EFFECT OF PROCESSING TEMPERATURE ON FABRICATION OF BIOINSPIRED BULK METALLIC GLASS-ZIRCONIA COMPOSITES WITH LAMELLAR ARCHITECTURE

Taeyoon Kim[1], Hyun Seok Oh[2], Je In Lee[1,*]

[1]*Department of Materials Science and Engineering, Pusan National University, Busan 46241, Republic of Korea*

[2]*Department of Materials Science and Engineering, University of Wisconsin-Madison, Madison, WI 53706, United States*

* *E-mail: jilee@pusan.ac.kr*

ABSTRACT

Bioinspired Zr-based metallic glass (BMG)-zirconia composites with lamellar architecture are fabricated via pressureless infiltration of BMG-forming melt into freeze-cast zirconia. The composites were processed at different temperatures (880 and 1000 ℃) to regulate the interfacial reaction between the glass-forming melt and zirconia. The influence of the processing temperature on microstructure and mechanical properties of the BMG-zirconia composites were investigated.

KEY WORDS

Bioinspired, infiltration, bulk metallic glass, zirconia

1. INTRODUCTION

Metal-matrix composites reinforced with ceramics have attracted interests due to their low density and high specific strength compared to the conventional alloys. Bulk metallic glasses (BMGs) have received attention due to their high strength and large elastic limit. Especially, Zr-based BMGs have been an attractive candidate for a matrix material of BMG composites because of their low melting point, high glass-forming ability [1], and excellent wettability [2-4]. In this study, we report the BMG-ZrO_2 composite with lamellar architecture. A freeze-cast ZrO_2 is infiltrated with a Zr-based glass-forming melt without any applied pressure at 880 and 1000 ℃. The microstructures of the composites are examined to investigate the effect of infiltration temperature on chemical reaction between the glass-forming melt and ZrO_2. Also, the relationship between the microstructure and the mechanical properties of the composites are investigated. The benefits of the composites with lamellar structures are investigated by comparing this study with other BMG-ceramic composites.

2. EXPERIMENTAL PROCEDURES

2.1 Materials

The $Zr_{46}Cu_{30.14}Ag_{8.36}Al_8Be_{7.5}$ (in at. %) bulk glass-forming alloy was used as a metallic material for the present BMG-ceramic composite. The BMG specimen was prepared by arc melting the mixture of pure Zr, Cu, Ag, Al pellets and commercial $Cu_{77.3}Be_{22.7}$ alloy under Ti-gettered Ar atmosphere, and casting into a copper mold. Freeze-cast 3 mol.% yttria partially stabilized zirconia was used as the reinforcement of the BMG-ZrO_2 composites. The scaffold was cut into 2.5 x 2.5 x 15 mm and sealed with the BMG-rod in a quartz under a vacuum atmosphere.

2.2 Methods

The sealed quartz tube was heat-treated at 880 and 1000 ℃ for 10 mins, and rapidly quenched for the formation of the metallic glass phases. The cross-section of the composites was observed using scanning electron microscope (SEM, Mira 3, Tescan). The mechanical properties were analyzed by compressive test using universal testing machine (UTM, QUASAR 50, Galdabini) under a strain rate of 1 x 10^{-4} s^{-1}.

3. RESULTS

Figure 1 shows the results of the compression test of the as-cast BMG and BMG/ZrO_2 composites infiltrated at 880 and 1000 ℃. The composites infiltrated at 880 ℃ showed about 50 % higher strength than the monolithic BMG. However, the composite prepared at 1000 ℃ showed lower compressive strength of 1300 MPa. This result suggests that the corrosion of the zirconia and crystallization of the matrix is responsible for the degradation of the mechanical properties of the BMG/ZrO_2 composites.

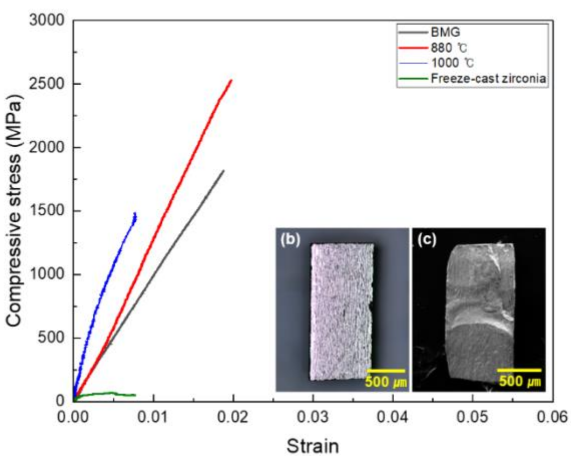

Figure 1. Compressive stress-strain curves of as-cast BMG and BMG/ZrO_2 composites

4. CONCLUSION

In this study, we fabricated lamellar structured BMG/ZrO_2 composites via melt infiltration technique. By applying Zr-based BMG which has excellent wettability to ceramics, the freeze-cast ZrO_2 were successfully infiltrated at each processing temperatures. The crystallization of the metallic layer and the chemical reaction increased as the processing temperature increased, and degradation of mechanical properties were observed. These results would give us the guideline on producing BMG-ceramic composites with excellent mechanical properties.

ACKNOWLEDGEMENTS

This work was supported by the POSCO Science Fellowship of POSCO TJ Park Foundation. T. Kim was supported by 2022-2023 BK21 FOUR Graduate School Innovation Support funded by Pusan National University (PNU-Global Fellowship program).

REFERENCES

1. Liu, T., et al., *Microstructures and Mechanical Properties of ZrC Reinforced (Zr-Ti)-Al-Ni-Cu Glassy Composites by an In Situ Reaction.* Advanced Engineering Materials, 2009. **11**(5): p. 392-398.
2. Ma, G., et al., *Wetting behavior of CuZr-based BMGs/alumina system.* Journal of alloys and compounds, 2008. **462**(1-2): p. 343-346.
3. Shen, P., et al., *Wetting of polycrystalline α-Al 2 O 3 by molten Zr 55 Cu 30 Al 10 Ni 5 metallic glass alloy.* Metallurgical and Materials Transactions A, 2009. **40**: p. 444-449.
4. Shen, P., et al., *Temperature dependence of the wettability between glass-forming alloy Zr55Cu30Al10Ni5 and polycrystalline ZrO2.* Journal of the American Ceramic Society, 2011. **94**(7): p. 2162-2170.