Fabrication of Ni-based bulk metallic glass matrix composite containing brass phases by SPS of gas atomized powders

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Attempts have been made to enhance the ductility of BMGs by introducing crystalline phases into the metallic glass matrix: partial devitrification of BMGs, adding particles or fibers during casting or consolidation process, and in-situ formed ductile phase precipitates. It was found that the metallic glass matrix composites(MGMCs) exhibit enhanced plasticity, not generally observed in monolithic BMGs. The improved mechanical properties in MGMCs are achieved by the formation of multiple shear bands and the confinement the propagation of the shear bands.

Spark plasma sintering(SPS) technique has recently attracted, because of its promising potential to obtain a fast densification with nearly no during the consolidation of metallic glass materials. In this work, we intend to present the synthesis of a large-scale $Ni_{59}Zr_{15}Ti_{13}Si_3Sn_2Nb_7Al_1$ MGMC containing ductile brass using spark plasma sintering of metallic glass powers. The thermal and mechanical properties of the MGMCs also were reported.

$Ni_{59}Zr_{15}Ti_{13}Si_3Sn_2Nb_7Al_1$ metallic glass powders used in this study were prepared by the high pressure gas atomization process. To produce the MGMCs containing a ductile phase, $Ni_{59}Zr_{15}Ti_{13}Si_3Sn_2Nb_7Al_1$ metallic glass powders and brass powders having a size smaller than 90 ㎛ were uniformly blended. Three composite samples containing different the amounts of brass powders (10, 20, 30 vol%) and a monolithic BMG sample were prepared for comparison. The mixed powders were pre-compacted, and then consolidated to form the disc shape having 20 mm in diameter and 5 mm in thickness by SPS. Structural characterization was performed by X-ray diffractometry(XRD) and optical microscopy(OM). The thermal properties of the samples were measured by differential scanning calorimetry(DSC). Mechanical properties of samples were measured at room temperature under compressive mode with a strain rate of 1×10^{-4} s^{-1}.

Fig. 1 shows typical optical micrographs of the polished cross section of $Ni_{59}Zr_{15}Ti_{13}Si_3Sn_2Nb_7Al_1$ MGMC containing 20 vol% brass by SPS. The ductile brass powders are relatively homogeneously distributed in the metallic glasses matrix without any pores and cavities. Fig. 2 shows typical XRD patterns taken from the monolithic BMG sintered sample and the MGMCs containing the brass powders. The monolithic sample shows a broad halo peak in the 2θ range of 34-47°, a characteristic of the metallic glass structure, while The the MGMCs show sharp peaks diffracted from the brass superimposed on a weak halo pattern, indicating that the matrix of the MGMCs consists of a fully amorphous phase.

Fig. 3 shows the stress-strain curves of the monolithic BMG and MGMC samples tested under the uniaxial compressive condition at room temperature. The monolithic BMG sample exhibits a fracture strength of about 2.4 GPa similar to that of as-cast sample(2.6 GPa) without the plastic deformation. This type stress-strain behavior has been commonly observed in the monolithic BMGs consolidated from metallic glass powders. In contrast, the MGMC samples show some macroscopic plasticity after yielding, and level of plastic strain reaches around 2% in the MGMC containing 30 vol% brass. With increasing the contents of brass phase, the level of plasticity strain increased, although the level of strength decreased. This behavior indicates that the catastrophic failure can be avoided by introducing a ductile second phase in the metallic glass matrix. Fig. 4 shows the optical micrograph of the outer surface of the failed MGMC containing 20 vol% brass. Multiple shear bands initiated from the brass powders are observed. It is also shows that the shear bands are confined within the matrix region between brass phases without propagation through the neighboring brass powders, indicating that the ductile brass powders are effectively played a role to inhibit of propagation of shear bands. Due to the formation of multiple shear bands and the confinement of propagation of shear bands, MGMC sample containing ductile brass powder shows the enhanced macroscopic plasticity under compression without catastrophic failure by a localized deformation on a dominant shear band.

The $Ni_{59}Zr_{15}Ti_{13}Si_3Sn_2Nb_7Al_1$ MGMCs reinforced by brass powders have been successfully synthesized by spark plasma sintering of gas atomized metallic glass powders in the supercooled liquid region. The brass powders are homogeneously distributed in the metallic glass matrix. With increasing the contents of brass phases, the levelof plasticity strain increased, although the level of strength decreased. In the MGMC containing 30 vol% brass, a macroscopic plastic strain around 2 % was achieved. The formation of multiple shear bands and confinement of propagation of shear bands lead to the plastic deformation in the MGMC samples.

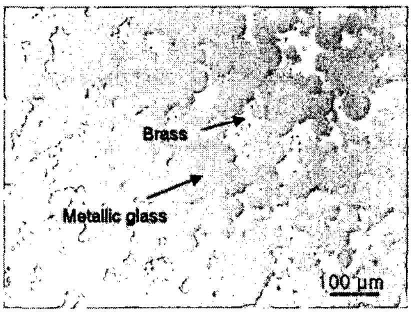

Fig. 1. Optical micrograph of the MGMC containing 20 vol % brass.

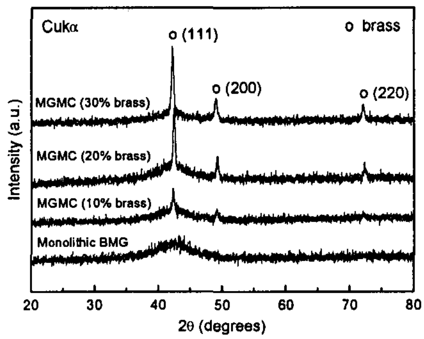

Fig. 2. XRD patterns of the monolithic BMG and MGMCs containing brass.

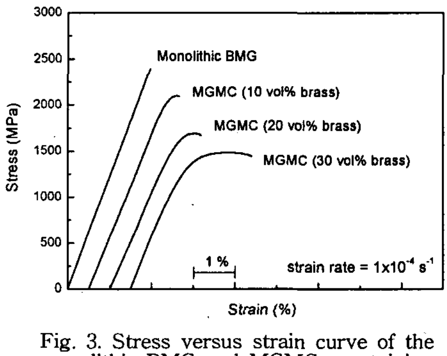

Fig. 3. Stress versus strain curve of the monolithic BMG and MGMCs containing brass.

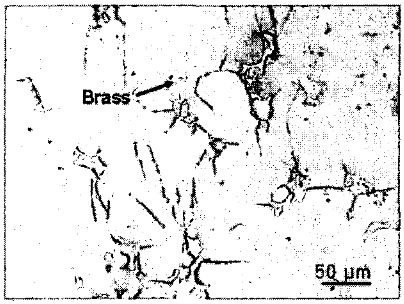

Fig. 4. Optical micrograph obtained from the outer surface of the failed MGMC containing 20 vol% brass.