**NE 795-014 Advanced Reactor Materials and Materials Performance**

**Exam 1**

Please provide your responses to the following questions. Point values indicated expected depth of response.

1. What are some key differences between high-temperature gas reactors and light water reactors? (8 pts)

Key differences are numerous between HTGRs and LWRs. Coolants: He versus water. Pressure: high pressure in LWRs and low pressure in HTGRs. Fuel system: UO2 pellets versus TRISO particles with a UO2 or UCO fuel kernel. Cladding: Zirconium cladding in LWRs versus the IPyC/SiC/OPyC layered structure in HTGR TRISO particles. Graphite is also the most common material in a HTGR core, whereas LWRs contain no graphite. HTGRs have a much larger temperature delta over the core, reaching much higher temperatures at the coolant exit. HTGRs are also often coupled with secondary systems which can utilize this heat for other processes. And so on…

1. What are the individual layers in a TRISO particle? What purpose does each layer have? (14 pts)

Fuel kernel: Fissile material. Often UO2 or UC2/UO2 (UCO). Generates heat.

Buffer: Porous graphite layer surrounding the fuel kernel. Allows for fuel expansion while mechanically decoupling the fuel kernel from the external layers. Porosity allows for gas generation without overpressurization.

IPyC: Inner pyrolytic carbon, highly dense graphite. Layer serves are a substrate for the SiC deposition, protects SiC from fission products, provides compressive stresses on SiC.

SiC: Primary fission product barrier and primary pressure vessel. Failure of the SiC constitutes a failure of the particle.

OPyC: Outer pyrolytic carbon, highly dense graphite. Protects the SiC layer during fabrtication. Provides compressive stresses on SiC.

1. What are the trade-offs between carbide and oxide fuel kernels? (10 pts)

UO2 fuel kernels are well understood and relatively easy to manufacture, while also effectively retaining a large portion of the fission products. However, excess oxygen generated during fission interacts with graphite in TRISO particles to generate CO, leading to pressurization of the particle. UC2 fuel removes oxygen from the system, thereby eliminating the generating of CO during fission. However, UC2 is more challenging to fabricate and does a worse job retaining fission products. Thus, a heterogeneous mixture of UO2 and UC2 is commonly adopted to utilize the effective fission product retention of UO2, while providing a fissile getter of oxygen in the form of UC2 to limit the production of CO.

1. How does the nature of irradiation damage accumulation change with irradiation temperature in SiC? (12 pts)

SiC has four temperature regimes with respect to radiation damage accumulation. At very low T, SiC goes amorphous. At low T above the amorphization temperature, the microstructure is dominated by black spot defects which are likely interstitial clusters. As the temperature increases, more recombination is allowed as defect diffusivities increase, and the concentration of BSDs is reduced. Thus, defect-induced swelling decreases with increasing temperatures at low temperatures (below 1000C). The BSD-induced swelling saturates at a given level of dose for a given temperature. At medium to high temperatures, interstitial loops are seen to form from the clustering of the individual small interstitial clusters. At high temperature, vacancies become sufficiently mobile to form voids and the microstructure becomes dominated by void swelling.

1. How does thermal conductivity change in SiC with irradiation? What are the primary phonon scatterers, and why can someone determine the thermal conductivity from the swelling in SiC? (10 pts)

The thermal conductivity in SiC is mediated by phonons. The primary phonon scatterers are point defects, primarily the BSDs generated at low to medium temperatures.

1. Discuss the role of fission products on the failure of TRISO particles? (10 pts)
2. How does graphite dimensionally change under irradiation? Why does this behavior happen? (14 pts)
3. List at three types of failure mechanisms for TRISO particles. (8 pts)
4. Provide one example of an advanced TRISO concept and explain why it is of interest. (8 pts)
5. What are three phenomena/behaviors needs to be accounted for in fuel performance modeling of TRISO fuels? What is one data need for fuel performance modeling? (6 pts)