Asian Journal of Chemistry; Vol. 26, No. 17 (2014), 5333-5335

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2014.18104

Effect of Sintering Temperature on Electrical Conductivity, Hardness and Friction Properties of Cu/MgB_2 Composites†

QING YANG[1,2,*], JINYANG HUANG[1], JUNTAO ZOU[1,2] and HUITAN FU[3]

[1]Faculty of Material Science and Engineering, Xi'an University of Technology, 5 South Jinhua Road, Xi'an 710048, P.R. China
[2]Shaanxi Province Key Laboratory for Electrical Materials and Infiltration Technology, Xi'an University of Technology, 5 South Jinhua Road, Xi'an 710048, P.R. China
[3]School of Material Science and Engineering, Henan University of Technology, 195 West Zhongyuan Road, Zhengzhou 450007, P.R. China

*Corresponding author: Tel./Fax: +86 29 82312185; E-mail: yangqing@xaut.edu.cn

AJC-15693

The Cu/MgB_2 composites with MgB_2 content of 10, 20, 30 vol. % were fabricated by pressing-sintering at 800 ºC and repressing-resintering at 900 ºC. The effect of sintering temperature on the properties of Cu/MgB_2 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 ºC contributed to the increase of relative density and hardness of Cu/MgB_2 composites with MgB_2 content lower than 30 vol. % and contributed to the increase of friction coefficient and electrical conductively of Cu-20 % MgB_2 composite. The properties of Cu/MgB_2 composites sintered at 800 ºC, which were lower than those sintered at 900 ºC, were increased and approximated to those sintered at 900 ºC after the repressing-resintering process.

Keywords: Cu/MgB_2 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 properties[1-3]. On the other hand, MgB_2 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 MgB_2[6-8]. In addition, MgB_2 shows particular interest for the photoinduced non-linear optics used for the shift of the phase transitions[9]. However, MgB_2 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 properties[10-12].

Previously, Liu *et al.*[12] reported the preparation of Cu/MgB_2 composites by reaction sintering of Cu-Mg-B system. We reported the fabrication of Cu/MgB_2 composites by vacuum sintering of copper and MgB_2[13]. However, the effect of fabrication process in particular the sintering temperature on the properties of Cu/MgB_2 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. % MgB_2 powders (200 mesh) were used as the starting materials. The Cu/MgB_2 composites were fabricated by pressing-sintering at 800 and 900 ºC for 2 h, respectively and then by repressing-resintering at 900 ºC 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/MgB_2 composites with MgB_2 content. When the MgB_2 content is

†Presented at 2014 Global Conference on Polymer and Composite Materials (PCM2014) held on 27-29 May 2014, Ningbo, P.R. China

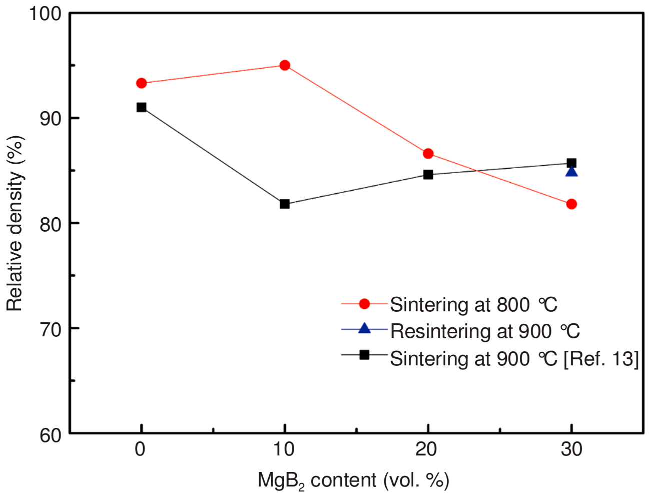

Fig. 1. Variation of relative density of Cu/MgB_2 composites with MgB_2 content

lower than 30 vol. %, the relative density of Cu/MgB_2 composites sintered at 800 ºC is higher than that sintered at 900 ºC. In particular, the relative density of Cu-10 %MgB_2 composite is increased by 16.1 %. The relative density of Cu-30 % MgB_2 composite sintered at 800 ºC is increased after repressing-resintering at 900 ºC and becomes slightly lower than that sintered at 900 ºC.

Fig. 2 shows the variation of hardness of Cu/MgB_2 composites with MgB_2 content. When the MgB_2 content is lower than 30 vol. %, the hardness of Cu/MgB_2 composites sintered at 800 ºC is higher than that sintered at 900 ºC. The hardness of Cu-10 % MgB_2 composite is particularly increased by 48.4 %. The hardness of Cu-30 % MgB_2 composite sintered at 800 ºC is increased after repressing-resintering at 900 ºC and becomes slightly higher than that sintered at 900 ºC.

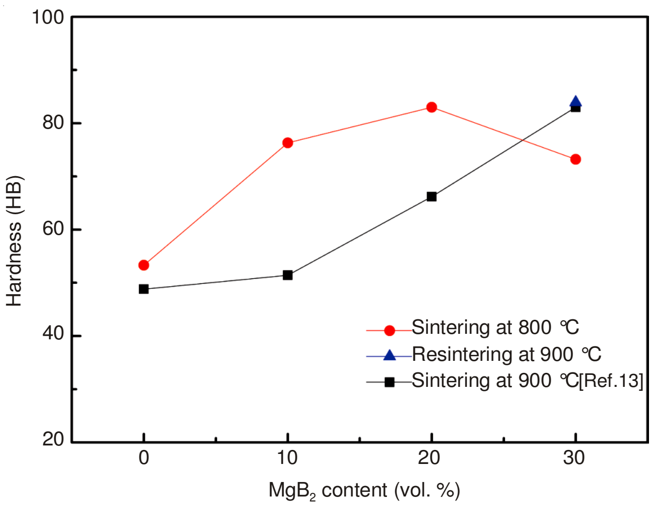

Fig. 2. Variation of hardness of Cu/MgB_2 composites with MgB_2 content

Fig. 3 shows the variation of average friction coefficient of Cu/MgB_2 composites with MgB_2 content. The average friction coefficient of Cu-20 % MgB_2 composite sintered at 800 ºC is 1.5 % higher than that sintered at 900 ºC. In addition, the average friction coefficient of Cu-10 % MgB_2 and Cu-30 % MgB_2 composites sintered at 800 ºC is increased after repressing-resintering at 900 ºC. The average friction coefficient of

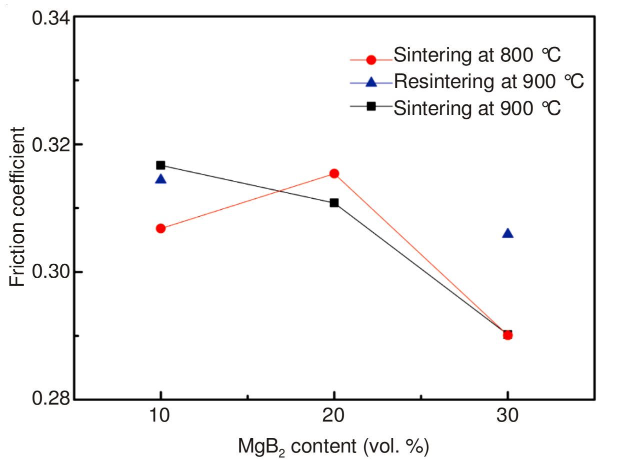

Fig. 3. Variation of average friction coefficient of Cu/MgB_2 composites with MgB_2 content

resintered Cu-10 % MgB_2 composite is slightly lower than that sintered at 900 ºC and the average friction coefficient of resintered Cu-30 % MgB_2 composite is 5.4 % higher than that sintered at 900 ºC.

Fig. 4 shows the variation of electrical conductivity of Cu/MgB_2 composites with MgB_2 content. The electrical conductivity of Cu-20 % MgB_2 composite sintered at 800 ºC is 11.9 % higher than that sintered at 900 ºC. In addition, the electrical conductivity of Cu-10 % MgB_2 and Cu-30 % MgB_2 composites sintered at 800 ºC is increased after repressing-resintering at 900 ºC and becomes slightly higher than that sintered at 900 ºC.

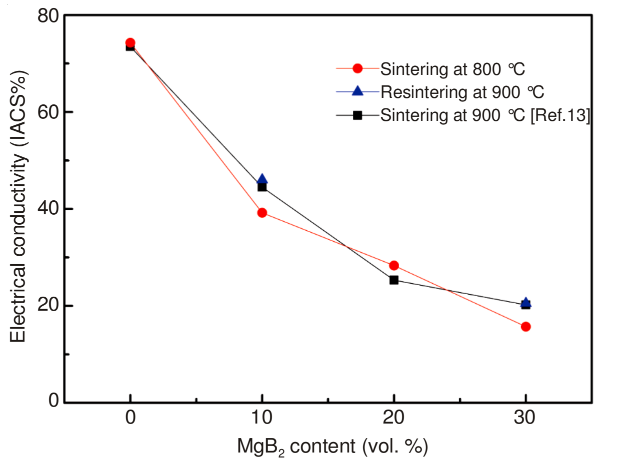

Fig. 4. Variation of electrical conductivity of Cu/MgB_2 composites with MgB_2 content

By comparing the properties of Cu/MgB_2 composites sintered at 800 and 900 ºC, it was found that the relative density, hardness, friction coefficient and electrical conductivity of Cu/MgB_2 composites varied with the sintering temperature. The decrease of sintering temperature from 900 to 800 ºC contributed to the increase of relative density and hardness of Cu/MgB_2 composites with MgB_2 content lower than 30 vol. % and contributed to the increase of friction coefficient and electrical conductively of Cu-20 % MgB_2 composite. On the other hand, it was found that the relative density and hardness of Cu-30 % MgB_2 composite sintered at 800 ºC and the friction coefficient and electrical conductively of Cu-10 % MgB_2 and

Cu-30 % MgB_2 composites sintered at 800 ºC could be increased after the repressing-resintering process, which approximated to that sintered at 900 ºC.

It is generally accepted that the sintering temperature is a controlling factor in sintering mechanism[14]. 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 hardness[14-16]. In addition, the higher sintering temperature may cause the formation of a small amount of oxidation, resulting in the lower density and lower electrical conductivity[2]. 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/MgB_2 composites was observed, the electrical conductivity still showed a declining trend with the increase of MgB_2 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-MgB_2. Therefore, the properties of as-sintered Cu/MgB_2 composites are a complex function of the sintering temperature and MgB_2 content.[16] In this work, the experimental results revealed that the difference of 100 ºC in the sintering temperature is important to improve the properties of Cu/MgB_2 composites. In addition, it was suggested that the higher properties could be obtained by pressing-sintering at 800 ºC or combining with repressing-resintering at 900 ºC rather than simply by pressing-sintering at 900 ºC.

Conclusion

The Cu/MgB_2 composites with MgB_2 content of 10, 20, 30 vol. % were fabricated by pressing-sintering at 800 ºC and repressing-resintering at 900 ºC and the properties including relative density, hardness, friction coefficient and electrical conductivity were compared with that sintered at 900 ºC. The decrease of sintering temperature contributed to the increase of relative density and hardness of Cu/MgB_2 composites with MgB_2 content lower than 30 vol. % and contributed to the increase of friction coefficient and electrical conductively of Cu-20 % MgB_2 composite by 1.5 and 11.9 %, respectively. In particular, the relative density and hardness of Cu-10 % MgB_2 composite were increased by 16.1 and 48.4 %, respectively. On the other hand, the relative density and hardness of resintered Cu-30 % MgB_2 composite was increased and approximated to that sintered at 900 ºC. The average friction coefficient of resintered Cu-10 % MgB_2 composite was increased and approximated to that sintered at 900 ºC and the average friction coefficient of resintered Cu-30 % MgB_2 composite was 5.4 % higher than that sintered at 900 ºC. The electrical conductivity of resintered Cu-10 % MgB_2 and Cu-30 % MgB_2 composites was increased and approximated to that sintered at 900 ºC.

ACKNOWLEDGEMENTS

A part of this work is supported by China Postdoctoral Science Foundation Funded Project (No. 2013M532071) and Shaanxi Provincial Project of Special Foundation of Key Disciplines, China.

REFERENCES

1. K. Dash, B.C. Ray and D. Chaira, *J. Alloys Comp.*, **516**, 78 (2012).
2. G. Celebi Efe, T. Yener, I. Altinsoy, M. Ipek, S. Zeytin and C. Bindal, *J. Alloys Comp.*, **509**, 6036 (2011).
3. J.S. Kim, D.V. Dudina, J.C. Kim, Y.S. Kwon, J.J. Park and C.K. Rhee, *J. Nanosci. Nanotechnol.*, **10**, 252 (2010).
4. J. Nagamatsu, N. Nakagawa, T. Muranaka, Y. Zenitani and J. Akimitsu, *Nature*, **410**, 63 (2001).
5. P.C. Caneld, S.L. Bud'ko and D.K. Finnemore, *Physica C*, **385**, 1 (2003).
6. M.A. Aksan, A. Guldeste, Y. Balci and M.E. Yakinci, *Solid State Commun.*, **137**, 320 (2006).
7. Z.Q. Ma, Y.C. Liu, Q.Z. Shi, Q. Zhao and Z.M. Gao, *Supercond. Sci. Technol.*, **21**, 065004 (2008).
8. Y. Tang, X. Kong and J. Zang, *Physica C*, **469**, 1902 (2009).
9. N.S. AlZayed, I.V. Kityk, S. Soltan, A. Wojciechowski, A.O. Fedorchuk, G. Lakshminarayana and M. Shahabuddin, *J. Alloys Comp.*, **594**, 60 (2014).
10. P.C. Canfield, D.K. Finnemore, S.L. Bud'ko, J.E. Ostenson, G. Lapertot, C.E. Cunningham and C. Petrovic, *Phys. Rev. Lett.*, **86**, 2423 (2001).
11. W. Goldacker, S.I. Schlachter, S. Zimmer and H. Reiner, *Supercond. Sci. Technol.*, **14**, 787 (2001).
12. D.B. Liu, M.F. Chen, A. Rauf, C.X. Cui and J.J. Tan, *J. Alloys Comp.*, **466**, 87 (2008).
13. Q. Yang, J. Zou, Z. Liu and X. Yu, *Mater. Sci. Forum*, **749**, 141 (2013).
14. M. Rahimian, N. Ehsani, N. Parvin and H.R. Baharvandi, *Mater. Des.*, **30**, 3333 (2009).
15. M. Rahimian, N. Ehsani, N. Parvin and H.R. Baharvandi, *J. Mater. Process. Technol.*, **209**, 5387 (2009).
16. B. Leszczynska-Madej, *Arch. Metall. Mater.*, **58**, 43 (2013).