EFFECTS OF HEAT TREATMENTS ON MICROSTRUCTURE CHANGES IN THE INTERFACE OF CU/SS316L JOINT MATERIALS - Q. Xu and T. Yoshiie (Kyoto University, Japan) and D. J. Edwards (Pacific Northwest National Laboratory)*

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EXTENDED ABSTRACT

The joining of dissimilar metals will likely be an important fabrication step in the use of copper alloys for advanced reactor designs. One possibility is that precipitation and dispersion strengthened copper alloys will be joined with 316L austenitic stainless steel for heat sink applications in the first wall and divertor structures of fusion power systems. In the present study, the effects of heat treatment on microstructural stability in the interface of CuNiBe/SS316L and CuAl25/SS316L have been investigated.

GlidCop CuAl25/SS316L and CuNiBe/SS316L joints formed by hot isostatic pressing (HIP) of solid plates were examined in this study. The joints were fabricated at a bonding temperature of 1255K for CuAl25/SS316L, and at 1245K for CuNiBe/SS316L. The pressure and the holding time for the HIP process were fixed at 101 MPa and 2 h. For further details on the materials and joining procedures please refer to reference 1.

The joints were thinned to 0.1 mm, and cut into 3 mm discs for transmission electron microscope (TEM) observation. Two kinds of annealing experiments were carried out to investigate the microstructural stability of the joint. Isochronal annealing of thinned CuAl25/SS316L TEM specimens was conducted in-situ using a high temperature heating stage in a JEOL 2000ES TEM. The specimens were annealed over the temperature range of 298-973K at 100K intervals, and the temperature was maintained for 30 minutes. Bulk specimens of the two joints were annealed separately at 573K and 673K for 100 h, respectively, and TEM specimens prepared by ion milling from the cross-section of the joints. The interfaces were examined using TEM and scanning electron microscopy (SEM, JEOL JSM-5800LV) to characterize the interfacial and the overall microstructure.

Figure 1 shows the SEM micrograph of as-received CuAl25/SS316L and CuNiBe/SS316L joints. Energy dispersive x-ray line analyses were conducted for Fe, Ni, Cr and Cu. Typical results of EDX line analyses (Fe and Cu) are also shown in the figure. It was found that there was interdiffusion of the two base materials. The concentration of Fe, Cr and Ni decreased and that of Cu increased in the region of stainless steel adjacent Cu alloy. Many precipitates, mainly composed of Cr and Fe, were found in the Cu alloy side of interfaces. In the CuAl25/SS316L joints, small voids, about 2 μm in diameter, were observed in the Cu alloy side near the interface, whereas in the CuNiBe/SS316L joints, voids, about 5 μm in diameter, were observed in the interface, and small voids, about 1 μm in diameter, were observed in the SS316L near the interface. Figure 2 shows the TEM micrograph of CuAl25/SS316L and CuNiBe/SS316L interfaces. As in the microstructures observed by SEM, the precipitates were not found at the interface of both joints. Also, voids were only found at the interface of CuNiBe/SS316L, and they were not observed in the Cu matrix and stainless steel far from interface.

Typical microstructures in the joints before and after the annealing experiment are shown in Figure 3. Figure 4 shows that the microstructures at the interfaces of the joint materials

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were thermally stable even after annealing at 573K or 673K for 100 h. The microstructures in the matrix of both joints and the interdiffusion within joints were also not affected by the annealing.

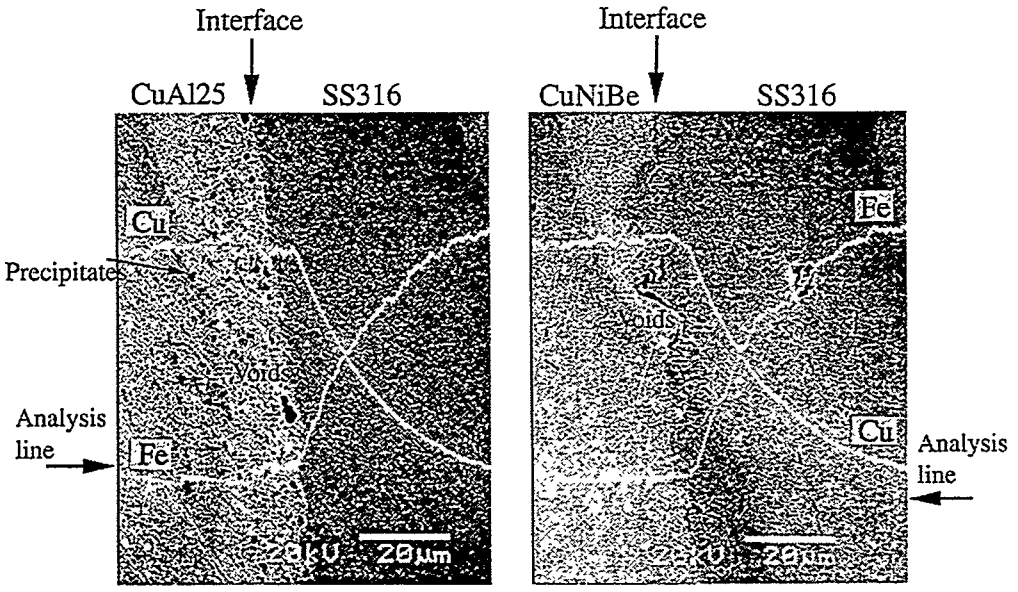

Figure 1. SEM micrograph of joint materials of CuAl25/SS316L and CuNiBe/SS316L, and typical results of EDX line analyses.

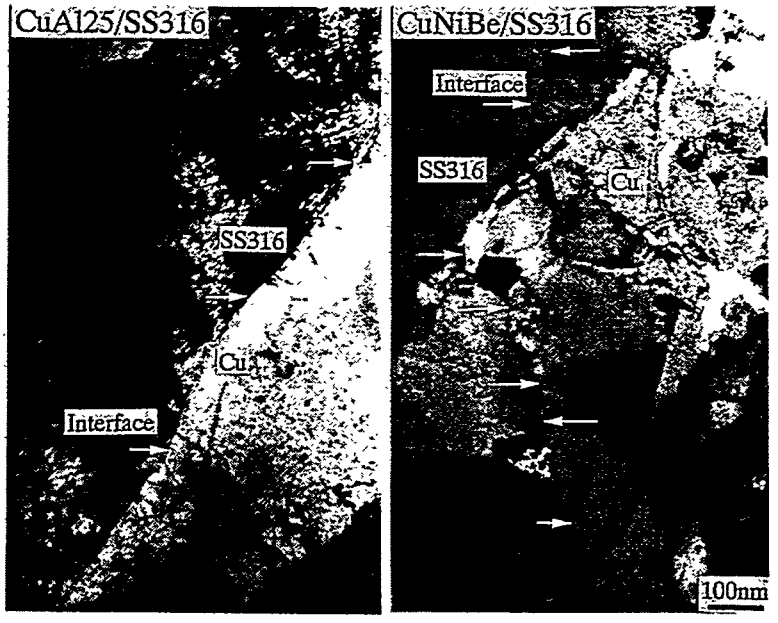

Figure 2. Microstructure in the interface of as-received joint materials.

Figure 3. Typical microstructure in the bonded joint of CuAl25/SS316L before and after isochronal annealing.

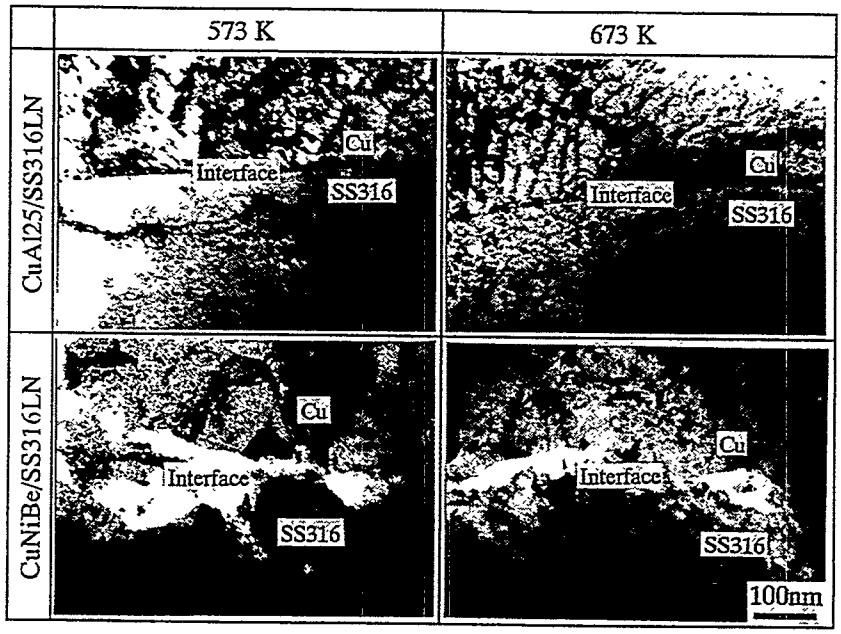

Figure 4. Microstructure in the interface of joint materials annealed at 573K and 673K for 100 h.

The results of annealing experiments showed that temperatures ≤ 673K did not change the initial microstructure or composition of CuAl25/SS316L and CuNiBe/SS316L joints. Although there are no data from annealing experiments longer than 100 hours, it is expected that the microstructure and composition of CuAl25/SS316L and CuNiBe/SS316L are stable at temperatures below 673K . However, irradiation may lead to significant changes because of radiation-enhanced segregation, precipitation or dissolution near and at the interface that could alter the properties. In addition, the preexisting voids near the interface of the joints may coarsen under irradiation and enhance the sensitivity of joints to failure. Given the uncertainties in the response to irradiation, neutron irradiation experiments should be performed at appropriate temperatures to investigate the response of the different materials.

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