Consolidation of Bulk Metallic Glass Composites

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Abstract

Bulk metallic glass (BMG) composites combining a $Cu_{54}Ni_6Zr_{22}Ti_{18}$ matrix with brass powders or $Zr_{62}Al_8Ni_{13}Cu_{17}$ metallic glass powders were fabricated by spark plasma sintering. The brass powders and Zr-based metallic glass powders added for the enhancement of plasticity are well distributed homogeneously in the Cu-based metallic glass matrix after consolidation. The BMG composites show macroscopic plasticity after yielding, and the plastic strain increased to around 2% without a decrease in strength for the composite material containing 20 vol% Zr-based amorphous powders. The proper combination of strength and plasticity in the BMG composites was obtained by introducing a second phase in the metallic glass matrix.

Keywords : Bulk metallic glass, consolidation, powder, spark plasma sintering

1. Introduction

Bulk metallic glasses (BMGs) have shown superior properties such as high strength, low Young's modulus and large elastic limit [1]. However, they usually show little overall room temperature plasticity due to the formation of highly localized shear bands under loading, leading to catastrophic failure. This lack of plasticity restricts the industrial applications of BMGs as structural materials. Therefore, it is need to design composite microstructure to overcome this problem. BMG composites have attracted during recent years much attention as a way to further improve mechanical or functional properties compared to monolithic BMGs.

The consolidation of amorphous alloy powders into bulk materials have been received much attention because it enables production without limitations in a sample shape and dimension with novel properties. This consolidation process can be possible using the significant viscous flow of the supercooled liquid [2,3]. However, consolidated monolithic BMGs generally show no macroscopic plasticity.

In this work, we report the consolidation of Cu-based BMG composites containing second phases by spark plasma sintering of metallic glass powders.

2. Experimental and Results

Metallic glass powders ($Cu_{54}Ni_6Zr_{22}Ti_{18}$ and $Zr_{62}Al_8Ni_{13}Cu_{17}$) produced by high pressure gas atomization process and commercial brass powder were used as starting materials. The details of the atomization processing procedures have been given elsewhere [6]. To fabricate the BMG composites, Cu-based metallic glass powders and second powders (brass powders or Zr-based metallic glass powders) were blended in a Tubular blender. In this study, the second phase content was fixed at 20 vol%. The mixed powders were pre-compacted, and then consolidated to form the disc-shape samples with 13 mm in diameter and 5 mm in thickness using spark plasma sintering (SPS) method.

Figs. 1(a) and (b) show OM image of the polished cross section of the Cu-based BMG composite containing 20 vol% brass (CB sample) and SEM image of the Cu-based BMG composite containing 20 vol% Zr-based metallic glass (CZ sample), respectively. In both samples, the second phases (brass and Zr-based metallic glass) were distributed homogeneously in the metallic glass matrix. In the CB sample, the flow stress of brass is relatively lower than that of the matrix viscous flow during consolidation that the mixed powders can be deformed well following the macroscopic shape variation. The CZ sample shows the dual metallic glass phases well deformed, suggesting that the nearly full densification is achieved by flow deformation of powders in the overlapped supercooled liquid region.

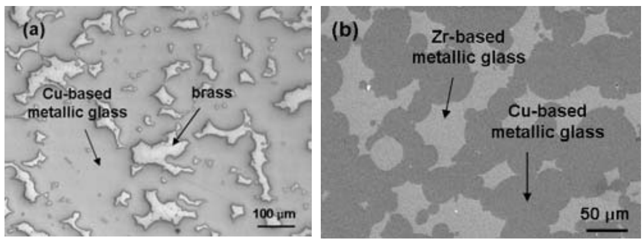

Fig. 1. Micrograph of the Cu-based BMG composites: (a) containing 20 vol% brass and (b) containing 20 vol% Zr-based metallic glass.

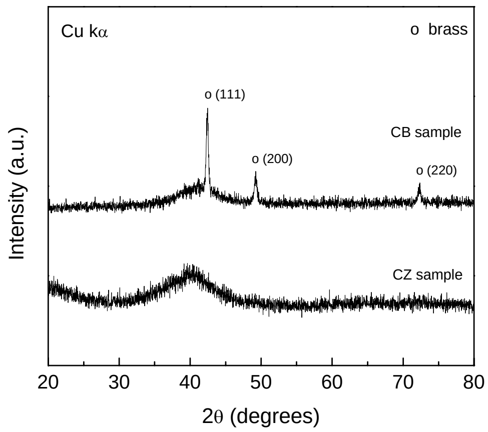

Fig. 2. XRD patterns of the two kinds of the consolidated BMG composite samples.

Fig. 2 shows typical XRD patterns obtained from the two kinds of consolidated BMG composites. The CB sample displays the sharp diffraction peaks of the brass superimposed on the halo pattern, indicating that there is no significant crystallization of the metallic glass matrix, while the CZ material shows a broad peak, superimposed on a weak halo peak, indicating that the BMG composites consist of dual amorphous phases.

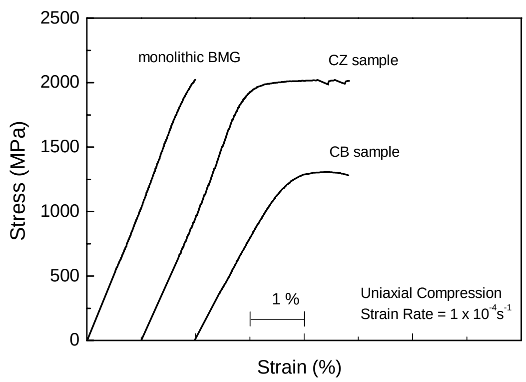

Fig. 3. Stress-strain curves of the monolithic BMG and BMG composites.

Stress-strain curves of the three samples tested under the uniaxial compressive condition at room temperature are shown in Fig. 3. The consolidated monolithic $Cu_{54}Ni_6Zr_{22}Ti_{18}$ BMG exhibits a fracture strength about 2.0 GPa similar to that of as-cast sample (2.1 GPa), but no plastic strain. In contrast, the CB and CZ samples showed some macroscopic plasticity after yielding, and level of plastic strain reached around 1.4% and 2.0%, respectively. The strength of the CB sample is relatively lower than that of the monolithic BMG sample, but the CZ sample, has almost the same compressive strength of 2.0 GPa as the monolithic BMG. In BMG matrix composites, enhancing the total plasticity results from the formation of shear bands initiated from the interface between the second phase and metallic glass matrix as well as of blocking the shear band propagation through its energy absorbing ability [4,5].

3. Summary

The Cu-based BMG composites were obtained after the spark plasma sintering of mixture of gas-atomized amorphous powders and second phase powders, followed by a consolidation process. The formation of BMG composites with enhanced plasticity was successfully achieved by introducing a second phase in the metallic glass matrix. The proper combination of the strength and plasticity in BMG composites may open the possibility of practical applications.

4. References

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