§8. Development of High Strength W/V/Au/ ODS-Cu Joint using HIP Process

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Divertors with high heat removal capabilities and resistance to severe heat and particle load are one of the key components of fusion reactors. One of the promising candidate material combinations for constituting the divertors are tungsten (W) and copper (Cu) alloys. W is considered as a leading candidate for the plasma facing material (PFM) or components (PFC) because of its highest melting point among the metal elements (3695 K), good thermal conductivity (167 W m^{-1} K^{-1} at 293 K), low sputtering yield, and low hydrogen isotope retention and so on. On the other hands, Cu alloy have higher thermal conductively compared with the other metallic materials. Under such development phase, oxide dispersion-strengthened copper alloys (ODS-Cu) such as GlidCop® can be an advanced candidate for the divertor components. Therefore, establishment of the bonding process between W and ODS-Cu is considered to be a necessary technology for the advancement of divertor systems. The difficulty in bonding W and Cu materials is originated from quite low mutual solubility, large difference in the melting points (Δmp=2337 K), and very different coefficient of thermal expansion (ΔCTE=12 x 10^{-6}/K). Thus, insert materials between W and ODS-Cu is expected to be effective to the bonding.

In this study, vanadium (V) and gold (Au) are selected as insert materials between W and ODS-Cu. These layers have advantages for the W/ODS-Cu bonding such as high solubility of the adjacent materials, plasticity and thermal conductivity, and low activation. V has an intermediate CTE and a melting point between W and Cu, which mean a grading of physical properties in the joints. These metals are expected to be used as new bonding materials based on diffusion reaction. Because the bonding materials have very different melting points, the bonding should be carried out by two steps. After the bonding, the melting point of the interface is higher than that of conventional brazing materials. For diffusion bonding, the initial thickness of insert materials is considered to be a key parameter. The objective of this study is to investigate the effect of thickness of Au layer between V and Cu on the interface structure and mechanical properties of the joints. The pure V inserts between W and C are 1.5 mm thick sheets. The following two cases of the inserts were compared.

1. Without Au insert
2. With Physical Vapor Deposition (PVD)-Au insert (0.7 μm)

Fig.1. shows bending strength at room temperature for the two interfaces (V/Cu and W/V) with and without a PVD-Au. Bending test of V/Cu interface exhibited yielding for the both joints with and without PVD-Au. Averaging the 5 data showed that the yield strength of the joint with and without Au was 333MPa, 308MPa, respectively. There are close to the tensile yield strength of GlidCop® at room temperature. On the other hand, strength of interface of between W and V is 280MPa, 121MPa, respectively. The fracture occurred not at the interface but in W during the bending test between W and V.

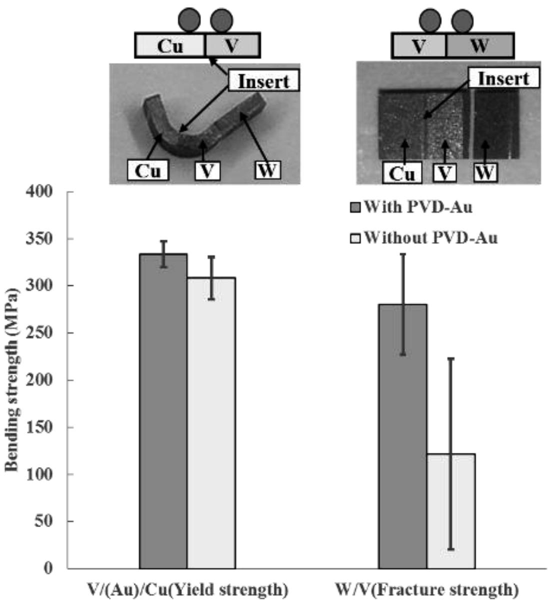

Fig. 1. Bending strength measured at room temperature for the two interfaces (V/Cu and W/V) with and without a PVD-Au. The results are shown as the average of 5 specimens.