4.7 NEUTRON IRRADIATION EFFECTS IN TUNGSTEN-COPPER COMPOSITES—L. M. Garrison, Yutai Katoh (Oak Ridge National Laboratory) Jeremy Moon (University of Nevada-Reno), Joseph Willenborg (University of Tennessee-Knoxville)

OBJECTIVE

The aim of this work is to evaluate tungsten-copper based composites for potential use as part of a plasma-facing component for future fusion reactors.

SUMMARY

As part of the TITAN program, two types of tungsten-copper composites were irradiated in HFIR at temperatures from 300 to 900°C and fast neutron fluences of 0.01 to 20 $\times 10^{25}$ n/m^2 at E>0.1 MeV. One material was a tungsten-copper laminate composite composed of 0.1 mm alternating layers of tungsten and copper. Tensile tests have previously been completed on the tungsten-copper laminate and EDS and EBSD analysis of the material is underway. The other material was a tungsten-copper powder sintered composite, with 75% W and 25% Cu. Tensile tests of unirradiated and irradiated tungsten-copper sintered composite have been completed and are being analyzed.

PROGRESS AND STATUS

Tungsten-copper laminates

Three tungsten-copper laminate samples that were part of the TITAN program were analyzed with scanning electron microscopy (SEM), energy dispersive spectrometry (EDS), and electron backscatter diffraction (EBSD). These three samples were previously tensile tested at room temperature. Their conditions were sample SW40 unirradiated and 15.5% total elongation, sample SW25 0.15 dpa (calculated for tungsten) at 760°C and 0.15% total elongation, and sample SW40 0.70 dpa (calculated for tungsten) at 710°C and 0% total elongation. In the unirradiated state, the tungsten foil is ductile, but has less than 2% total elongation on its own. The additional elongation comes from the copper layers of the laminate. After irradiation, it is expected that the tungsten foil becomes brittle, but the copper should remain ductile. However, in tensile testing the composite after irradiation, the copper was unable to maintain the ductility that the composite experienced before irradiation. To see if any changes were occurring in the tungsten to copper interface during irradiation that might negatively impact the composite behavior, these three samples were analyzed with the SEM.

The data is still being analyzed, but a few initial observations can be made. For one, initially the tungsten to copper interface is very distinct and clean (Figure 1). After irradiation, the interface still does not show noticeable mixing of the tungsten and copper, but voids or gaps are noticeable at the tungsten-copper interfaces (Figure 2). Also, within the three tungsten layers (top, middle, and bottom layers of the composite) horizontal striations can be seen in Figure 2. These appear to be lines of voids or gaps within each tungsten foil following the rolling direction of the tungsten foil. Although the laminate did not have any measurable elongation in the tensile test after 0.7 dpa irradiation, it can be seen that the copper layers successfully stopped many vertical cracks in the tungsten foil layers from propagating through the entire composite (Figure 2).

Although the optical images of several of the W-Cu laminate samples have yellow or orange colors on the top tungsten layer, such as in Figure 3, the EDS analysis did not measure significant oxygen, as would be present if the tungsten were oxidized. The EDS did show that Cu is on top of the W in some areas, as on the edge pictured in Figure 4. Therefore, the yellow and orange seen in the optical images is believed to be a combination of a) some Cu on the top surface from the fabrication and b) possible color enhancement from the imaging mode in the optical microscope rather than from a tungsten oxide.

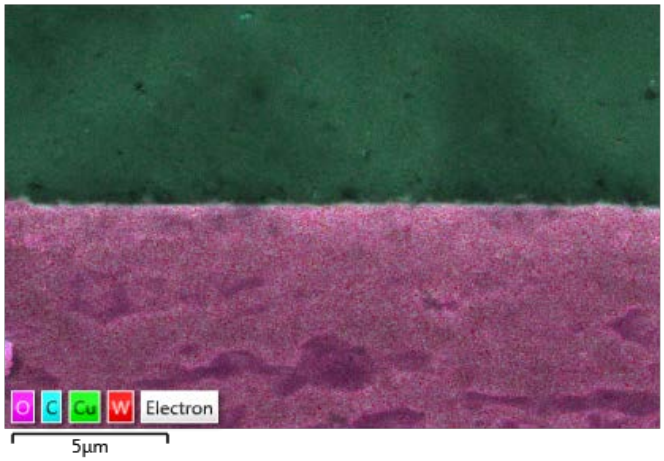

Figure 1. EDS element map of polished edge of tungsten-copper laminate sample SW40.

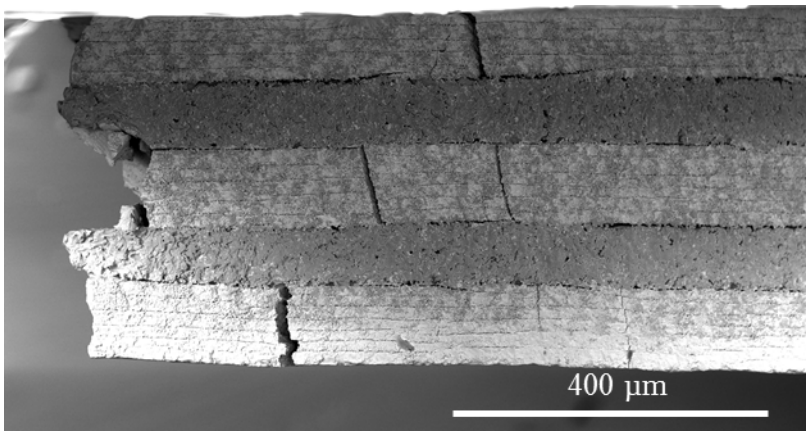

Figure 2. SEM image of the edge of the gauge section near the fracture end of SW15. The tensile direction is horizontal on the page.

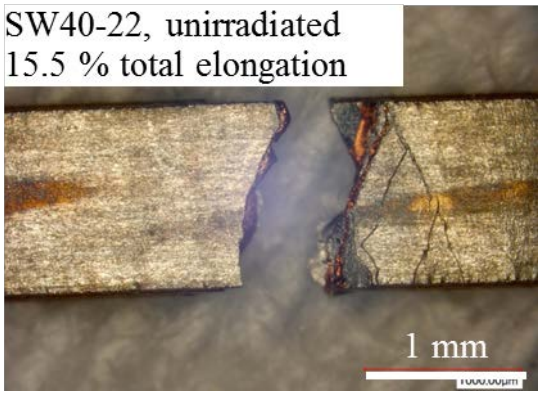

Figure 3. Optical image of SW40, unirradiated and tested at 22°C.

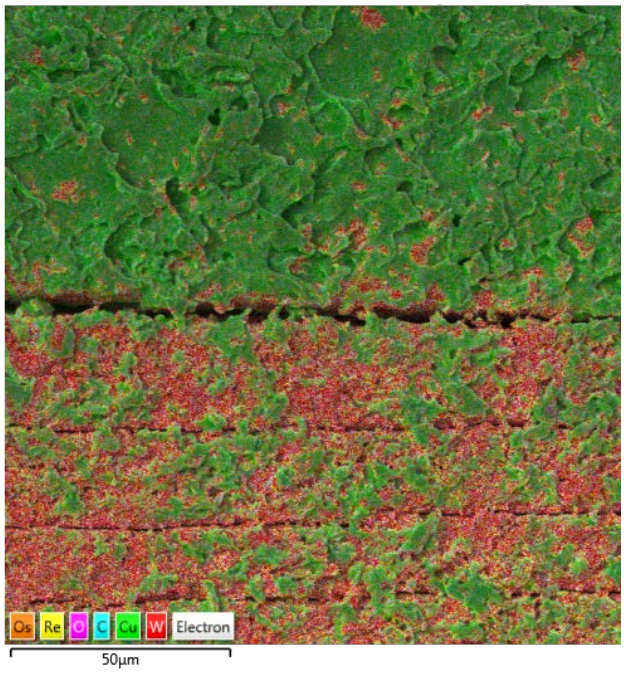

Figure 4. EDS map of unpolished edge of SW25 after irradiation. The top layer is copper and the bottom layer is tungsten, but surface deposits of copper are observed.

Tungsten-copper sintered composite

Previous analysis of the tungsten-copper laminate composites irradiated in the TITAN program showed that the laminate composites quickly loose ductility after low dose irradiation. The design space for such a continuous composite may be small because of the extreme mismatch of tensile strength in the two materials after irradiation.

As an alternative to the tungsten-copper laminate composite, a powder sintered tungsten copper composite with 75% W and 25% Cu was investigated. A polished surface of one of the tungsten copper sintered composites is shown in Figure 5. A closer examination reveals that there are sharp boundaries between the rounded W particles and the Cu. As expected, no interlayer or mixed phase formed between the elements.

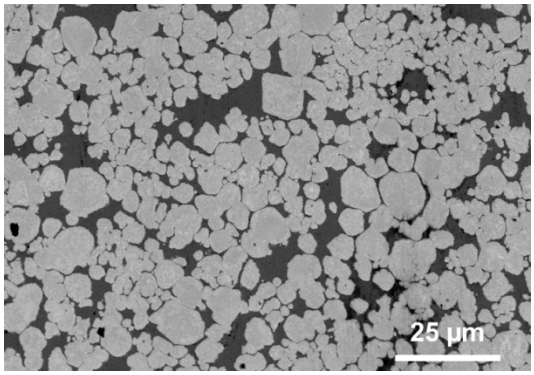

Figure 5. SEM image of the powder sintered tungsten copper composite.

Two identical tungsten-copper sintered composite samples were tensile tested at room temperature. The tensile data plotted in Figure 6 does not account for machine compliance, so the elastic region is not representative of the material properties. The material does show ductility at room temperature, which is a significant improvement as compared to traditional sintered tungsten. Examining the fracture surface of one of the samples, limited reduction in area is detected near the fracture surface, and the fracture surface itself has a bright copper-color (Figure 7).

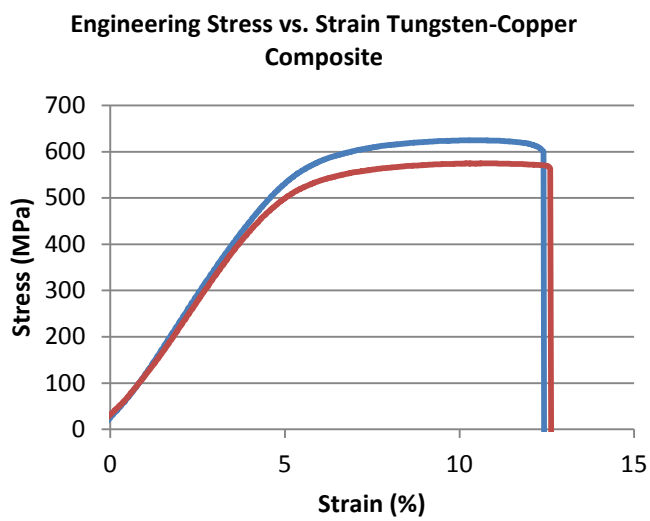

Figure 6. Tensile curves of the tungsten-copper sintered composite tested at room temperature.

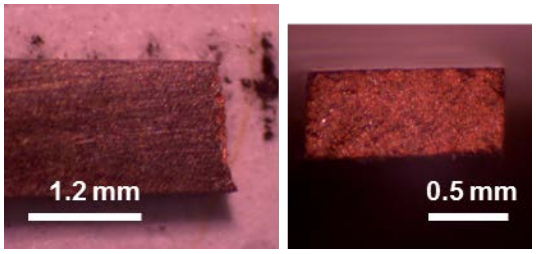

Figure 7. Fracture surface of the tungsten-copper sintered composite.

Some of the tungsten-copper sintered composite was irradiated and tensile tested as part of the TITAN program. These samples have sample IDs that begin with “KW”. The analysis of the tensile data of the irradiated material is underway and will be compared with the tungsten-copper laminate composite data.