pellet performance .

Review of UO_2 ATF fuel pellet

The US, Korea and China have obtained some new achievements for enhancing UO_2 ATF pellet .

The Institutions active in this field are listed below.

US: AREVA, University of Florida

Korea: KAERI

China: CGN

Review of UO_2 ATF fuel pellet

US achievement

1. Enhanced Thermal Conductivity Diamond Composite Nuclear Fuel

- 10% by Volume Diamond Particles embedded in UO_2 Matrix (Fig 1)
- Composite Fuel Produced by Spark Plasma Sintering - 15X15 and 17X17 - 10% Diamond/UO_2 pellets
- Major Enhanced Thermal Conductivity for Diamond embedded Fuel (Fig 2)
- 10% Diamond/4.95% UO_2 Pellets will undergo irradiation in ATR (Oct 2014 insertion) in high power location
- First Capsule removed for PIE –Spring 2015

Figure 1: SEM of Sintered Diamond Pellets magnified 200x

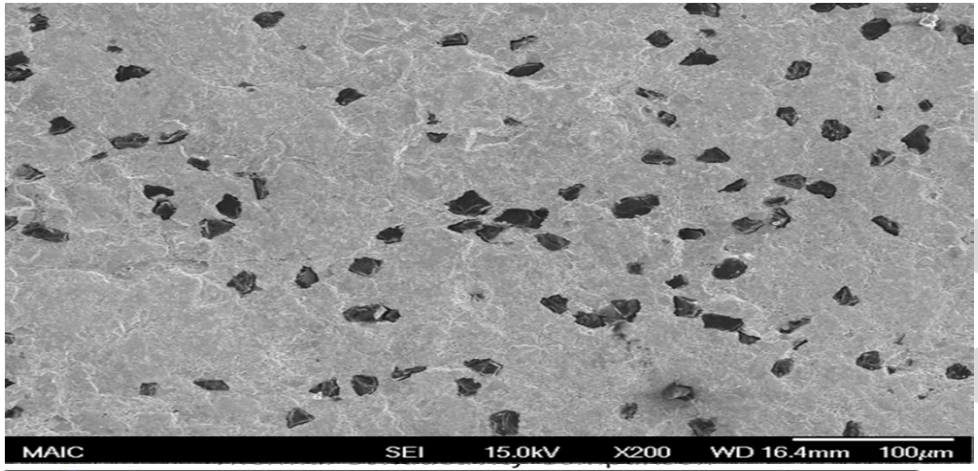
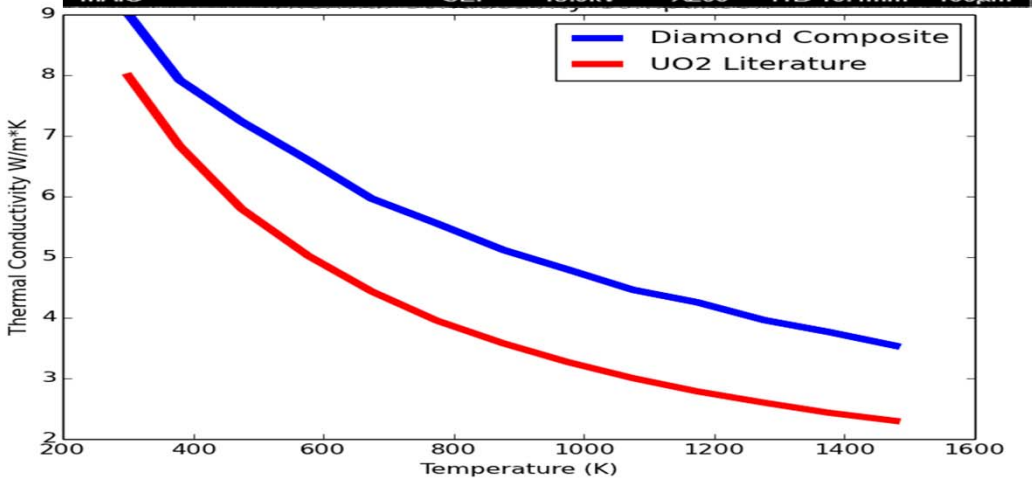


Figure 2: Thermal Conductivity for 10% VF 12 µm Diamond NP fuel pellets



Review of UO_2 ATF fuel pellet

2. Enhanced Thermal Conductivity UO_2 – SiC Composite Nuclear Fuel

- SiCp (powders) and SiCw (whiskers) dispersed in UO_2 Matrix (Fig 4) Fabricated by Spark Plasma Sintering
- Fabricated by Spark Plasma Sintering
- Consistent Enhanced Thermal Conductivity (Fig 3)
- 15X15 and 17X17 pellets (Fig 5 and 6) have been produced to high density (96 -98%)
- 10% SiCw in 4.95% enriched UO_2 will undergo irradiation in Advanced Test Reactor (ATR) beginning Oct 2014 and first post irradiation examinations (PIE) following irradiation in 2015

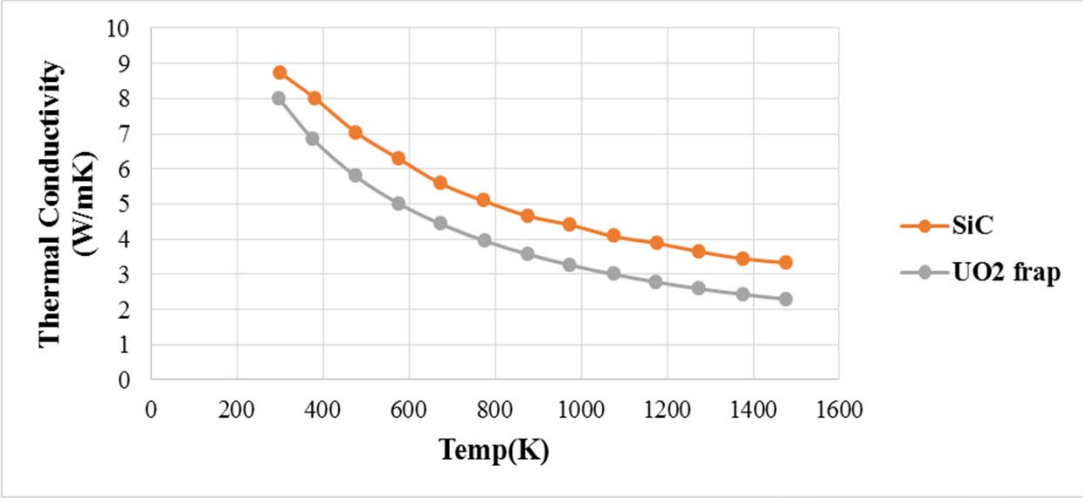


Figure 3: Thermal Conductivity of UO_2-SiC pellets varying with temperature

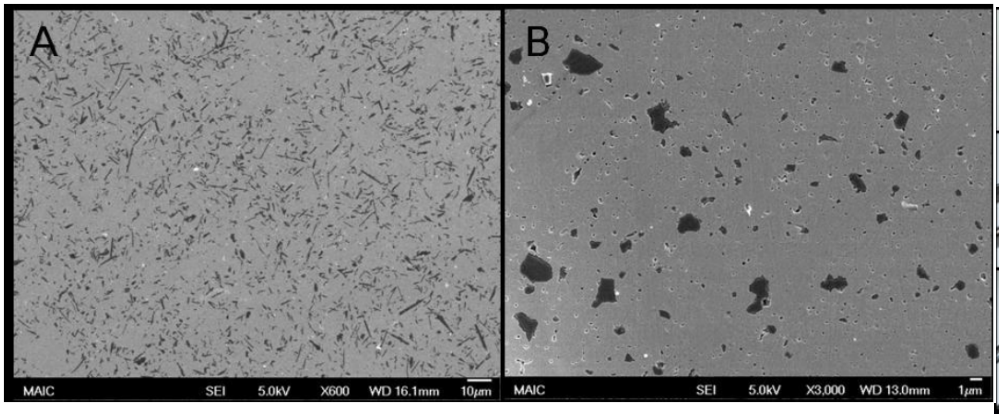


Figure 4: SEM images of sintered pellets (a) SiC_{powder} dispersed in UO_2 and (b) $SiC_{whiskers}$ dispersed in UO_2

Figure 5: 17x17 UO_2-SiC_w pellets fabricated for irradiation in the ATR with a comparison of 15x15 and 17x17 sized pellets (top left)

Figure 6: UO_2 – SiC research pellets utilized for various tests

Review of UO_2 ATF fuel pellet

Korea achievement

R&D program for Accident Tolerant Fuels, which is funded by Korean government, was launched at the beginning of 2012.

This 5-year project (2012-2016) are:

- Determine the potential candidates for ATF pellets.
- Test out-of-pile performances & establish DBs for fuel materials.
- Irradiate ATF pellets in research reactors.

Long-term project (2017-2022) are:

- Fabricate a LTA or LTRs of ATF by the end of 2022.
- In-reactor test in a commercial power plant.

Review of UO_2 ATF fuel pellet

Korea develops microcell UO_2 pellet. It make many micro-cell in a pellet by oxides or metals additives to reduce the release of fission products such as Cs and I to the environment.

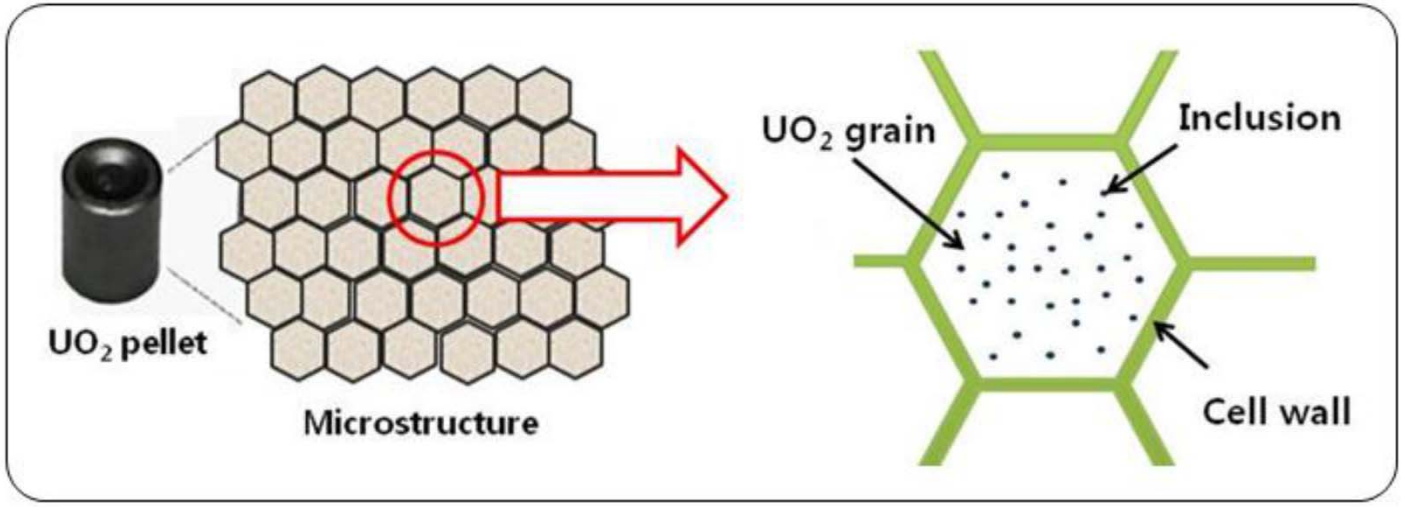
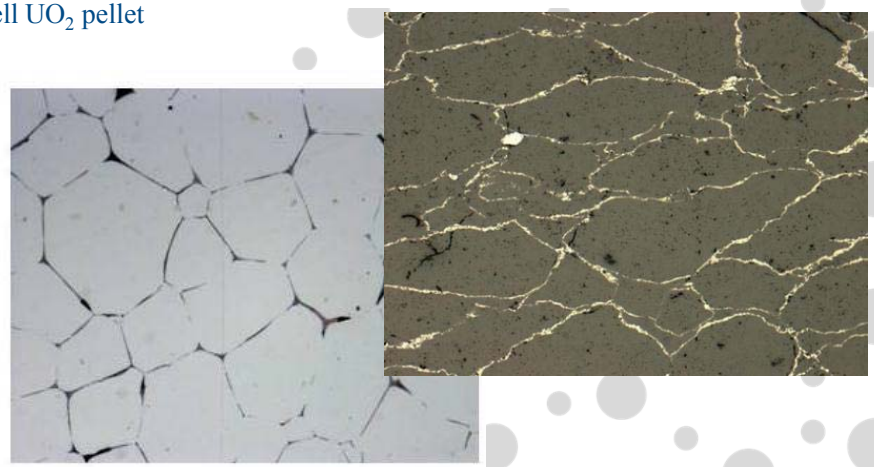


Figure 7: The microstructure of microcell UO_2 pellet



Review of UO_2 ATF fuel pellet

1. Ceramic microcell UO_2 pellets

Benefits:

- Corrosion at inner surface of cladding would be reduced
- Enhanced deformation behavior
- Very large grain : Oxidation & wash-out resistance

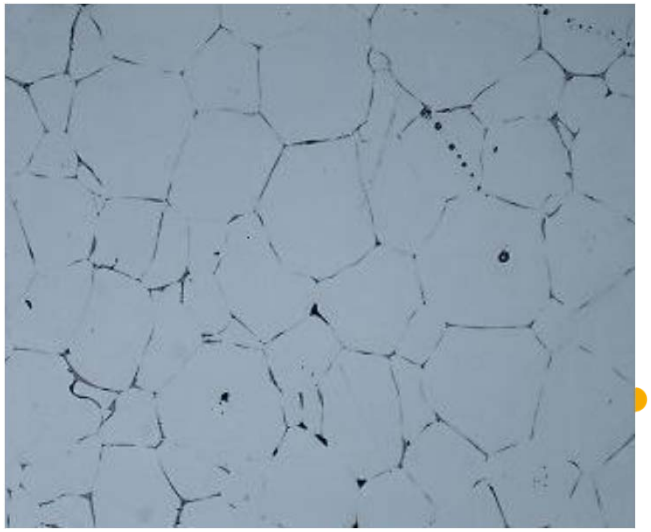


Figure 8: The ceramic wall of microcell UO_2 pellet

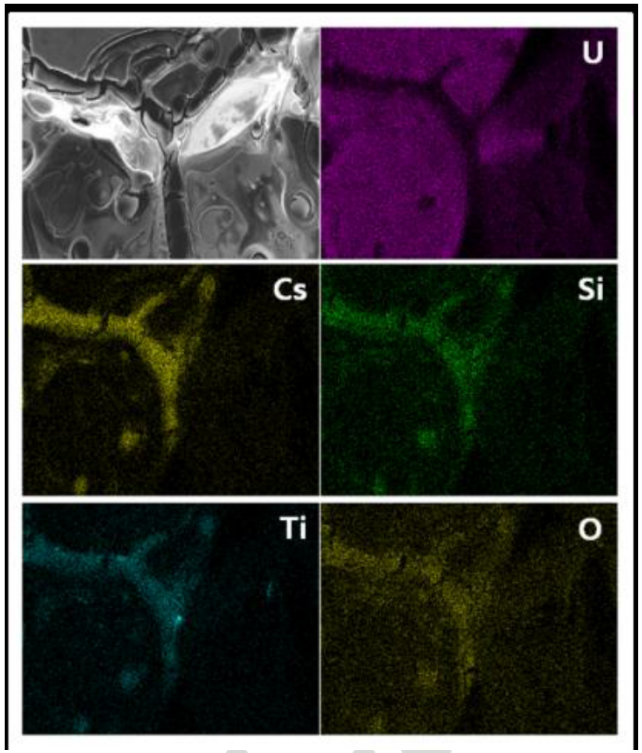


Figure 9: The elements distribution in the ceramic wall UO_2 pellet

Review of UO_2 ATF fuel pellet

2. Metals microcell UO_2 pellets

Benefits:

- Connected metallic walls increase thermal conductivity and reduce pellet temperature.
- Cold pellet and metallic walls : Reduce fission products release.
- Reduced temperature gradient: mitigates pellet cracking and PCMI.
- Peak clad temperature during the LOCA would be reduced.

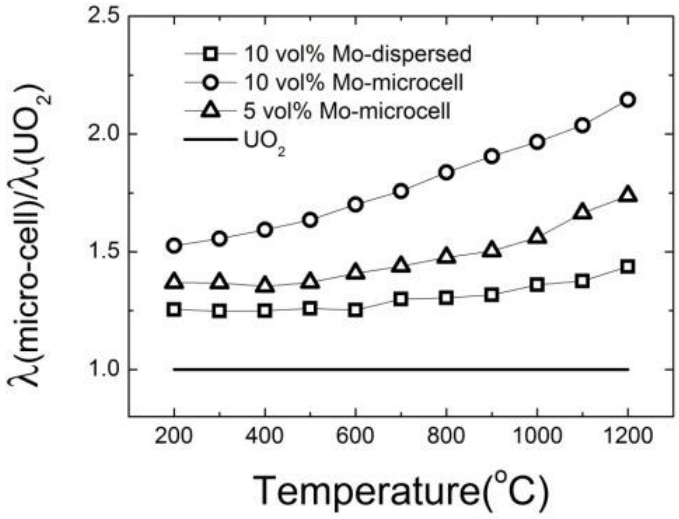


Figure 10: The thermal conductivity of Mo-UO_2 pellet

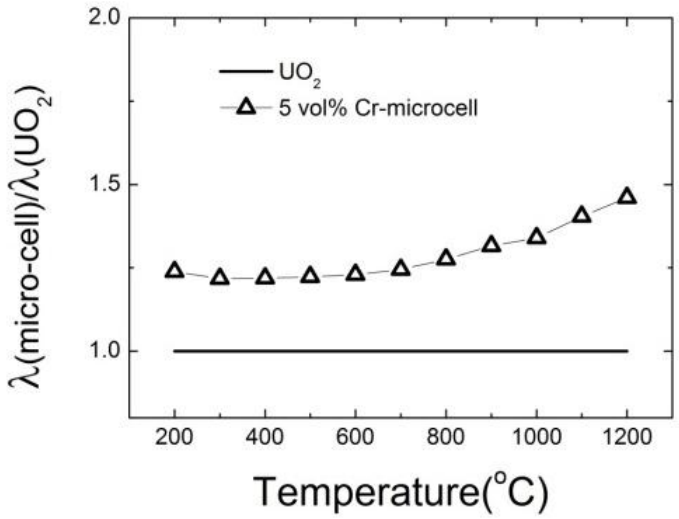


Figure 11: The thermal conductivity of Cr-UO_2 pellet

Review of UO_2 ATF fuel pellet

Various tests are being conducted :

- Thermal: Melting Temperature, Thermal conductivity, Heat capacity, Thermal expansion.
- Mechanical: Creep, Toughness, Thermal shock.
- Chemical: Water corrosion, High temperature oxidation, FPs retention, Cladding reaction, long-term stability.
- Etc: Neutronics, Manufacturability, Economy Various tests are being conducted.

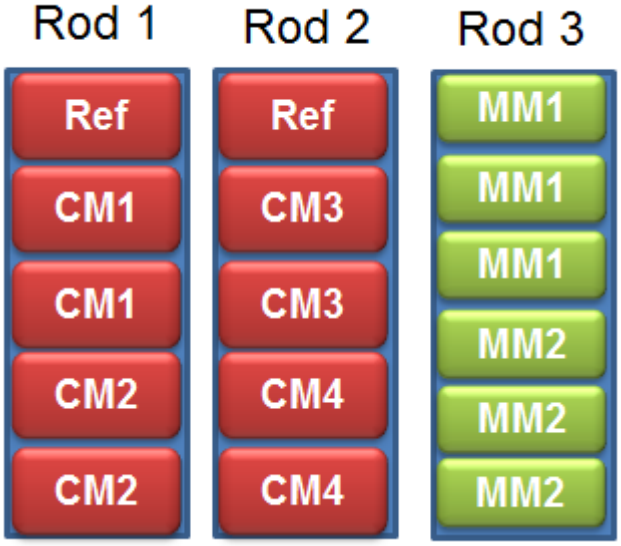
Review of UO_2 ATF fuel pellet

Irradiation test plan in HANARO:

- Three test rods : microcell UO_2 pellets.
- Target burnup : 20 GWd/MTU.
- Stability of wall and pellet, Cs capture ability.
- Irradiation period : 2014.11~

CM: Ceramic micro-cell pellet (4kinds)

MM: Metallic micro-cell pellet (U-Mo1, U-Mo2, U-Cr)



Review of UO_2 ATF fuel pellet

China achievement

China government launched R&D program for Accident Tolerant Fuels at the end of 2013. CGN is the leader of R&D program. CGN has obtained large grain size UO_2 pellet.

Oxidation additive such as Al_2O_3 and Nb_2O_5 are mixed with UO_2 powder, and sinter in 1650℃ for 6 hours. The grain size is much larger than pure UO_2 pellet. UO_2 with Al_2O_3 pellets grain size obtains 40~50μm, UO_2 with Nb_2O_5 pellets grain size obtains more than 70μm.

The oxidation additive pellets reduced fission product releasing and optimized the center temperature of pellets.

Review of UO_2 ATF fuel pellet

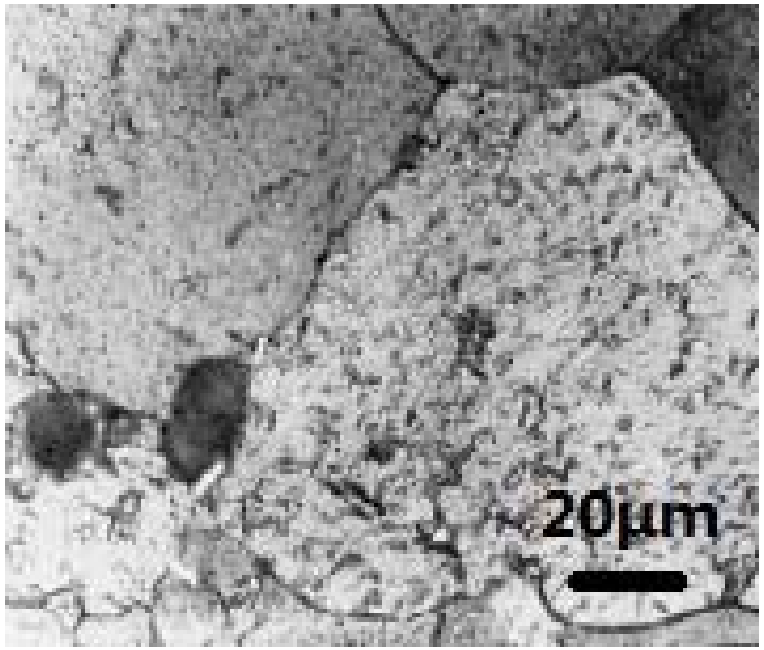


Figure 12: The microstructure 1%wtNb_2O_5-UO_2 pellet

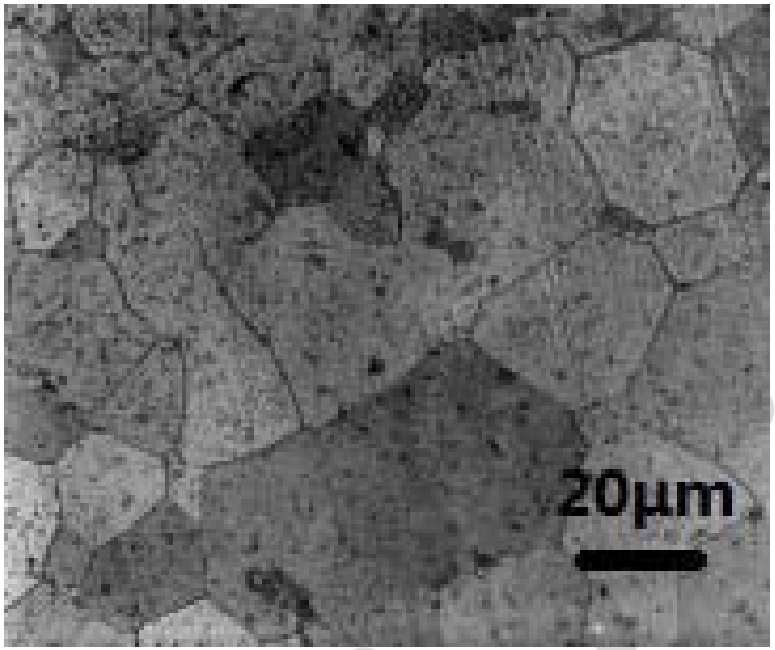


Figure 13: The microstructure 1%wtAl_2O_3-UO_2 pellet

Summary

- University of Florida in US is leading the diamond and SiC composite pellets technology. The thermal conductivity of composite pellets increase significantly.
- KAERI in Korea is developing microcell UO_2 pellets independently. The oxidations and metals additives are used to make a cell wall to reduce fission products release. It also increase the thermal conductivity of pellets.
- CGN established the ATF development union and launched a enhancing UO_2 pellets performance program. By mixing Al_2O_3 and Nb_2O_5 additives to UO_2 powder, CGN obtains pellets which have large grain size. The pellets reduce fission products release and increase the thermal conductivity.

Summary

- An extensive international cooperation is necessary
- All the researchers should joint together
- Enhancing UO_2 pellets performance should be the near-term purpose of ATF fuel pellet development.

Thank you for attention