Microstructure and Mechanical Properties of Ti-Ni/Cu Harmonic Structure Composite

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Grain refinement is well known to improve the mechanical properties of materials. The nano grain structure materials show very high strength but a limited ductility because of the early plastic instability. On the other hand, harmonic structured materials with fine and coarse grain areas demonstrate high strength and sufficient ductility simultaneously. The harmonic microstructure consists of fine-grained network and disperses coarse grained areas. The fine-grained network area has a role of the strength increase and the dispersed coarse grained area has a role of maintaining the elongation. The harmonic structure can achieve the trade-off mechanical properties simultaneously. In addition, the harmonic structured composites consist of a low fraction metal region like network and a dispersed another major metal region like island by using deferent metals. The harmonic structure composite also improves various trade-off mechanical properties. For example, the Mo/Cu harmonic structure composites demonstrate low coefficient of linear expansion and enough thermal conductivity despite the trade-off relationship between low thermal expansion and high thermal conductivity. In this study, the microstructure and mechanical properties of the Ti-Ni/Cu harmonic structured composites fabricated by mechanical milling (MM) and spark plasma sintering (SPS) processes are investigated in detail.

Ti-Ni alloy powder (approximately 184 μm) and pure Cu powder (approximately 122 μm) were used in this study. These powders were mechanically milled using planetary ball mill equipment with an SKD11 container and SUJ2 steel balls in Ar atmosphere for 21.6 to 86.4 ks at cryogenic temperature. The MM powder consists of the Ti-Ni alloy of the surface and Cu of the middle. Such as MM powder was sintered by using the SPS apparatus at 1073 K for 1.8 ks. The microstructure of the SPS compacts was characterized using scanning electron microscopy (SEM) / energy dispersive X-ray spectroscopy (EDS) and X-ray diffraction (XRD). The mechanical properties of SPS compacts were evaluated based on the tensile tests at 373 K.

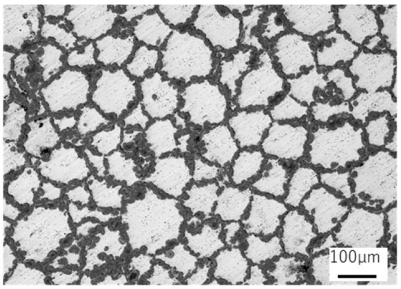

Fig.1 SEM micrograph of harmonic structure of SPS compact of the MM powder for 43.2 ks.

The sintered compacts of MM powders produced by each milling time demonstrate the harmonic structure with the network and dispersive areas as shown in Fig. 1. The XRD results reveal that network and dispersive areas correspond to Cu-Ni-Ti alloy and Cu, respectively. This reason is the Cu diffusion during sintering. The MM time increase leads to decreasing the grain size in the network area without change the network area fraction. Fig.2 shows the tensile test results of Ti-Ni/Cu harmonic structure composite produced by each MM time and Cu compact. The MM time increase leads to increase the tensile strength and to decrease the elongation. The grain refinement of network area without increasing network area fraction is effective to improve the mechanical properties of the harmonic structure composite.

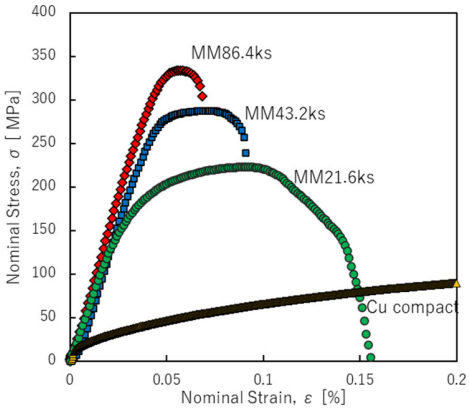

Fig.2 Tensile test results of SPS compact of Cu powder and the MM powder for 21.6 to 86.4 ks.