§14. Development of Oxide Dispersion Strengthened-Copper Using a MA-HIP Method

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The divertors of fusion reactors are subject to a high thermal heat load. In the helical DEMO reactor FFHR, the steady thermal load is assumed to exceed 10 MW/m^2. Thus development of heat sink materials having a high heat removal capacity is required. For this purpose, copper alloys have a large advantage in thermal conductivity. Although copper alloys are susceptible to neutron irradiation and thus were not considered as DEMO candidates, the reduced neutron fluence in the recent FFHR design has lead to revisiting them as heat sink materials. In ITER, use of precipitation strengthened (PS)-Cu (CuCrZr) are being considered. However PS-Cu have issues such as instability of microstructure at high temperatures. On the other hand, dispersion strengthened (DS)-Cu are known to have higher stability in microstructure and strength at high temperature. The conventional DS-Cu have been produced by internal oxidation and extrusion, which, however, can cause inhomogeneity and coarsening of dispersed particles and formation of anisotropic microstructure.

In this study, we research into improvements of DS-Cu using Mechanical Alloying (MA) followed by Hot Isostatic Pressing (HIP). MA can disperse particles finely and homogeneously, and HIP can form dense microstructure. In this study, effects of additive elements (Al, Zr) and MA conditions (rotation speed and duration) are investigated. Cu-1wt. %Al (Cu-Al) and Cu-1wt. %Zr (Cu-Zr) are alloyed using planetary ball mill, with rotation rates of 50, 200 and 300 rpm for 1 to 5 hours. HIP is carried out at 950C for 1 hour in an argon atmosphere of 150MPa.

Figure 1 shows effect of Mechanical Alloying (MA) on particles. The original particles start to combine with each other around 200-300 rpm for 1 hour, which is considered to be the starting point of alloying. In MA condition of 300rpm, the particle aggregates and change to flattening from 2hr to 5hr.

Figure 2 shows As- HIPed metallic structure after MA. The grain exhibits reduced grain size and increased hardness with rotation rates of MA. Large precipitates or inclusions are not observed in either matrix or grain boundaries. This results has demonstrated that MA-HIP of Cu with Al or Zr addition can produce homogeneous structure with refined grains. In other hands, hardness varies widely, which is considered that induced energy by MA is inhomogeneous. In future study, improvement of rotation rates for MA is planned.

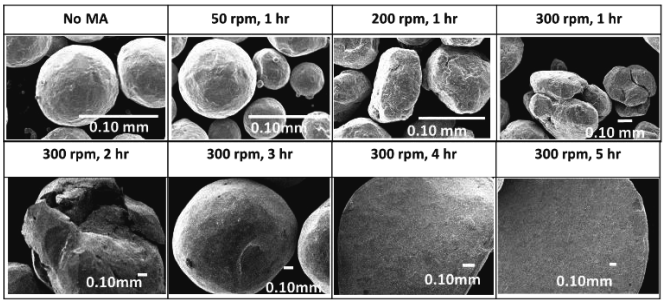

Figure 1 Effect of Mechanical Alloying (MA) on particles.

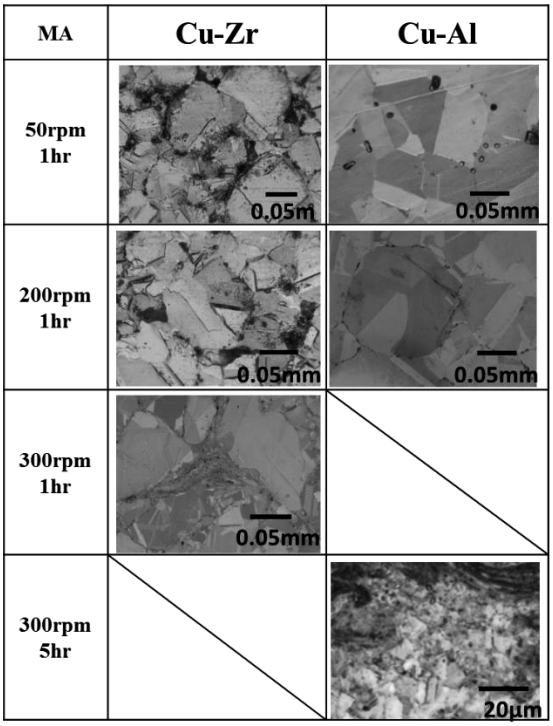

Figure 2 As- HIPed metallic structure after MA