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Some Properties of Cu-B_4C Composites Manufactured by Powder Metallurgy

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Abstract

In this study, some properties of cold pressed Cu-B4C composites were investigated. Commercial copper powders with 40 µm particle size were reinforced with B4C in a 40µm particle size at ratios of 0, 1, 2, 3 wt.% for improving mechanical properties of copper used for electrical conductivity. Cu-B4C composites have been fabricated by powder metallurgy method and sintered at 700□C for 2h in open atmosphere and then subjected to cold pressing following sintering process. The presence of Cu and B4C which are dominant components in the sintered composites were confirmed by X-ray diffraction analyses technique and SEM-EDS. Scanning electron microscope (SEM-EDS) was showed that B4C particles are distributed homogenously in the copper matrix. The relative densities of Cu and Cu-B4C composites sintered at 700°C are ranged from 97.5% to 90.19%. Microhardness of composites ranged from 80.65 to 87.5 HB and the electrical conductivity of composites changed between 90.04 %IACS and 68.87 %IACS. It was observed that cold pressed Cu - 1 wt.% B4C composites revealed promising physical properties.

Keywords: Cu-B_4C composites, cold pressing, electrical conductivity, powder metallurgy.

1. INTRODUCTION

In recent years, copper is widely used in industrial applications due to its high electrical and thermal conductivities, low cost (comparing with Ag and Au) and ease of fabrication. However, the relatively low hardness, low strength and poor wear resistance limit its extensive applications. These shortcomings could be avoided by the incorporation of ceramics into the copper matrix, such as oxides, carbides and borides [1, 2]. The incorporation of ceramic particulate reinforcement can improve the high temperature mechanical property and wear resistance significantly, without severe deterioration of thermal and electrical conductivity of the matrix [3]. Among the various ceramic particles, Al_2O_3, SiC and TiB_2 particles are commonly used. The particle reinforced metal matrix composites can be synthesized by such methods as standard ingot metallurgy (IM), powder metallurgy (PM), disintegrated melt deposition (DMD) technique, spray atomization and co-deposition approach. Different method results in different properties. The PM processing route is generally preferred since it shows a number of product advantages. Powder metallurgy process (PM) lends itself well for economical mass production components. Different metal matrix composites are manufactured by this PM route. The uniform distribution of ceramic particle reinforcements is readily realized. On the other hand, the solid-state process minimizes the reactions between the metal matrix and the ceramic reinforcement, and thus enhances the bonding between the reinforcement and the matrix. However, the coefficient of thermal expansion (CTE) mismatch between the reinforcement and the matrix will give rise to high residual stress, which leads to the low tensile ductility of the composite [4]. Boron carbide (B_4C) cermets and boron carbide-based composites serve as promising materials for a variety of applications that require elevated mechanical properties, high neutron absorption cross section, high melting point, good wear and corrosion resistance [5, 6]. Boron carbide (B_4C) serves as a potential reinforcement for making composite material due to its high hardness (2900–3900kg/mm^2), high neutron absorption cross-section and excellent thermo-electrical properties in addition to low density (2.52 g/cm^3), high melting point (~2450 ◦C), high elastic modulus (448 GPa) and chemical inertness. B_4C high modulus ratio (1.8×10^7 m) and preserved hardness even at temperatures above 1100 ◦C makes it as a strengthening medium in high temperature applications. These unique properties of B_4C at room and high temperature makes it a key material for various high technology applications, such as fast-breeders, neutron moderators in nuclear reaction, power generation in deep space flight applications, microelectronic, medicinal, light-duty bulletproof armors, blasting nozzles, abrasive water-jet cutting equipment, high temperature thermoelectric devices, high-temperature structural parts, cutting tools, rocket propellants, wear-proof parts and thermo-mechanical applications [7]. However, one drawback of

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the boron carbide is lower thermal conductivity (TC). The research about improving the TC of the B_4C cermets and boron carbide-based composites is much less, two authors have previously fabricated B_4C/metal and B_4C/C composites to obtain high thermal conductivity materials, respectively [5].

In the present investigation, ceramic based B_4C is introduced to metallic copper to improve mechanical properties of copper.

2. EXPERIMENTAL DETAILS

Commercial copper with a particle size of 40 µm and SiC powders with a particle size of approximately 40 µm were used as starting materials. Commercial copper powders were reinforced with B_4C at ratios of 0, 1, 2 and 3 wt.%, respectively. These powder mixtures were compacted by unaxial hydrolic press and then sintered at 700°C for 2h in open atmosphere for manufacturing composite samples. Then, sintered composites were exposed to cold pressing by unaxial hydrolic press with a pressure of 180 bar. Following the manufacturing process, composites were analyzed by XRD technique using Cu Kα radiation with a wavelength of 1.5418˚A in order to determine the phases formed in the composites body. Microstructures of the samples were examined by Jeol LV6000 scanning electron microscope and Nikon Eclipse optical microscope. EDS analysis was conducted to detect Cu, B_4C and possible copper oxides, copper-boron compounds within and at Cu-B_4C interfaces. The relative density of the composites was measured according to Archimed's principle, the microhardness and the electrical conductivity of both pure copper and composites were determined by Brinell Hardness with a load of 31.25 kg 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 DISCUSSION

3.1. Microstructure

Optical micrographs of pure copper and Cu-B_4C composites sintered at 700°C for 2 hours were shown in Figure 1. As it can be seen in Fig., copper matrix is seen as light colored areas and black-cornered shapes denote B_4C particles. Reinforcement particles, It was observed that B_4C were homogenously distributed in the copper matrix. Copper grain boundaries are distinguishable from the microstructures after the etching of samples with nitride acid of 10% solution (Fig.1).

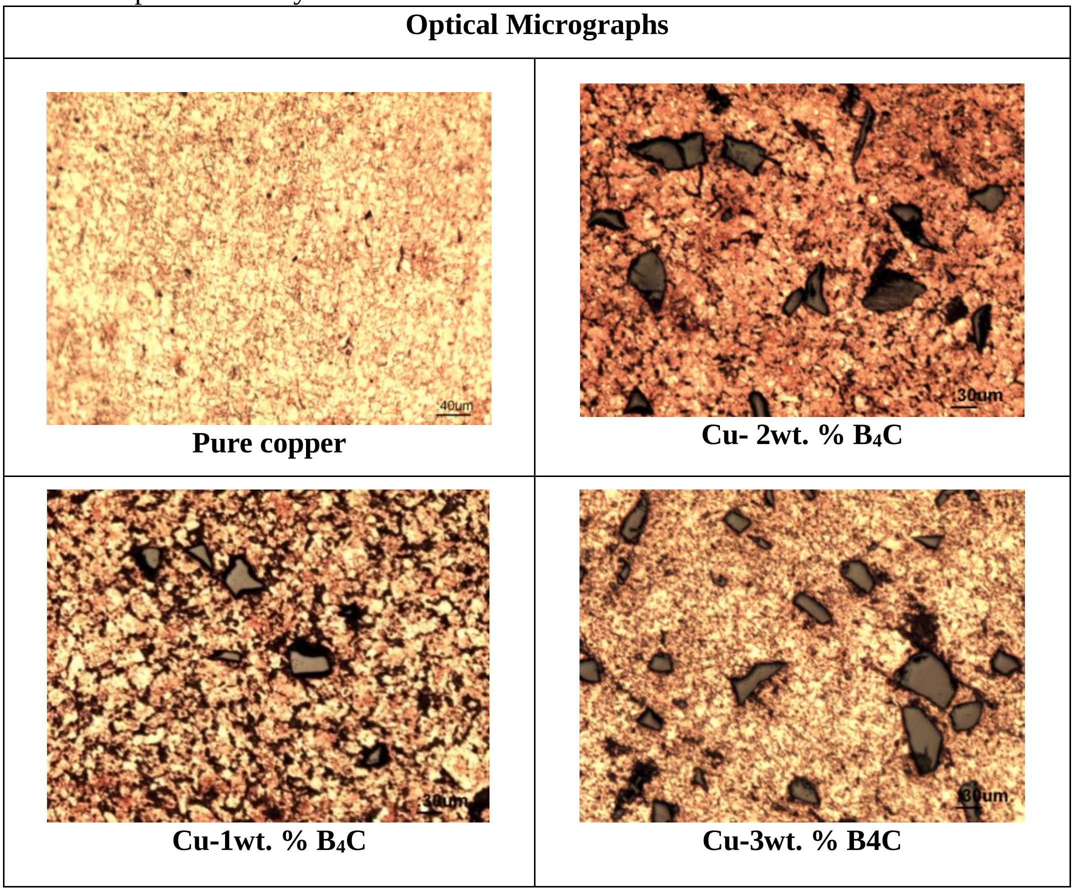
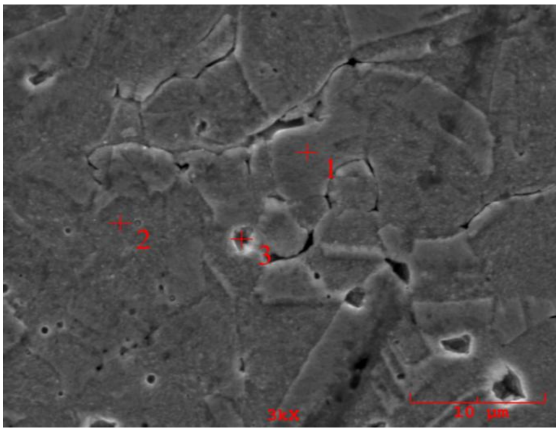


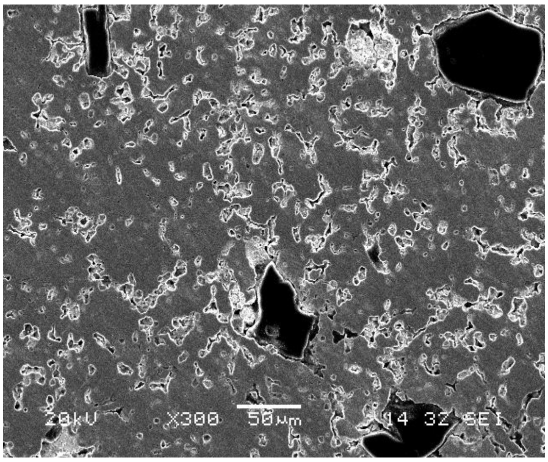
Figure 1 - Optical micrographs of pure copper and Cu-B_4C composites sintered at 700 °C for 2 hours.

Figure 2a-c shows the SEM images with EDS analyses of the composite samples as well as pure copper. The dark, cornered shapes indicate B_4C and grey colored zones point out copper matrix as confirmed by EDS analysis (Fig. 2a-c). In the SEM images, white areas probably indicate alumina resulted from polishing and does not characterize any phase (Fig. 2b). Result of general EDS analysis, there were small amounts of oxygen element in copper and composites samples (Fig. 2a-c). This was probably resulted from the oxidation of the matrix during sintering, however Al evidence as well as oxygen in the EDS analysis also indicated alumina remained from polishing process.



wt.%	Marks		
	1	2	3
O	0.997	0.980	0.498
Al	0.309	0.118	0.435
Cu	98.694	98.902	99.067

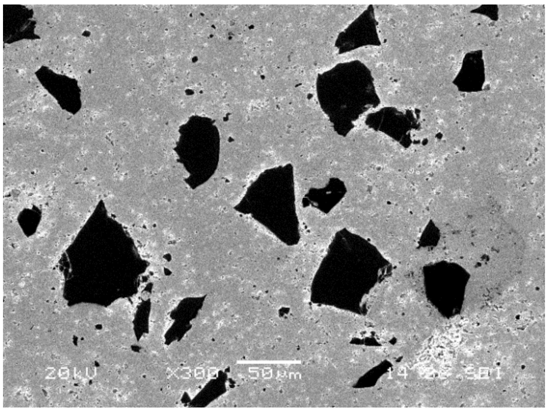
(a)



Sample	wt. %		
	O	Al	Cu
Cu-1wt. % B_4C	7.248	4.818	87.934

(b)

Figure 2 - SEM images with EDS analyses of samples sintered at 700 °C for 2 hours, (a) püre copper, (b) Cu-1wt. % B_4C, (c) Cu-3wt.% B_4C



Sample	wt. %		
	O	Al	Cu
Cu-3wt. % B_4C	2.570	1.790	95.640

(c)

Figure 2(continued) - SEM images with EDS analyses of sintered samples sintered at 700 °C, (a) pure copper, (b) Cu-1wt. % B_4C, (c) Cu-3 wt.% B_4C.

3.2. XRD Analysis

XRD analysis showed that no copper-oxide and B_4C phase, due to amount of B_4C in the samples possibly remained under the detection limits of XRD instrument, were detected and the dominant phase consisted of copper (Fig. 3-4), SEM-EDS analyses revealed small amount of oxygen and evidence of B_4C phase were existed in the samples.

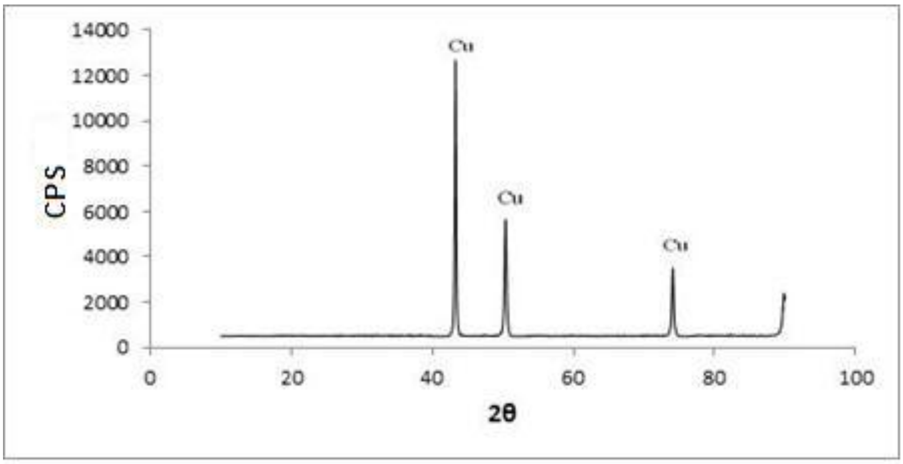


Figure 3 - XRD analysis of pure copper.

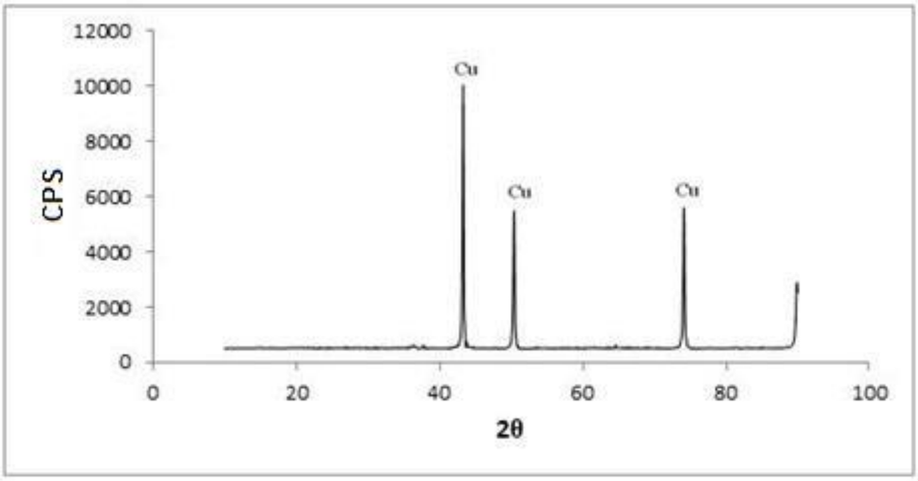


Figure 4 - XRD analysis of Cu – 3 wt. % B_4C.

3.3. Relative Density-Hardness-Electrical Conductivity

Relative density, hardness and electrical conductivity values of sintered and cold pressed commercial pure copper and Cu-B_4C composites were given in Table 1. From the Table 1, the relative density and the electrical conductivities of the Cu-B_4C composites decreased, while hardness values of them increased with the increment in the amounts of B_4C. Copper has high thermal expansion, while B_4C has low, by the result of this, significant amount of dislocation occurred because of great thermal expansion mismatch during sintering. Thus, by increasing amount of B_4C in composites, the hardness of the composites increased. Nevertheless, electrical conductivity of the samples decreased by decreasing the relative density because of lower density means higher porosity which acts insulation barrier for electron pass through between Cu grains [8]. It can be claimed that cold pressed Cu - 1 wt.% B_4C composites revealed promising physical properties according to obtained results given in Table 1.

Table 1 - Relative densities, hardnesses and electrical conductivity values of cold pressed copper and Cu-B_4C composites.

Properties	**wt.% B_4C**			
	0	**1**	**2**	**3**
Relative density, %	97,5	92,15	91,15	90,19
Hardness, HB	80,65	81,7	82,8	87,5
Electrical conductivity, %IACS	90,04	80,91	69,1	68,87

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