Effect of Sintering Temperature on Electrical Conductivity, Hardness and Friction Properties of Cu/MgB₂ Composites†

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The Cu/MgB₂ composites with MgB₂ content of 10, 20, 30 vol. % were fabricated by pressing-sintering at 800 °C and repressing-resintering at 900 °C. The effect of sintering temperature on the properties of Cu/MgB₂ composites including the relative density, hardness, friction coefficient and electrical conductivity was investigated. The results showed that the decrease of sintering temperature from 900 to 800 °C contributed to the increase of relative density and hardness of Cu/MgB₂ composites with MgB₂ content lower than 30 vol. % and contributed to the increase of friction coefficient and electrical conductivity of Cu-20 % MgB₂ composite. The properties of Cu/MgB₂ composites sintered at 800 °C, which were lower than those sintered at 900 °C, were increased and approximated to those sintered at 900 °C after the repressing-resintering process.

Keywords: Cu/MgB₂ composite, Vacuum sintering, Resintering, Sintering temperature.

INTRODUCTION

Copper is used in a wide variety of commercial applications due to its high electrical and thermal conductivity. The copper matrix composites reinforced by various ceramics such as oxides, carbides and borides have been investigated to improve their mechanical properties¹⁻³. On the other hand, MgB₂ has been widely investigated as a high-temperature superconductor since it was discovered in 2001^{4,5}, such as the effect of copper addition on the superconducting property of MgB₂⁶⁻⁸. In addition, MgB₂ shows particular interest for the photoinduced non-linear optics used for the shift of the phase transitions⁹. However, MgB₂ may serve as a candidate for reinforcement of copper matrix due to its excellent properties such as low density, low electrical resistivity, low linear thermal expansion coefficient and high mechanical properties¹⁰⁻¹².

Previously, Liu *et al.*¹² reported the preparation of Cu/MgB₂ composites by reaction sintering of Cu-Mg-B system. We reported the fabrication of Cu/MgB₂ composites by vacuum sintering of copper and MgB₂¹³. However, the effect of fabrication process in particular the sintering temperature on the properties of Cu/MgB₂ composites is still not clear. Therefore, the effect

of sintering temperature on the electrical conductivity, hardness and friction properties is investigated in this research.

EXPERIMENTAL

The copper powders (270 mesh) mixed with 10, 20, 30 vol. % MgB₂ powders (200 mesh) were used as the starting materials. The Cu/MgB₂ composites were fabricated by pressing-sintering at 800 and 900 °C for 2 h, respectively and then by repressing-resintering at 900 °C for 2 h. The density was measured based on Archimedes drainage method. The hardness was evaluated by Brinell hardness tester. The friction test was performed on a friction tester in a pin-on-disc contact configuration under dry condition at room temperature in air. The applied load was 100 N, the rotation speed was 200 rpm, the counterpart material was 45 steel and the test time was 1800 s. The electrical conductivity was evaluated by eddy current electrical conductivity tester.

RESULTS AND DISCUSSION

Fig. 1 shows the variation of relative density of Cu/MgB₂ composites with MgB₂ content. When the MgB₂ content is

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Fig. 1. Variation of relative density of Cu/MgB₂ composites with MgB₂ content

lower than 30 vol. %, the relative density of Cu/MgB₂ composites sintered at 800 °C is higher than that sintered at 900 °C. In particular, the relative density of Cu-10 % MgB₂ composite is increased by 16.1 %. The relative density of Cu-30 % MgB₂ composite sintered at 800 °C is increased after repressing-resintering at 900 °C and becomes slightly lower than that sintered at 900 °C.

Fig. 2 shows the variation of hardness of Cu/MgB₂ composites with MgB₂ content. When the MgB₂ content is lower than 30 vol. %, the hardness of Cu/MgB₂ composites sintered at 800 °C is higher than that sintered at 900 °C. The hardness of Cu-10 % MgB₂ composite is particularly increased by 48.4 %. The hardness of Cu-30 % MgB₂ composite sintered at 800 °C is increased after repressing-resintering at 900 °C and becomes slightly higher than that sintered at 900 °C.

Fig. 2. Variation of hardness of Cu/MgB₂ composites with MgB₂ content

Fig. 3 shows the variation of average friction coefficient of Cu/MgB₂ composites with MgB₂ content. The average friction coefficient of Cu-20 % MgB₂ composite sintered at 800 °C is 1.5 % higher than that sintered at 900 °C. In addition, the average friction coefficient of Cu-10 % MgB₂ and Cu-30 % MgB₂ composites sintered at 800 °C is increased after repressing-resintering at 900 °C. The average friction coefficient of

Fig. 3. Variation of average friction coefficient of Cu/MgB₂ composites with MgB₂ content

resintered Cu-10 % MgB₂ composite is slightly lower than that sintered at 900 °C and the average friction coefficient of resintered Cu-30 % MgB₂ composite is 5.4 % higher than that sintered at 900 °C.

Fig. 4 shows the variation of electrical conductivity of Cu/MgB₂ composites with MgB₂ content. The electrical conductivity of Cu-20 % MgB₂ composite sintered at 800 °C is 11.9 % higher than that sintered at 900 °C. In addition, the electrical conductivity of Cu-10 % MgB₂ and Cu-30 % MgB₂ composites sintered at 800 °C is increased after repressing-resintering at 900 °C and becomes slightly higher than that sintered at 900 °C.

Fig. 4. Variation of electrical conductivity of Cu/MgB₂ composites with MgB₂ content

By comparing the properties of Cu/MgB₂ composites sintered at 800 and 900 °C, it was found that the relative density, hardness, friction coefficient and electrical conductivity of Cu/MgB₂ composites varied with the sintering temperature. The decrease of sintering temperature from 900 to 800 °C contributed to the increase of relative density and hardness of Cu/MgB₂ composites with MgB₂ content lower than 30 vol. % and contributed to the increase of friction coefficient and electrical conductivity of Cu-20 % MgB₂ composite. On the other hand, it was found that the relative density and hardness of Cu-30 % MgB₂ composite sintered at 800 °C and the friction coefficient and electrical conductivity of Cu-10 % MgB₂ and

Cu-30 % MgB₂ composites sintered at 800 °C could be increased after the repressing-resintering process, which approximated to that sintered at 900 °C.

It is generally accepted that the sintering temperature is a controlling factor in sintering mechanism¹⁴. However, the different effect of sintering temperature on the properties of ceramic reinforced metal matrix composites has been reported^{2,14-16}. At higher sintering temperature, a denser structure could be obtained due to the higher diffusion rate, which then resulted in the higher hardness¹⁴⁻¹⁶. In addition, the higher sintering temperature may cause the formation of a small amount of oxidation, resulting in the lower density and lower electrical conductivity². On the other hand, the grain growth may occur at higher sintering temperature, which would result in the lower hardness^{2,15}. Although the effect of sintering temperature on the electrical conductivity of Cu/MgB₂ composites was observed, the electrical conductivity still showed a declining trend with the increase of MgB₂ content, which can be attributed to the increase in the electron-photon scattering and decrease in the mean free path of electrons and photons due to the increased interface of Cu-MgB₂. Therefore, the properties of as-sintered Cu/MgB₂ composites are a complex function of the sintering temperature and MgB₂ content.¹⁶ In this work, the experimental results revealed that the difference of 100 °C in the sintering temperature is important to improve the properties of Cu/MgB₂ composites. In addition, it was suggested that the higher properties could be obtained by pressing-sintering at 800 °C or combining with repressing-resintering at 900 °C rather than simply by pressing-sintering at 900 °C.

Conclusion

The Cu/MgB₂ composites with MgB₂ content of 10, 20, 30 vol. % were fabricated by pressing-sintering at 800 °C and repressing-resintering at 900 °C and the properties including relative density, hardness, friction coefficient and electrical conductivity were compared with that sintered at 900 °C. The decrease of sintering temperature contributed to the increase of relative density and hardness of Cu/MgB₂ composites with MgB₂ content lower than 30 vol. % and contributed to the increase of friction coefficient and electrical conductivity of Cu-20 % MgB₂ composite by 1.5 and 11.9 %, respectively. In particular, the relative density and hardness of Cu-10 % MgB₂

composite were increased by 16.1 and 48.4 %, respectively. On the other hand, the relative density and hardness of resintered Cu-30 % MgB₂ composite was increased and approximated to that sintered at 900 °C. The average friction coefficient of resintered Cu-10 % MgB₂ composite was increased and approximated to that sintered at 900 °C and the average friction coefficient of resintered Cu-30 % MgB₂ composite was 5.4 % higher than that sintered at 900 °C. The electrical conductivity of resintered Cu-10 % MgB₂ and Cu-30 % MgB₂ composites was increased and approximated to that sintered at 900 °C.

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