4.8 HIGH-HEAT FLUX TESTING OF LOW-LEVEL IRRADIATED MATERIALS USING PLASMA ARC LAMPS—A.S. Sabau, Y. Katoh (Oak Ridge National Laboratory) and K. Ibano (Osaka University)

OBJECTIVE

The objective of this work, part of the US-Japan PHENIX collaboration, is testing of irradiated materials that are candidate divertor component materials and mock-up divertor components under high-heat flux using Plasma Arc Lamps (PAL).

SUMMARY

A review was conducted of relevant physical phenomena that take place during high-heat flux testing (HHFT) in order to identify areas of concentration in the ORNL program for materials characterization. Planning of activities for handling the irradiated specimens in FY17 was started in order to ensure a close coordination between the multidisciplinary efforts needed for a comprehensive material science study of irradiated effects during HHFT. Temperature-dependent physical and mechanical properties for the SiC were obtained for use as input in the numerical simulations of the HHFT to reveal insight on the temperature and stress conditions for the four W/SiC specimens. The setup of thermo-mechanical model simulations for the high-heat flux testing of W/SiC specimens was completed.

PROGRESS AND STATUS

Effort was conducted in three main areas: (a) planning of activities for handling the irradiated specimens in FY17, (b) analysis of data acquired during HHFT of four W-SiC specimens, and (c) development of a simplified thermo-mechanical model in ABAQUS for the simulation of the state of stress and deformation during HHFT.

Planning of activities for handling the irradiated specimens in FY17 was started. A review was conducted on relevant physical phenomena that take place during HHFT in order to identify areas of concentration for specimen characterization. Based on this review, the following physical phenomena will be considered for understanding irradiation effects during HHFT of W-based materials:

1. Time to anneal irradiation defects.
2. Thermal conductivity degradation.
3. Change in mechanical properties.
4. Change in microstructure.
5. Defect evolution during HHFT.

Basic materials property information and constitutive equations for materials behavior in the harsh fusion environment will be provided based on materials science investigations. The tasks, which are needed for this materials science study, were identified to be the following:

1. Understand the temperature distribution in the specimen during HHFT.

    a. Assess accuracy of using thermocouples on the back surface of the specimen for temperature measurement.
    b. Model the temperature distribution in the specimen during HHF.

2. Understand the state of stress within the specimen.

    a. Model the specimen deformation, plastic deformation, and build-up of residual stresses during HHFT.

3. Microstructural characterization (before/after HHFT).

    a. Surface SEM.
    b. Profilometry (ORNL).

4. Defect characterization (before/after HHFT).

    a. STEM imaging.
    b. TEM imaging.
    c. Large-area high-speed STEM-X-ray mapping.

5. Property measurement (before/after HHFT).

    a. Thermal conductivity.
    b. Micro-hardness.

Fixtures which were required to clamp the specimens directly on Cu cooling module were fabricated for the PHENIX program at ORNL (Table 2).

Table 1. Clamping holders fabricated for the PHENIX project at ORNL

Sample Diameter [mm]	Sample Thickness [mm]	Clamp Material	Fabrication
10	3	Ta10W	ORNL
10	3	Ta	PHENIX/Japan
10	2	Ta10W	ORNL
10	1	Ta10W	ORNL
6	2	Ta10W	ORNL
6	1	Ta10W	ORNL

Data acquired during HHFT of W/SiC specimens (Table 1) at ORNL was analyzed. The main variables in the high-heat flux testing were the number of cycles at high heat flux and average cycle duration (Table 1). Figure 1 shows micrographs of taken from edge of the specimen S1, indicating irregular surface morphology of the SiC surface.

Table 2. Main variables for high-heat flux testing of W/SiC specimens 10 mm in diameter (SiC thickness was 1mm), PHENIX program specimens

No.	W thickness [mm]	[1]No. Cycles	[1]Average cycle time [s]	Cycle duration [s]	Max. Heat Flux [W/cm^2]	Average Heat Flux [W/cm^2]	Total heat input [MJ/cm^2]	Total time at high-heat flux [s]	Notes
1	2	122	11.1	10-15	288	264	0.361	1,356	edge melting
2	2	100	10.9	5-15	300	274	0.301	1,094	
3	1	101	11.3	10-15	288	272	0.311	1,146	edge melting
4	1	127	13	10-18	288	273	0.498	1,664	

[1] Number of cycles at heat fluxes above 210 W/cm^2 .

The setup of thermo-mechanical model simulations for the high-heat flux testing of W/SiC specimens was completed. Temperature-dependent physical and mechanical properties for the SiC were obtained for use as input in the numerical simulations of the HHFT to reveal insight on the temperature and stress conditions for the four W/SiC specimens. Numerical simulations of the HHFT will be conducted to reveal insight on the state of stress that may have lead to the surface cracking for the melting observed in the 1-st and 3-rd W/SiC specimen.

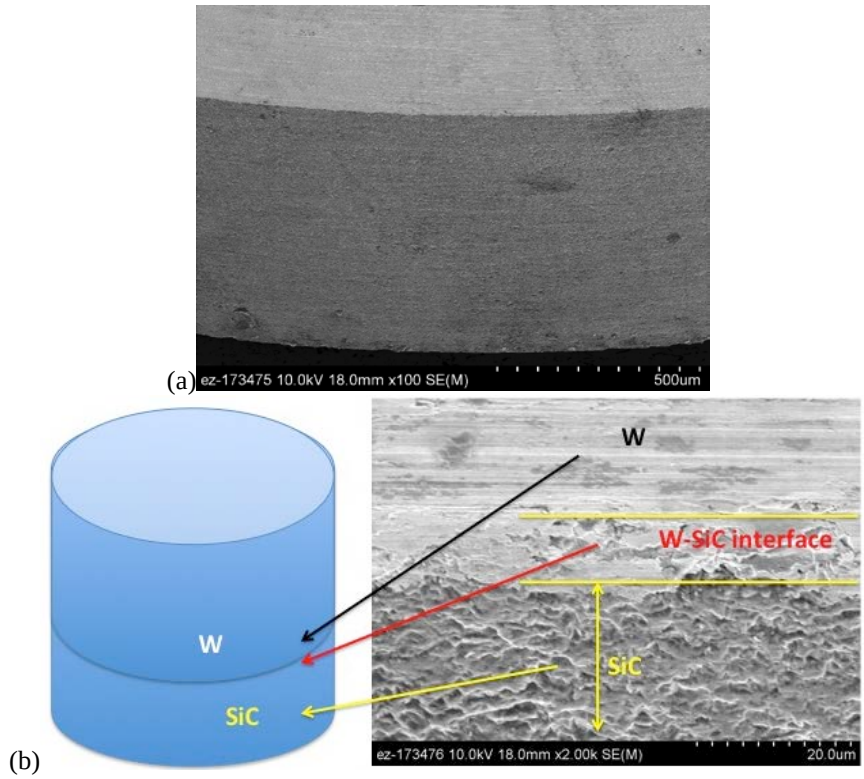

Figure 1. SEM micrographs for specimen S1 taken around the circumference: (a) low magnification, and (b) high magnification showing surface irregularities on the circumference of the SiC surface. The specimen was tilted 39°.