ORNL/TM-2011/193

OAK RIDGE
NATIONAL LABORATORY
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FOR THE DEPARTMENT OF ENERGY

Deep Burn Team

Coated Particle Fuel and Deep Burn Program

Monthly Highlights

June 2011

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

UT-BATTELLE
ORNL-27 (4-00)

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Coated Particle Fuel and Deep Burn Program

Monthly Highlights
for
June 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 May 2011, ORNL/TM-2011/126**,** was distributed to program participants on June 9, 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

Fuel performance modeling *(INL)*
Assembly-level calculations have been performed on heterogeneous fuel assemblies containing conventional enriched UO_2 and Transuranic-only FCM fuel using DRAGON. The number of FCM fuel pins is such that they can contain all TRU produced in the UO_2 pins into the FCM pins into one recycle pass. Peaking factors were calculated and studies aimed at meeting a 1.2 peaking factor limit have commenced. Various FCM pin arrangements are under investigation for acceptable peaking and reactivity coefficients.

Nuclear system support of Coated Particle fuel development *(Logos)*
The full core model of the CE System-80 core with Deep Burn of Transuranics was continued to the equilibrium core.

A preliminary safety analysis was performed on the CE System-80 core, based on the parameters derived from the analysis of the equilibrium full core.

Work was started on the full core transition stages of the Westinghouse 17x17 DB core.

An interim report on the work performed by Logos to June 30 in support of Coated Particle Fuel development was submitted to DOE-NE.

3. Thermochemical Data and Model Development

3.1 Thermochemical Behavior

Thermochemical behavior *(ORNL)*
The leak integrity for the new TGA/DSC for thermochemical measurements on fuel materials was tested, leaks repaired, and the unit was found to be ready for use. Testing of the specialty gas compositions to control oxygen potential using an oxygen sensor was successfully completed. Experiments to qualify the unit demonstrating controlled oxidation and reduction of cerium dioxide are being completed.

A thermochemical database containing fission product data was improved using newly developed models for urania with rare earths.

3.2 Thermomechanical Modeling

Thermal conductivity modeling *(ORNL)*
Thermal conductivity modeling of silicon carbide has completed calculation of the thermal conductivity of point defects at 800K using the Green-Kubo method. Investigations of five defect concentrations were completed. The results provide a useful relationship between defect concentration and the effect on thermal conductivity.

Samples of optimized TRISO-SiC discs will be prepared for measurement of thermal conductivity and coefficient of thermal expansion to provide a database for life prediction modeling.

Thermomechanical behavior of TRISO in SiC matrix *(ORNL)*
A model system consisting of ZrO_2 rod with trilayers of C/SiC/C coating has been designed to provide an approach to measure the interfacial strength of these coating layers. Modeling of the first principal stress state for the proposed model system was also carried out to provide guidelines on the dimensions of each constituent to keep the stress state similar to that developed in TRISO particles.

3.3 Actinide and Fission Product Transport

Ag transport in ZrC *(UW-M)*
Temperature dependence of Ag diffusivity in ZrC is being studied using *the encapsulating source method* as developed at UW-Madison. In June, materials necessary for Zr-Ag encapsulating were gathered and an arc melter with a sufficiently large capacity was arranged to be utilized in the preparation of the alloys. Suitable times to ensure proper diffusion depths in the experiments at various diffusion annealing temperatures were determined.

4. TRU TRISO Development

4.1 TRU Kernel Development

Glovebox installation at REDC *(ORNL)*
The two glove boxes at the Radiochemical Engineering Development Center (REDC) for the internal gelation process have been connected to the ventilation system and the glove boxes have been approved for operation. Since the laboratory will shortly be returned to operation as a posted contamination zone, certain key electronics have been moved to a clean area until needed. Plutonium will not be introduced into the glove boxes without prior permission from the DOE program manager.

If the program approves REDC operation of the two glove boxes with TRU materials, then initial TRU experiments will focus on the determination of suitable gelation conditions and evaluation of the enhanced wash procedure. Work is continuing to secure approval for use of a 2000°C sintering furnace at REDC to enable full sintering of TRU fuel kernels..

Fabrication of urania kernels containing SiC *(ORNL)*
Uranium microspheres with 4 mol % silicon carbide have been made using 18, 20, 21, and 22 gauge (droplet formation) needles. The final diameter of these microspheres should range from 325 to 600 μm after they are sintered. With the small silicon carbide addition, it appears that 19 and 22 gauge needles are needed to make 500 and 350 μm kernels, respectively. Internal gelation tests with the 22 gauge needle were completed and resulting microspheres have been calcined. Beveled, 19 gauge needles have been special ordered, but they are not expected until late July. Approximately 30 grams of microspheres will be prepared for future sintering and coating tests once the program determines the desired diameter for the uranium kernels with silicon carbide. Finally, preparation of additional acid deficient uranyl nitrate solution with depleted uranium is underway.

4.2 Coating Development

TRISO coating development *(ORNL)*
Assembly of the new chemical vapor deposition fluidized bed particle-coating furnace designed for TRISO coating of Pu containing fuel kernels was completed this month. The assembly of the furnace and the issue of an associated letter report signifies on time completion of the June 30 milestone 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."

5. LWR Fully Ceramic Fuel

5.1 FCM Fabrication Development

FCM pellet fabrication *(ORNL)*
All sample fabrication, machining, metrology of FCM pellets with surrogate particles were completed for the HFIR test. Irradiation test capsules were fabricated. Metal Matrix Microencapsulated (M3) Rods were also fabricated with surrogate TRISO particle for HFIR irradiation.

FCM in accident conditions *(ORNL)*
Accident Testing of LWR Fuels continues with a series of high temperature tests at atmospheric and high pressures at different time durations and gaseous environments, intended to examine a broad class of materials for fuel cladding under accident conditions. Test matrices for atmospheric and high pressure systems were defined. Procurement of all materials was completed: Zircaloy-2, Zircaloy-4, Westinghouse SiC Cladding, NITE SiC, CVD SiC, FCM Fuel, SiC/SiC composites, 304L, 317L, 321, 347 austenitic stainless steels and P-91 ferritic steel. The high-pressure tests have started, and the first test at 1200ºC, 150 psi steam for 8 hour duration was completed.

5.2 FCM Irradiation Testing

HFIR irradiation of FCM *(ORNL)*
Fabrication of the first FCM rabbit capsules continues on schedule for HFIR irradiation in the August cycle. These capsules 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 June 30, 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	70
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	65
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	45
5	M31AF080103 - Submit report summarizing progress and path forward on thermochemistry of high-burnup fuel including experimental path-forward.	M2	9/30/2011	60
6	M31AF080204 - Report on Operational Approval to fabricate transuranic-bearing kernels in Bldg. 7920.	M3	6/30/2011	Completed
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	Completed
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	80
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	35

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