ORNL/TM-2011/71

OAK RIDGE NATIONAL LABORATORY

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Coated Particle Fuel and Deep Burn Program

Monthly Highlights

February 2011

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

UT-BATTELLE

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Monthly Highlights
for
February 2011

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Table of Contents

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 January 2010, ORNL/TM-2011/30**,** was distributed to program participants on February 8, 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. Thermochemical Data and Model Development

2.1 Thermochemical Modeling

Thermochemical Behavior *(ORNL)*
The thermal analyzer continues to be used to develop baseline information and to determine operational capabilities. Literature on the phase relationships between uranium, palladium, silicon, and carbon were reviewed and preliminary thermochemical calculations were performed.

2.2 Actinide and Fission Product Transport

Pd Interactions With SiC *(ORNL)*
Work continues on calculating the effect of defects on the thermal conductivity of silicon carbide. Specifically the effect from vacancies, interstitials, and anti-site defects were investigated at two different temperatures (500 and 800 K) and three different concentrations. In general, defects lower the thermal conductivity of SiC. The Si interstitial has the largest effect on the thermal conductivity and the Si anti-site (SiC) has the smallest effect.

2.3 Radiation Damage and Properties

Thermal Conductivity of SiC *(ORNL)*
A representative of cross section of TRISO particle with a UO_2 kernel was used to model the residual first principal tensile stress of each constituent layer via the use of micro-FEA. It is assumed that all constituents are linearly elastic and there is a perfect interfacial bonding between adjacent materials. The initial micro-FEA result shows that all of the residual first principal stresses are tensile ranging from 44 to 2800 MPa, which are not valid assumptions. Thus, an interfacial bonding parameter (gap element) or interfacial friction parameter would be introduced at all interfaces via the use of ANSYS to refine the stress state analysis.

3. TRU TRISO Development

3.1 TRU Kernel Development

Glovebox installation at the REDC *(ORNL)*
The two new glove boxes at the ORNL Radiochemical Engineering Development Center (REDC) that house the sol-gel system that will be used to fabricate the TRU gel spheres have passed the helium leak test, the pressure decay test, and the vacuum decay test. After the HEPA filters are installed, the glove box review committee will begin its approval process. Approval is expected in early April.

Approval to operate the inert glove box line housing the sintering furnace to be used to calcine and sinter the air-dried kernels at the ORNL REDC has been rescheduled for June 30. In the event that further delays in approval of the inert glove box line are encountered, an alternative furnace (which can go up to 1340°C) has been located and can be used if necessary. While this alternative furnace may not be able to completely sinter the TRU fuel kernels, it can be used to determine whether the new wash procedure - developed in FY10 and proven on zirconia kernels - results in strong plutonia kernels without cracking and spalling. The demonstration of the new wash procedure for plutonia microsphere fabrication is the key technical question to be answered this year.

Work control documentation for kernel production *(ORNL)*
The Research Safety Summary (RSS) and procedure to prepare the TRU solutions for the sol-gel fabrication process was approved in February. The review of the RSS for kernel calcining and sintering submitted in January has been postponed to accommodate the potential use of the alternative furnace noted above. Also this month, the procedure for the kernel product qualification tests was written. At the moment, we are waiting to combine the kernel product qualification test procedure with the procedure for using the sintering furnace should it prove necessary. If we choose to use the alternative furnace, we may be able to use the existing RSS and procedures for that system.

Fabrication of urania kernels containing SiC *(ORNL)*
Uranium microspheres containing silicon carbide, to serve as an oxygen getter for high burnup applications, will be prepared using existing facilities and safety documentation in ORNL Building 4501. An existing internal gelation system located in a radiological fume hood is being modified to enable SiC powder addition to the broth. At 20% burnup, only 0.04 mole of SiC per mole of uranium will be needed. The initial fabrication of uranium microspheres containing SiC is expected by the middle of March.

3.2 Coating Development

TRISO coating system *(ORNL)*
Progress in the coating technology has been in continued fabrication and procurement of furnace and control components for the new coater system for actinide bearing materials.

4. Advanced TRISO Applications

4.1 Metal Matrix Fuels for LWR *(ORNL)*

The Hot Isostatic Pressing (HIP) of a small sample of Metal Matrix Microencapsulated fuel was successfully conducted.

5. LWR Fully Ceramic Fuel

5.1 FCM Fabrication Development *(ORNL)*

Fabrication of multiple Fully Ceramic Microencapsulated fuel pellets with focus on achieving ideal microstructure continued. Various powder mixtures of nano and micron size are being investigated with variable content of oxide additive.

5.2 FCM Irradiation Testing *(ORNL)*

Design drawings for the FCM HFIR rabbit experiments are currently in technical review. The design consists of an 8.2 mm diameter pellet with TRISO fuel kernels embedded in the pellet matrix. The pellet may be made from either SiC or a zirconium alloy. The kernels may be true TRISO fuel particles or surrogate particles using ZrO_2 as the "fuel" material. Initial tests to gather data on the performance of the irradiation vehicle and assembly will use surrogate kernels.

6. Fuel Performance and Analytical Analysis

6.1 Fuel Performance Modeling

Burnup and reactivity of FCM fuels *(INL)*
Initial studies comparing various reactivity coefficients of TRU-only FCM fuel to UO_X and MOX LWR fuel at the single cell are being finalized. Extension to assembly-level calculations is underway. Preliminary fuel performance calculations evaluating the behavior of the FCM fuel in LWR conditions have been performed and show promise under steady state depletion.

Fuel Performance and Safety in Reactors *(LOGOS)*
LOGOS is presently conducting full-core studies on the performance and safety of the FCM TRU fuel in LWR. The two LWR core configurations being analyzed are 16x16 System-80 and 17x17 Westinghouse. The work is organized to include:

- Neutronics performance studies, aimed at the maximization of TRU burnup within acceptable ranges of refueling cycles and enrichment.
- Neutronics safety analysis, evaluating reactivity coefficients in the FCM TRU fueled LWR cores.
- Thermohydraulics performance studies, aimed at minimizing the perturbation introduced by the use of FCM TRU fuel in LWR operations.
- Thermohydraulics safety analysis, evaluating the safety of FCM TRU fuel with respect to Departure from Nucleate Boiling margins and Loss of Coolant events.

LWR Fully Ceramic Fuel Neutronic Analysis *(ORNL)*
Reactor neutronic models are being developed for a 1/4 core design using 17x17 Westinghouse fuel assemblies with FCM fuel pins. This model will be used for several purposes including the investigation of fuel assembly designs to optimize FCM loadings and to understand fuel and reactor performance. Calculated parameters will include pin peaking factors, assembly peaking factors, core lifetime and reactor feedback parameters. During February lattice physics models were completed and an initial 1/4 core model was developed and is being tested.

Appendix I

Coated Particle and Deep Burn Fuels Program - ORNL FY2011

Milestone Status February 28, 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	28
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	10
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	25
5	M31AF080103 - Submit report summarizing progress and path forward on thermochemistry of high-burnup fuel including experimental path-forward.	M2	9/30/2011	25
6	M31AF080204 - Report on Operational Approval to fabricate transuranic-bearing kernels in Bldg. 7920.	M3	2/23/2011	60
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	4/25/2011	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	30
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	30
12	M31AF080307 - Report on final design of rabbit irradiation vehicle for fueled and surrogate FCM fuel.	M3	3/17/2011	60
13	M31AF080306 - Issue report on FCM optimization with surrogate TRISO.	M3	8/12/2011	25
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	10
15	M2N11OR130202 – 7.2.7 Procure glove boxes for TRU-TRISO coating	M2	3/31/2011	75

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