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HIP法によるW/V/Au/ODS-Cu接合の開発研究
Development of high strength W/V/Au/ODS-Cu joint using HIP process

能登　裕之[1]、山田　哲也[2]、菱沼　良光[1]、室賀　健夫[1]
Hiroyuki NOTO[1], Tetsuya Yamada[2], Yoshimitsu Hishinuma[1], Takeo Muroga[1]
[1]核融合科学研究所、[2]名古屋大学大学院
[1]National Institute for Fusion Science, [2]Nagoya University

The divertor with higher heat removal capabilities and heat resistance to severe heat and particle load are one of the key components to operate fusion reactors. One of the candidate material combination for fabricating the divertor is tungsten (W) and copper (Cu) alloy because W and Cu have promising properties for the divertor application. W has high melting point, low hydrogen isotope retention, low sputtering yield, and so on. Cu alloy has higher thermal conductively compared with the other metal materials. In fact, copper alloy (Cu-Cr-Zr) pipes are tried to join with W by conventional brazing on the ITER project. On the other hand, oxide dispersion-strengthened copper alloys (ODS-Cu) such as GlidCop® (Cu-0.3wt%Al2O3) has superior mechanical properties at high temperatures than Cu-Cr-Zr, and thus can be an advanced candidate for the divertor components. Therefore, the establishment of the bonding process between W and ODS-Cu is an essential technology to succeed the divertor system using ODS-Cu.

W and Cu are almost insoluble with each other and they have very different coefficient of thermal expansion (CTE). Thus, the 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 interlayers to the joint between W and ODS-Cu. These layers have advantage for the W/ODS-Cu bonding such as high solubility, plasticity and thermal conductivity, and low activation. V and Au have extremely different melting points, these metal expected to use as a new bonding material based on diffusion reaction. The new bonding proceeded with two steps. The first step is the W/V bonding by solid-phase diffusion reaction. The second step is the W-V/Au/ODS-Cu bonding using the Hot Isostatic Press (HIP). The HIP process condition was 950 ˚C for 1 hr in argon atmosphere of 200 MPa. The melting point in the interface between Au and ODS-Cu is decreased by the eutectic reaction, and referred as the Transient Liquid Phase bonding. In this study, Au inserts was compared Thickness of 0 and 0.7 µm, 300 µm which fabricated as no inserts and physical Vapor Deposition (PVD), foil, respectively.

The smooth interfaces without reaction layers and large defects were observed in the W/V and Au/ODS-Cu interface. However, the hardened region (300 µm) by V/Au reaction were observed in the V/Au interface region.

In the case of joints using extremely thin inset (0.7 µm), the inter-diffusion layer was not observed in interface of V/GlidCop®(Cu) as shown Fig.1.

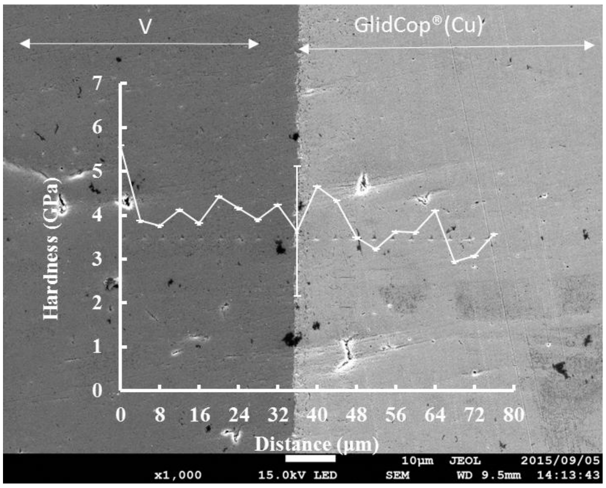

Fig.1 SEM image of the cross section area of V/GlidCop®(Cu) joint with PVD-Au, showing hardness profile measured by Nano-indentation method. This hardness profile means that the hardening induced solution of Au in parent metals did not generate, and inter-metallic compound did not formed. In addition, residual of Au was not observed by composition analysis. It is considered that this joints reached homogenization without localization of Au elements. Thus joints with PVD-Au has a beneficial effect of suppressing the formation of brittle region.

In addition, the overall bending strength of the W/V/Au/ODS-Cu joints using HIP process will be reported.