§20. Development of a Dispersion Strengthened Copper Alloy using a MA-HIP Method

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Cu alloys are promising materials for use as the heat sink materiasl of divertors because of their good thermal conductivity. In recent years a number of studies have been carried out on Cu-based materials in order to find an optimal combination of high mechanical strength and high thermal conductivity. Under such a situation, dispersion strengthened (DS)-Cu such as Glidcop® (Cu-Al_2O_3) is known to have higher stability in microstructure. The conventional DS-Cu has been produced by internal oxidation and extrusion, which, however, can cause inhomogeneity and coarsening of the dispersed particles and anisotropic microstructure and properties. In this paper, we propose a process using the combination of Mechanical Alloying (MA) and Hot Isostatic Pressing (HIP), as is well known for the process of Oxide Dispersion Strengthened Steels (ODSS). In the present study, addition of pure metal were carried out expecting their oxygen gettering effects and the effects of MA time was investigated. As to the metal to be added, Al was selected for the purpose to compare with Glidcop®.

The Cu-1 wt. % Al (labeled as Cu-Al) was produced by MA and HIP method. And the alloying was carried out with a rotating rate of 250 rpm for 1~32 hrs in Ar gas atmosphere. The mechanically alloyed powders were then loaded into a mild steel capsule, degassed at 500 ˚C for 1 hr in 0.1 Pa vacuum. The powders were sintered by HIP at 1223 K for 1 hr with a pressure of 150 MPa. It should be noted that, throughout the series of the process, the materials were not exposed to the air.

Fig. 1 shows a graph plotting the Vickers hardness with the grain size. The data obtained for Glidcop® are also included for comparison. The relations of average grain size and Vickers hardness is given by Hall-Petch equation (1).

$$HV = HV_0 + k \cdot d^{-\frac{1}{2}} \quad (1)$$

where, HV is the Vickers hardness, HV_0 is hardness of single crystal, k is the material constant and d is average grain size. The almost linear increase in hardness in the figure may imply that the change observed Hall-Petch rule. However, Glidcop® has similar composition and similar hardness to the present alloy with 250 rpm and 32 hrs although the grain size is much smaller. This means that the hardening of the present alloys with the MA time is not solely by the grain refinement, but other hardening mechanisms would be operating.

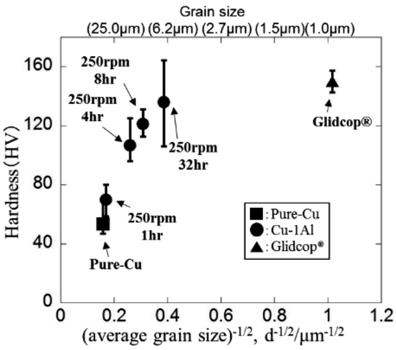

Fig.1. Hardness of the materials produced as a function of grain size.

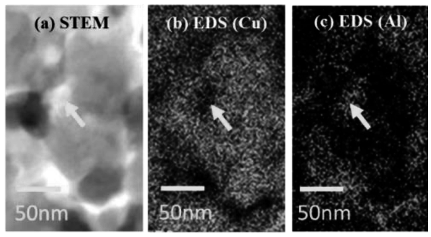

Fig.2. STEM image (a) and EDS chemical mapping for Cu (b) and Al (c) for the alloy with MA for 32 hrs and HIP.

Fig. 2 shows STEM and EDS chemical mapping images for Cu and Al for the alloys with MA of 32 hrs and HIP. The white area in STEM image is rich in Al, showing precipitation of Al-rich phases occurred. Al is an element that induces long-term radioactivity by neutron irradiation. Low activation can be a necessary requirement for the divertor materials, although it is thought that the issue is not as serious as that for blanket structural materials. In this study, Al was selected to enable direct comparison with Glidcop®. After verifying the effectiveness of the present procedure, it is planned to move on to other additives such as Hf and Zr.