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An investigation of the effect of SiC particle size on Cu–SiC composites

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ABSTRACT

In this study mechanical properties of copper were enhanced by adding 1 wt.%, 2 wt.%, 3 wt.% and 5 wt.% SiC particles into the matrix. SiC particles of having 1 μm, 5 μm and 30 μm sizes were used as reinforcement. Composite samples were produced by powder metallurgy method and sintering was performed in an open atmospheric furnace at 700 °C for 2 h. Optical and SEM studies showed that the distribution of the reinforced particle was uniform. XRD analysis indicated that the dominant components in the sintered composites were Cu and SiC. Relative density and electrical conductivity of the composites decreased with increasing the amount of SiC and increased with increasing SiC particle size. Hardness of the composites increased with both amount and the particle size of SiC particles. A maximum relative density of 98% and electrical conductivity of 96% IACS were obtained for Cu–1 wt.% SiC with 30 μm particle size.

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1. Introduction

Today, copper and copper alloys remain one of the major groups of commercial metals, ranking third behind only iron/steel and aluminum in production and consumption. They are widely used because of their excellent electrical and thermal conductivities, outstanding resistance to corrosion, ease of fabrication, and good strength and fatigue resistance. Pure copper is used extensively for cables and wires, electrical contacts, and a wide variety of other parts that are required to pass electrical current [1]. But its application at high temperature is limited due to poor mechanical properties [2,3]. Adding hard particles into copper matrix, not only enhances the mechanical performance and wear resistance but also keeps its desirable electrical and thermal conductivity, thus the application scope of copper is extended [4,5]. Among copper-based composites, high strength, high conductivity, resistance to high temperatures, and wear, are very important and necessary qualities for electric contact materials, resistant electrodes, and many other industrial applications as compared to pure copper and copper alloys [6–10]. Copper-base metal matrix composites with reinforcing ceramic particles such as oxides, borides and carbides were developed to utilize as electrode materials because the ceramic particles are stable at high temperatures [11]. SiC particles could be used as reinforcement material to enhance the strength of copper matrix [12]. The mechanical and physical characteristics, especially the high specific strength and modulus of the SiC-fibers, make them an interesting choice for reinforcing metal and ceramic matrix composites. Temperatures up to 800 °C have no significant effect on these properties [13], thus SiC is a key candidate for high-temperature applications [14]. Cu–SiC composites have attracted strong interest as they combine high thermal and electrical conductivity with mechanical strength, mouldability and low production cost [12,15,16]. They could be used as electrical contact materials in relays, contactors, switches, circuit breaks, electronic packaging where good electrical and thermal conductivity as well as welding or brazing properties are required [12,16]. In the present work SiC particle reinforced copper matrix composites were produced by powder metallurgy technique. Influence of the particle size and concentration of SiC on mechanical and electrical properties of copper were studied. The morphology, microstructure, microhardness, and electrical property of Cu/SiC composite have been investigated.

2. Experimental details

2.1. Production of test materials

In order to manufacture Cu–SiC composites copper powder with 99.9 percent (pct) purity and 10 μm particle size and SiC powder with 99.5 percent (pct) purity and 1, 5 and 30 μm particle size were used as starting materials. The powders including 1 wt.%, 2 wt.%, 3 wt.% and 5 wt.% SiC reinforcement were mixed mechanically. Prior to sintering, the mixture was cold pressed into a cylindrical compact in a metal die of 15 mm in diameter under a axial pressure of 280 MPa (Fig. 1). The sintering of Cu and Cu–SiC composites were performed at 700 °C for 2 h in an open atmospheric furnace. Within the furnace compacted samples were embedded

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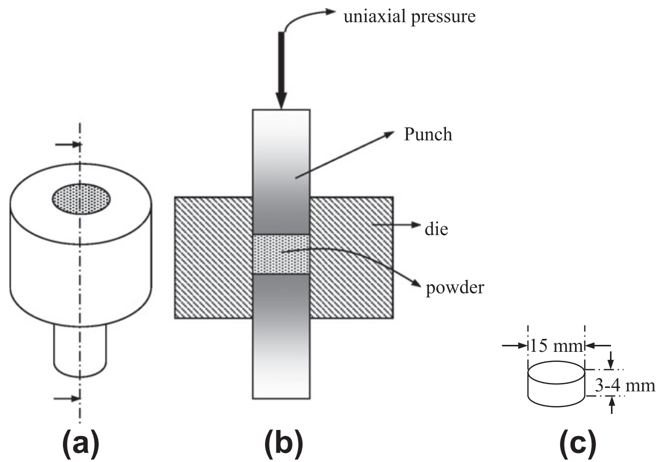

Fig. 1. Schematic presentation of die used: (a) die, (b) cross-section of die, and (c) pressed compact sample.

into the graphite powder. As soon as the samples were removed from the furnace at 700 °C they were immediately pressed with a load of 850 MPa in order to increase the relative density and electrical conductivity.

2.2. Characterization

Phase analyses of starting powders and sintered samples were performed via Rigaku X-ray diffractometer by using Cu Kα radiation with a wavelength of 1.5418 A over a 2θ range of 10–90°. The relative densities of the samples were measured using the Archimedes' principle. Microstructural analyses were performed by scanning electron microscopy and optical microscopy. In order to detect the Cu, SiC and any oxide of Cu and SiC particles, EDS analyses were performed. Microhardness of both pure copper and composites were determined using Vickers indentation technique with a load of 50 g for Cu–SiC composites with 1 μm SiC particle, and of 100 g for the composites with 5–30 μm SiC particle. The samples were first surface finished and then five measurements were performed on each sample and averaged to obtain the accurate hardness of the specimen. Microhardness measurements were performed by taking care of the indentation mark to include the Cu grains and SiC particles homogenously. Electrical conductivities of polished samples were determined by GE model electric resistivity measurement instrument.

3. Results and discussion

3.1. Microstructure

Fig. 2 illustrates the SEM microstructures of Cu powder and SiC reinforcement agent of different particle size. As can be seen copper powder is in spherical shape and 10 μm size and SiC particles are in irregular and angular shape and 1, 5, 30 μm size.

Microstructural morphologies of polished surfaces of the sintered composites reinforced with SiC particles of different sizes were shown in Fig. 3. Grey regions imply Cu matrix and dark grey and cornered particles imply the reinforcement component of SiC.

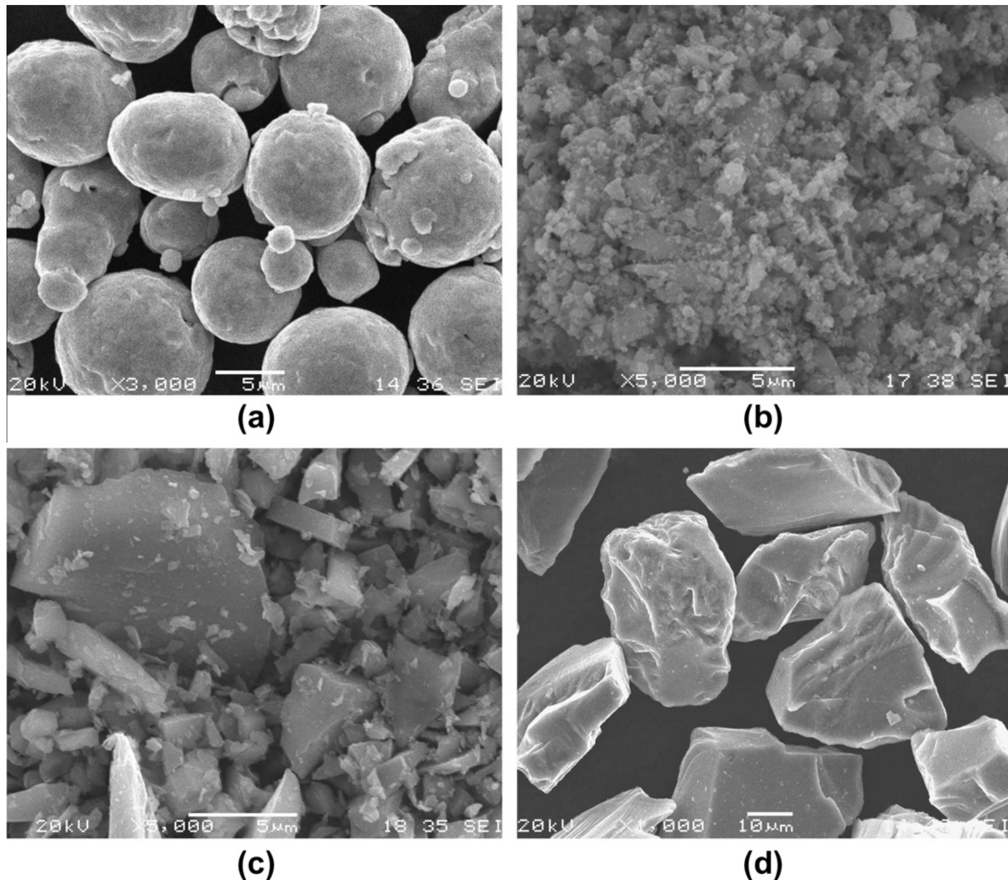

Fig. 2. SEM micrographs of starting powders of: (a) Cu powder with 10 μm particle size, (b) SiC powder with 1 μm particle size, (c) SiC powder with 5 μm particle size, and (d) SiC powder with 30 μm particle size.

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