ORNL/TM-2011/30

OAK RIDGE NATIONAL LABORATORY

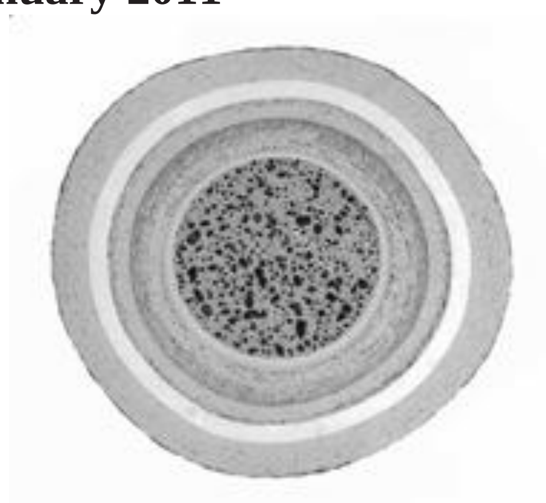
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Deep Burn Team

Coated Particle Fuel and Deep Burn Program

Monthly Highlights

January 2011



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

UT-BATTELLE

ORNL-27 (4-00)

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ORNL/TM-2011/30

Coated Particle Fuel and Deep Burn Program

Monthly Highlights
for
January 2011

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Table of Contents

Acronyms and Abbreviations

CP	Coated Particle
DB	Deep Burn
DOE	Department of Energy
DSC	Differential Scanning Calorimetry
FCM	Fully Ceramic Matrix
FCPICS	Tracking program for project
FRAPCON	Computer code for calculating the behavior of fuel rods
HTR	High Temperature helium-cooled Reactor
INL	Idaho National Laboratory
KLMC	Kinetic Lattice Monte Carlo computer code
Logos	Logos Nuclear Systems
LWR	Light Water Reactor
ORNL	Oak Ridge National Laboratory
REDC	Radiochemical Engineering Development Center (ORNL)
RSS	Research Safety Summary
SEM	Scanning Electron Microscope
TGA	ThermoGravimetric Analysis
TRISO	tri-structural isotropic
TRU	transuranic elements
UTK	University of Tennessee, Knoxville

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 December 2010, ORNL/TM-2011/10**,** was distributed to program participants on January 12, 2011. As reported last month, 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 Deep Dive presentation to USDOE-NE (*ORNL*)

On January 4, 2011 a second programmatic deep dive was held for the benefit of NE Senior Management. As this briefing closely followed a previous deep dive, a detailed program description was not necessary. The primary focus was on recent achievement with the fully ceramic fuel, and the potential application of this fuel to specific light water application. The presentation was relatively short and much of the hour-long period was devoted to discussion of the technology and potential application.

1.3. 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

Virtual Workshop on Fuel Modeling *(ORNL)*

A virtual workshop on Deep Burn Fuel Modeling was organized and hosted by ORNL on January 19. The goal was to identify important areas for the development of constitutive models, supported by needed experimental efforts, and the application of the models to fuel behavior codes. The purpose of discussion was to determine a concise list of issues unique to modeling high burnup coated particle fuels embedded in a silicon carbide matrix and tasks for addressing those. Also addressed was achieving the correct balance of (1) fundamental property generation, (2) empirical property relationships and (3) code development.

The results of seven presentations and the discussions that followed was to provide (1) guidance on fuel development, particularly for the SiC matrix FCM fuel in first order dealing with the temperature gradient and stress gradient issues, and (2) an ultimate 6 year objective of a fully informed macro code like PASTA or PARFUME. Progress was also made in determination of the appropriate balance between the relationships/properties development and code refinement moving forward.

Twenty researchers from INL, LLNL, Logos, ORNL, UCB, UF, UTK and UW-M were able to participate in this virtual workshop, most of them without the burden of travel to the meeting site.

2.1 Thermochemical Modeling

Thermochemical behavior *(ORNL)*

The investigation of effects of rare earths with 3+ valence on the thermochemistry of fluorite structure fuel phase continues.

2.2 Actinide and Fission Product Transport

Transport through coating layers *(UTK)*
Efforts have begun to develop the strategy for modeling Cs and Ag transport in TRISO fuel for deep burn LWR application conditions.

2.3 Radiation Damage and Properties

Thermal conductivity of SiC *(ORNL)*

The degradation of thermal conductivity caused by isotopic impurities and voids in SiC was calculated by equilibrium Green-Kubo and nonequilibrium molecular dynamic methods. The dependence of thermal conductivity on the size of the voids and mass of the impurities was investigated. The convergence of results with the size of modeling cells was investigated.

3. TRU TRISO Development

3.1 TRU Kernel Development

Glovebox installation at the REDC *(ORNL)*

Work continued on items that must be completed on the new glove boxes in Lab 109 at the Radiochemical Engineering Development Center (REDC) before the Readiness Assessment can be performed. Windows and gloves were installed, and final leak testing of those two boxes is underway. The USQD required to authorize the weld repair is awaiting action.

Fabrication of the new feedthroughs for the optical inspection microscope in the characterization glove box was completed. Subsequent testing of the wiring for the feedthroughs identified a communication problem with the camera. Work is underway to understand and fix the problem.

The electrical review of the high-temperature furnace and the glove boxes was completed. Issues identified by the Electrical AHJ (Authority Having Jurisdiction) include wire sizes, conductor lengths, size of cabinet openings, spacing of components, and labeling. All these items can be easily remedied after completion of leak testing.

Other glove box modifications include a new off gas manifold fabrication package that has been sent to a local machine shop for fabrication. Design of a new auxiliary ventilation control system (dump valve system) was completed, to provide a direct line from the glove box interior to the facility off gas system if the pressure exceeds the high-pressure set point. Instrument air and a dedicated electrical circuit are being installed to support this device. Preparation of documentation to support procurement and fabrication of the system components is underway. The new HEPA filters were received and fabrication of the brackets to support these filters inside the inert glove boxes (directly connected to oil filled bubblers in the new dump valve system) is underway.

Work control documentation for kernel production *(ORNL)*

The Research Safety Summaries (RSSs) and the procedures to form TRU microspheres using the internal gelation system and to wash the TRU microspheres were approved this month. The RSS and procedures to prepare the TRU solutions, to qualify the TRU microspheres (diameter and sphericity) and to sinter the microspheres were completed and submitted for approval. However, completion of the procedure to calcine and sinter the microspheres has been delayed pending resolution of the electrical wiring and connection issues with the high-temperature furnace.

Calculations were initiated to determine the specific activities and the dose rates of Np and Pa as a function of time. The results, combined with the mass of Np-237 needed for fabrication of (Pu, Np) oxide kernels, will be used to determine whether the Pa must be removed right before sol-gel fabrication work begins, since Pa cannot be nondestructively removed from the gel spheres or kernels.

Fabrication of urania kernels containing SiC *(ORNL)*

The potential to fabricate urania kernels with SiC added to serve as an oxygen getter (to control oxygen potential at high burnup) was assessed this month. It was concluded that the fabrication process procedures, equipment, and approvals required to support the work are all in place.

Fabrication of gadolinium microspheres *(ORNL)*

Examination of the potential to fabricate Gd microspheres for use as a neutron poison in Deep Burn applications was initiated. The fabrication of Gd oxide kernels using the internal gelation process is not feasible because the pH of precipitation is too high. Two alternative options were identified: (1) Gd kernels could be made using the external gelation process (the normal process used by the French); the main differences between internal and external gelation are not too significant. With the external process, the droplets pass through NH_3 gas instead of air, and they are collected in NH_4OH instead of silicone oil. In addition, the feed solution additives are different. This option takes longer to set up and require some equipment modification, but generates less waste. (2) Available Gd nanopowder (up to ~ 30 wt %) could be added to a solution (such as Ti, Zr, etc.) that will form a gel using the internal gelation process. This option would use the same equipment and procedures that were used to add SiC particles to microspheres. Cost and schedule estimates are being generated.

3.2 Coating Development

TRISO coating system *(ORNL)*

The fabrication of components for the new coating furnace continued this month. A visit to the fabrication shop resolved a few outstanding questions, and discussions with the power supply vendor clarified details in the transformer specifications. The procurement package for the custom coating glove box is being prepared and the purchase requisition will be submitted in February.

4. Advanced TRISO Applications

4.1 Metal Matrix Fuels for LWR *(ORNL)*

Fabrication of Metal Matrix Microencapsulated fuel was successfully conducted by hot pressing two samples. TRISO particles were mixed with pure zirconium metal powder and hot pressed to achieve a fully dense metal matrix that adheres remarkably well to the particles.

5. LWR Fully Ceramic Fuel

5.1 FCM Fabrication Development *(ORNL)*

Three different FCM pellets with surrogate (zirconia kernel) TRISO particles were hot-pressed. The powder mixture and hot pressing conditions were altered again to achieve more ideal microstructures. Optimization of the hot-pressing technique will continue during the upcoming months to achieve uniform and defect-free pellets with high TRISO particle fraction. The last FCM pellet was initially cold pressed and placed in a larger graphite die with pure powder surrounding it in an effort to achieve near net shape pellets that could be machined to high dimensional tolerances.

5.2 FCM Irradiation Testing *(ORNL)*

Design drawings have been developed for HFIR rabbit capsule irradiation of both the fueled and surrogate FCM material. The design consists of a stack of 8.2 mm diameter cylindrical fuel pellets separated by graphite or SiC spacers. The fuel stack is contained within a Zirlo alloy holder, which is situated within an outer aluminum alloy 6061 housing cylinder. The housing is an existing, approved component that is used for most current rabbit irradiations in HFIR. The drawings are currently in the initial review stage and will be revised as the thermal analysis proceeds. Neutronic analysis of the pellets has begun, to provide estimates of the burnup of the fuel particles and the heat generation rates of the supporting materials.

6. Fuel Performance and Analytical Analysis

6.1 Fuel Performance Modeling

Code development for FCM fuels *(ORNL)*

The second phase of applying the FRAPCON code to FCM fuel behavior has been initiated.

Burnup and reactivity of FCM fuels *(INL)*

Studies comparing various reactivity coefficients of FCM fuel in a reference configuration to standard UO_X and MOX LWR fuel have been performed using unit cell calculations. Effects of particle packing and kernel size on these coefficients have been calculated and are currently being analyzed further. Studies on the effects of erbium burnable poisons on burnup and reactivity coefficients have also been performed.

Appendix I

Coated Particle and Deep Burn Fuels Program - ORNL FY2011

Milestone Status January 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	20
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	20
5	M31AF080103 - Submit report summarizing progress and path forward on thermochemistry of high-burnup fuel including experimental path-forward.	M2	9/30/2011	20
6	M31AF080204 - Report on Operational Approval to fabricate transuranic-bearing kernels in Bldg. 7920.	M3	2/23/2011	55
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	35
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	25
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	15
12	M31AF080307 - Report on final design of rabbit irradiation vehicle for fueled and surrogate FCM fuel.	M3	3/17/2011	25
13	M31AF080306 - Issue report on FCM optimization with surrogate TRISO.	M3	8/12/2011	15
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	0
15	M2N11OR130202 – 7.2.7 Procure glove boxes for TRU-TRISO coating	M2	3/31/2011	75

** status not reported

Appendix II – Project Participants

Deep Burn Task	Name	Organization
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TRU Fuel Modeling	Ted Besmann	ORNL
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Actinides and Fission Product Transport	Roger Stoller Paul Schuck John Wills Sven Ruden Giulia de-Lorenzi-Venneri Art Voter Duane Wallace Todd Allen Dane Morgan Izabela Szulfarska	ORNL ORNL LANL LANL LANL LANL LANL Univ. Wisconsin, Madison Univ. Wisconsin, Madison Univ. Wisconsin, Madison
Radiation Damage and Properties	Roger Stoller German Samolyuk Stanislav Golubov John Wills	ORNL ORNL Univ. Tennessee, Knoxville LANL
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TRU Kernel Development	Rodney Hunt Valmor de Almeida Jack Collins	ORNL ORNL Subcontract
Coating Development	Jim Miller Jerry McLaughlin Brian Jolly Kevin Cooley	ORNL ORNL ORNL ORNL
Characterization Development and Support	Rodger Martin Steve Nunn Dixie Barker Ivan Dunbar Andrew Kercher Chinthaka Silva	ORNL ORNL ORNL ORNL Univ. Tennessee, Knoxville Oak Ridge Associated Universities
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