Proceedings of the 3rd International Congress APMAS2013, April 24–28, 2013, Antalya, Turkey

Comparing of Commercial and Cemented Cu–SiC Composites

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SiC with 30 μm particle size reinforced copper composites have been fabricated by powder metallurgy method and sintered at 700 °C for 2 h in open atmosphere. Copper powder was produced by cementation method and obtained as commercial for comparing. Cemented and commercial copper powders were reinforced with SiC having 30 μm particle size at ratios of 0, 1, 2, 3, and 5 wt% for improving mechanical properties of copper without decreasing the electrical conductivity. The presence of Cu and SiC which are dominant components in the sintered composites were confirmed by X-ray diffraction analyses technique. Scanning electron microscope showed that SiC particles are distributed homogeneously in the copper matrix. The relative densities of Cu and Cu–SiC composites sintered at 700 °C are ranged from 98.0% to 96.2% for commercial Cu–SiC composites, 97.55 to 95.0% for cemented Cu–SiC composites, microhardness of composites ranged from 133 to 277 HV for commercial Cu–SiC composites and 127 to 229 HV for cemented Cu–SiC composites, and the electrical conductivity of composites changed between 95.6%IACS and 77.2%IACS for commercial Cu–SiC composites, 91.7%IACS and 69%IACS for cemented Cu–SiC composites. It was observed that there is a good agreement between cemented Cu–SiC and commercial Cu–SiC composites.

DOI: 10.12693/APhysPolA.125.417

PACS: 81.05.Bx, 81.05.Je, 81.05.Ni

1. Introduction

Copper is a mostly used industrial and functional metal for various thermal and electronic applications, i.e. electronic packaging, electrical contacts, and resistance welding electrodes. This is because of good thermal and electrical conductivity, high plasticity and excellent resistance to corrosion and oxidation. Copper is present in the wastewaters of many industries, often at high concentration. Due to its cost, it is incentive to recover it from wastewaters. The most used recovery methods are chemical precipitation, ion exchange, carbon adsorption, reverse osmosis, and electrodialysis, all of them have drawbacks. Cementation is the recovery of an ionized metal from solution by spontaneous electrochemical reduction to its elemental metallic state, with consequent oxidation of a sacrificial metal. The cementation process has several advantages, such as recovery of metals in essentially pure metallic form, simple control requirements and low energy consumption [1, 2].

In this study copper powder was produced by cementation method and obtained as commercial for comparison. Nevertheless, the low mechanical property at both room and high temperatures limits the extensive application of pure copper [3]. Composites are of interest because combining different materials often yields properties that go far beyond the law of mixtures. The addition of ceramic reinforcements such as carbides and oxides to form metal matrix composites enhances the properties such as elastic modulus, strength, wear resistance, and high-temperature durability. Metal matrix composites are broadly used in components of various pieces of industrial equipment [4]. It is well documented that the reinforcement of copper with ceramic particulates significantly improves the high-temperature mechanical properties and wear resistance without severe deterioration of thermal and electrical conductivities of the matrix. Therefore, Cu-based composites are considered to be promising candidates for applications where high conductivity, high mechanical properties, and good wear resistance are required [5].

SiC could be used as a reinforcement to enhance the strength of copper matrix. SiC/copper composites combine both the superior ductility and toughness of copper and high strength and high modulus of SiC reinforcements [6]. In recent years, Cu/SiC composites have received considerable attention to meet the challenges of thermal management in the rapidly increasing power of advanced electronics. It is the most expected candidate to be used as electrical contact materials in relays, contactors, switches, circuit breaks, and electrical brushes in rotation or sliding devices [4, 6]. The aim of this study is to improve hardness of ductile copper at the same time to keep the electrical conductivity at a reasonable level and to compare these properties of commercial and cemented Cu/SiC composites.

2. Experimental study

Commercial copper with a particle size of 10 μm, cemented copper with a particle size of approximately 2–6 μm, and SiC powders with a particle size of 30 μm were used as starting materials. Cementation of copper from $CuSO_4$ solutions using metallic iron powder was performed. Cemented and commercial copper powders

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were reinforced with SiC having 30 μm particle size at ratios of 0, 1, 2, 3, and 5 wt%, respectively. This powder mixtures were compacted by uniaxial hydraulic press and then sintered at 700 °C for 2 h in open atmosphere to obtain composites. As sintered composites were exposed to X-ray diffraction (XRD) analysis using Cu K_α radiation with a wavelength of 1.5418 Å in order to determine the phases formed in the composites body. Microstructures of the samples were examined by JEOL LV6000 scanning electron microscope (SEM). Energy dispersive X-ray spectroscopy (EDS) analysis was conducted to detect Cu, SiC, and possible copper oxides, copper–silicon compounds within the Cu–SiC interfaces. The relative density of the composites was measured according to Archimedes' principle, the microhardness and the electrical conductivity of both pure copper and composites were determined by Vickers indenter and GE model electrical resistivity measurement instrument. The results of electrical conductivity values were performed on the polished samples. The electrical conductivity of samples was determined by taking inverse of resistivity.

3. Results and discussions

SEM micrographs and EDS analyses of sintered commercial and cemented Cu–SiC composites with 5 wt% SiC were given in Fig. 1. SEM studies showed that Cu–SiC composites manufactured by powder metallurgy technique have a dense and homogeneous structure and SiC particles are uniformly distributed around copper particles. In micrographs black and cornered phases indicate the SiC, light grey areas indicate the Cu matrix, white areas probably indicate alumina resulting from polishing and do not characterize any phase and they result from altitude difference.

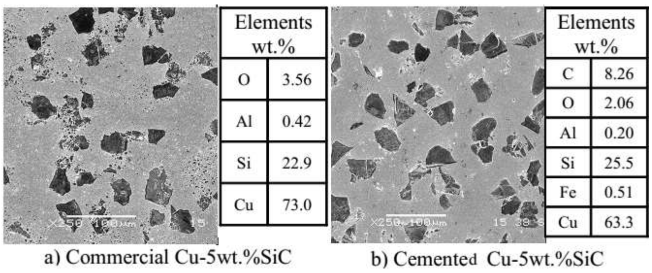

Fig. 1. SEM micrographs and EDS analyses of (a) commercial and (b) cemented Cu–5 wt% SiC composites sintered at 700 °C for 2 h.

It was verified by SEM–EDS analysis of cemented Cu–SiC composites that grey areas in micrographs contain Fe and O (Fig. 2). Fe resulted from the production of copper powder by cementation process and was oxidized at sintering temperature. In addition, in order to see distribution of Cu, Si, C, Al, and O_2, SEM map analyses were conducted for copper–SiC composite containing 3 wt% SiC (Fig. 3). Black shapes indicate SiC particles and oxygen and aluminium exists together. XRD analysis revealed that the dominant components of composites produced by powder metallurgy method are Cu and SiC (Fig. 4).

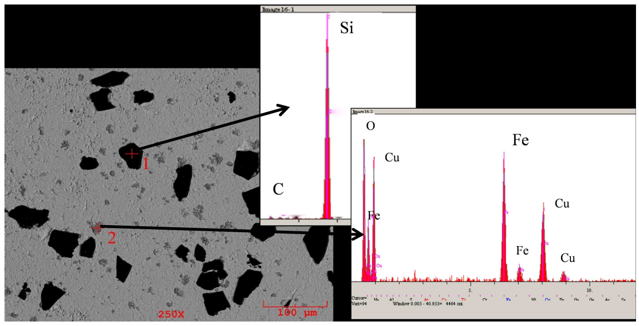

Fig. 2. SEM micrograph and EDS analyses of cemented Cu–SiC composites including 1 wt% SiC.

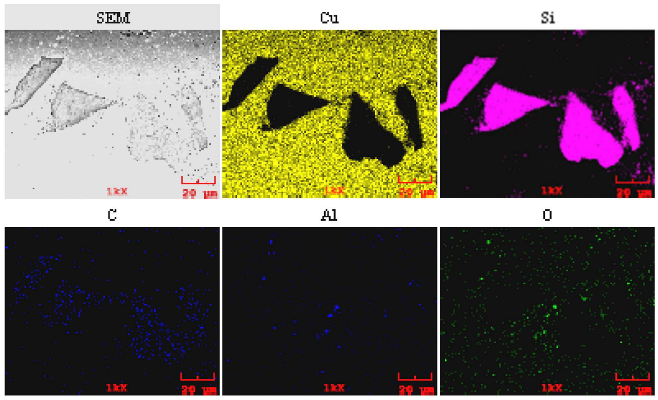

Fig. 3. SEM map analyses of Cu–3 wt% SiC composite sintered at 700 °C.

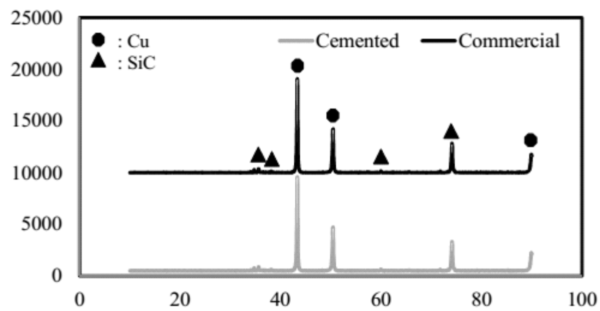

Fig. 4. XRD diffraction patterns of cemented and commercial Cu–SiC composites including 5 wt% SiC.

Relative density, hardness and electrical conductivity values of sintered commercial and cemented pure copper and Cu–SiC composites were given in Table. From Table, the relative density and the electrical conductivities of the both commercial and cemented Cu–SiC composites decreased, while microhardness values of them increased with the increment in the amounts of SiC. Nevertheless, electrical conductivity of the samples decreased by decreasing the relative density because lower density means higher porosity which acts insulation barrier for electron passthrough between Cu grains [2]. On the other hand, microhardness measurements were carried out by taking care that the indenter marks enclose Cu and SiC regions homogeneously.

TABLE

Relative densities, hardnesses and electrical conductivity values of commercial and cemented Cu–SiC composites.

	Properties	wt% SiC				
		0	1	2	3	5
Commercial	relative density [%]	98.0	97.7	97.4	96.9	96.2
	hardness [HV]	133	215	230	248	277
	electrical conductivity [%IACS]	95.6	91.3	87.0	84.6	77.2
Cemented	relative density [%]	97.5	97.0	96.5	95.4	95.0
	hardness [HV]	127	188	192	202	229
	electrical conductivity [%IACS]	91.7	83.0	80.5	72.4	69.0

In this study commercial and cemented copper matrix composites reinforced with 1 wt%, 2 wt%, 3 wt%, and 5 wt% SiC particles were manufactured successfully by powder metallurgy method. The distribution of SiC grains into Cu matrix is homogeneous and they are generally concentrated at grain boundaries of Cu grains. The relative densities of commercial Cu–SiC composites, sintered at 700 °C, are ranged from 98 to 96.2%, microhardness of composites ranged from 133 to 277 HVN and the electrical conductivity of composites changed between 95.6 and 77.2% IACS. The relative densities of cemented Cu–SiC composites, sintered at 700 °C, are ranged from 97.5 to 95.0%, microhardness of composites ranged from 127 to 229 HVN and the electrical conductivity of composites changed between 91.7 and 69.0% IACS. It can be claimed that cemented copper matrix can replace instead of commercial copper matrix.

Acknowledgments

The authors thank to experts Fuat Kayis for performing XRD and SEM–EDS studies and special appreciation are extended to technician Ersan Demir of Sakarya University for assisting with experimental studies. This work was conducted as project supported by TÜBİTAK (Scientific and Technological Research Council of Turkey) with contract number of 106M118.

References

[1] A. Dib, A.L. Makhloufi, *Chem. Eng. Proc.* **43**, 1265 (2004).

[2] M. Barmouz, M.K.B. Givi, J. Seyfi, *Mater. Charácter.* **62**, 108 (2011).

[3] G. Celebi Efe, I. Altinsoy, T. Yener, M. Ipek, S. Zeytin, C. Bindal, *Vacuum* **85**, 643 (2010).

[4] O. Ghaderi, M.R. Toroghinejad, A. Najafizadeh, *Mater. Sci. Eng. A* **565**, 243 (2013).

[5] M.R. Akbarpour, E. Salahi, H. Alikhani Fesari, E.Y. Yoon, H.S. Kim, A. Simchi, *Mater. Sci. Eng. A* **568**, 33 (2013).

[6] G.F. Celebi Efe, I. Altinsoy, M. Ipek, S. Zeytin, C. Bindal, *Kovove Mater.* **49**, 131 (2011).