ORNL/TM-2011/126

OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Deep Burn Team

Coated Particle Fuel and Deep Burn Program

Monthly Highlights

May 2011

TRISO-Coated Particle with Mixed Pu, Th Oxide Kernel after High Pu Burnup

ORNL-27 (4-00)

ORNL/TM-2011/126

Coated Particle Fuel and Deep Burn Program

Monthly Highlights
for
May 2011

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1. Project Management and Planning

1.1. Program reporting *(ORNL)*

During FY 2011 the CP & DB Program will report Highlights on a monthly basis, but will no longer produce Quarterly Progress Reports. Technical details that were previously included in the quarterly reports will be included in the appropriate Milestone Reports that are submitted to FCRD Program Management. These reports will also be uploaded to the Deep Burn website www.ms.ornl.gov/deep_burn/index.shtml

The Monthly Highlights report for April 2011, ORNL/TM-2011/125**,** was distributed to program participants on May 10, 2011. As reported previously, the final Quarterly for FY 2010, Deep Burn Program Quarterly Report for July – September 2010, ORNL/TM-2010/301, was announced to program participants and posted to the website on December 28, 2010.

1.2. Archiving program records *(ORNL)*

Program participants are requested to send reports, milestone documents and other pertinent documents to the webmaster, Shirley Shugart, shugartsa@ornl.gov, for uploading to the website.

2. Fuel Performance Modeling

2.1 Fuel Performance Analysis

Nuclear system support of coated particle fuel development (*Logos*)
The full core modeling of the CE System-80 core with Deep Burn of Transuranics was continued through the transition cores.

The basic reactivity feedbacks were calculated for the Westinghouse AP-1000 core with TRU Deep Burn and the full core model was initiated.

Reactor neutronic analysis *(ORNL)*
Neutronics modeling work is continuing to understand the pin and assembly power distribution for the proposed Fully Ceramic Matrix (FCM)-TRU assemblies. The emphasis has been on improving the power distribution of the FCM-TRU pins in the heterogeneous design with the current issue that the FCM pins contribute little power at the end of life. These calculations can be readily performed with single assembly models. There is also interest in investigating performance of homogenous fuel assemblies with a mixed core of FCM-TRU assemblies and UO2 assemblies to minimize the number of assemblies with the FCM-TRU pins. Multi-assembly and core models are being developed to analyze this and other core configurations that cannot be represented with single assembly models.

3. Thermochemical Data and Model Development

3.1 Thermochemical Modeling

Thermochemical behavior *(ORNL)*
In the area of thermochemical behavior, installation of the gas control cabinet and initial experimental runs were performed with the simultaneous thermal analyzer to test capabilities. Current efforts are focusing on verifying gas train compositions using the mass spectrometer and a to-be-installed oxygen analyzer. Computational modeling has been performed investigating formation of palladium compounds and possible reactions of SiC under loss of coolant conditions.

3.2 Thermomechanical Modeling

Thermal conductivity modeling *(ORNL)*
Thermal conductivity modeling of silicon carbide has continued with calculations completed for the thermal conductivity of point defects at 800 K using the Green-Kubo method. For defect concentrations of 1/1728 atoms, vacancies and interstitials generally reduce the thermal conductivity by 30% and anti-sites reduce it by 15%.

Thermomechanical behavior of TRISO in SiC matrix *(ORNL)*
Nano-indentation testing was performed on a polished TRISO-SiC sample manufactured in the early stage of the program to characterize the Young's modulus and hardness of the SiC matrix as well as of each individual coating layer. Results validated the Young's modulus values that have been employed for the stress state modeling of TRISO-SiC. On the other hand, modeling of the first principal stress state of TRISO particles indicated that there were uniformly compressive stresses (between -2.8 and -14.5 MPa) developed in the final stage of hot pressing at 1850°C. However, there were localized tensile stresses (up to 30 MPa) developed due to the point contacts between SiC particles and TRISO particles at the initial sintering stage at 1850°C. These initial tensile stresses gradually decrease and become compressive stresses when the SiC matrix is fully sintered.

3.3 Actinide and Fission Product Transport

Ag transport in TRISO *(UTK)*
Evaluating Ag transport through low temperature, high burnup TRISO fuel using 2-D and 3-D Kinetic Monte Carlo models continued. A reaction-diffusion model approach to simulating Pd transport to the SiC layer is being finalized.

Ag transport in ZrC *(UW-M)*
The temperature dependence of Ag diffusivity in ZrC is being studied using the *liquid encapsulating method* developed at UW-Madison. In May, a copper die for casting the encapsulating alloys was prepared. The capability for processing these alloys for constructing diffusion couples was also improved.

4. TRU TRISO Development

4.1 TRU Kernel Development

Glovebox installation at the REDC *(ORNL)*

Work to complete the qualification process of the new glove boxes that will be used to fabricate the TRU gel spheres at the Radiochemical Engineering Development Center (REDC) is nearly complete. The two glove boxes are expected to be approved for use in early June. However, plutonium will not be introduced into the glove boxes without prior permission from the DOE program manager.

Preparation of the TRU solutions will be performed in an older glove box currently authorized for the work. The sample preparations should take a minimum of 6 weeks, and the older glove box is scheduled to be decommissioned by the end of September.

Fabrication of urania kernels containing SiC *(ORNL)*

The new internal gelation system continues to be used to fabricate uranium microspheres with 4 mol % SiC, which will serve as an oxygen getter. Even though the amount of SiC is relatively small, its presence has significantly changed the fluid dynamics of the uranium feed solution. Previously, 18 and 21 gauge needles were needed to prepare uranium microspheres that became 500 and 350 μm uranium fuel kernels, respectively. With the small SiC addition, it appears that 19 and 22 gauge needles are needed to make 500 and 350 μm kernels. Internal gelation tests with the 22-gauge needle are currently underway. Small samples from these 22-gauge needle tests should be sintered in June or July. It is expected that these 350±15 μm kernels should be suitable for the initial coating experiments.

Past experience with the internal gelation system has shown that beveled needles can reduce the standard deviation of sphere diameters by more than a factor of two, compared to similar blunt end needles. Beveled 19-gauge needles have been special ordered, but they are not expected until late July. Therefore, 500 μm diameter uranium kernels with SiC should not be expected until August at the earliest.

4.2 Coating Development

TRISO coating development *(ORNL)*

The TRU particle coating furnace components have been delivered and final assembly of the new furnace is underway. The completion of the assembly of the furnace is on schedule to meet the June 30 milestone M21AF080203, “Complete fabrication and assembly of new coating furnace and issue letter report summarizing status of planned glove box coating facility.” Continuing effort will document work to date on installation of the in-cell TRU-coating facility. A plan is being developed for continuation of in-cell installation of coating equipment in 2012.”

5. LWR Fully Ceramic Fuel

5.1 FCM Fabrication Development

FCM pellet fabrication *(ORNL)*
Ten additional Fully Ceramic Microencapsulated fuel pellets have been fabricated for HFIR irradiation. Different pellets have unique particle loading and powder preparation conditions. Large (2.5-in. diameter) samples have been delivered for mechanical testing. Advance characterization of the FCM SiC matrix was conducted through a transmission electron microscopy study.

FCM in accident conditions *(ORNL)*
A component of the Accident Testing of LWR Fuels involves high-temperature high-pressure steam tests conducted at 1300ºC in 100% steam at 250 psi. Test materials included Zircaloy-2, Zircaloy-4, Westinghouse SiC cladding, and NITE SiC. (NITE SiC is a potential FCM matrix material.) The test duration was 48 hours during which all the zirconium metal samples fully reacted with steam, as expected. SiC samples partially reacted under these extreme conditions. Characterization of oxide/SiC interface using electron microscopy showed that results were consistent with previous observations.

5.2 FCM Irradiation Testing

HFIR irradiation of FCM *(ORNL)*
Fabrication of the first rabbit capsules for FCM irradiation is on schedule for insertion into HFIR for the August cycle. These rabbits will contain surrogate coated particles with a ZrO_2 core, embedded in either a SiC or a Zircaloy matrix.

Appendix I

Coated Particle and Deep Burn Fuels Program - ORNL FY2011

Milestone Status May 31, 2011

Item No.	Milestone number and description	Level	Due Date	% Complete
1	M31AF080104 - Report on Completed Design and Procurement of Simultaneous Thermal Analyzer.	M3	2/5/2011	Completed
2	M31AF080105 - Model physical properties of TRISO fuel and fuel matrix to high dose.	M3	7/20/2011	62
3	M31AF080106 - Issue report on thermochemistry and fission product transport and attack of high-burnup fuel including experimental verification path-forward.	M3	9/23/2011	50
4	M31AF080102 - Simultaneous thermal analyzer is to be installed in a glove box to be used for identification and characterization of evolving fuel chemistry.	M2	9/23/2011	40
5	M31AF080103 - Submit report summarizing progress and path forward on thermochemistry of high-burnup fuel including experimental path-forward.	M2	9/30/2011	45
6	M31AF080204 - Report on Operational Approval to fabricate transuranic-bearing kernels in Bldg. 7920.	M3	6/30/2011	85
7	M21AF080202 – Demonstrate fabrication of Transuranic kernels of Plutonium-239/3.5at% Neptunium-237 using newly installed glove box facilities in ORNL 7930 Hot Cell Complex.	M2	3/30/12	40
8	M21AF080203 - Complete fabrication and assembly of new coating furnace and issue letter report summarizing status of planned glovebox coating facility. Document work to date on installation of in-cell TRU-coating facility. Develop plan for continuation of in-cell installation of coating equipment in 2012.	M2	6/30/2011	75
9	M31AF080205 - Issue report documenting initial PIE of fuel compacts from the FTE-13 irradiation experiment focusing on Deep Burn relevant aspects of fuel.	M3	12/31/2011	30
10	M41AF080302 - Incorporate SiC and graphite matrix physical properties models into FRAPCON and perform preliminary analysis.	M3	12/17/2010	Completed
11	M31AF080303 - Issue report documenting the results of FRAPCON calculations comparing the fuel-clad physical interaction of SiC and graphite matrix options for fully ceramic matrix fuel form.	M3	2/25/2011	Completed
12	M31AF080307 - Report on final design of rabbit irradiation vehicle for fueled and surrogate FCM fuel.	M3	3/17/2011	Completed
13	M31AF080306 - Issue report on FCM optimization with surrogate TRISO.	M3	8/12/2011	60
14	M31AF080305 - Issue report documenting work performed to expand parameters beyond initial point design economic analysis of the Deep Burn fuel system to understand critical drivers which may impact fuel design.	M3	11/25/2011	20
15	M2N11OR130202 – 7.2.7 Procure glove boxes for TRU-TRISO coating	M2	3/31/2011	Completed
16	Temperature dependence of Ag diffusion in ZrC		9/30/11	15

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