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Studying the Properties of Cu-Al-SiC Composites Prepared by P/M Technique

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ABSTRACT

A composite of copper powder reinforced with SiCp (0-10 wt%) in which aluminum powder of (2 wt%) was added for improving wettability of the ceramie phase. . The composite mixture was prepared by mixing with a ball mill for one hour to ensure a homogenous distribution on the composite .Gteen compacts pressed at (350MPa) a steel mold of (12mm)diameter were then sintered at (900 °C) for two hours in an electric furnace, in argon atmosphere . Optical microscopy, Density, porosity content and Vicker's hardness test were then conducted for the sintered samples.

Obviously, it was concluded that there was enhancement of the physical and mechanical (hardness) properties of the sintered compacts with increasing the SiC content.

Keywords: wettability ,homogenous distribution .load transfer . Interface.

دراسة خصائص المتراكب (Cu-Al-SiC) الملبد متالورجيا المساحيق

الخلاصة

حضرت عينات متراكبة من مسحوق النحاس كمادة اساس ودقائق كاربيد السليكون بنسبة (0-10% وزنا) كمواد تدعيم، اما مسحوق الالمنيوم فقد تمت اضافته الى المزيج بنسبة ثابتة 2% وزنا وذلك لزيادة الترطيب السطحي. تم خلط المزيج بواسطة طاحونة كرات كهربائية دوارة لمدة ساعة للحصول على مسحوق متجانس. تم بعدها كبس العينات تحت ضغط يعادل (350MPa) بواسطة مكبس هيدروليكي في قالب فولاذي بقطر يساوي 12mm، ثم لبدت في درجة حرارة (900^0 C) لمدة ساعتين في جو من غاز الاركون. ثم فحص العينات المستحصلة باستخدام المجهر الضوئي وقياس الكثافة والمسامية والصلادة للعينات بواسطة جهاز(HVS- 1000). من خلال النتائج المستحصلة ظهر بأن اضافة كاربيد السليكون الى النحاس قد عزز من خواصه الفيزيائية والمكيانيكية.

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INTRODUCTION

It may considered that Cu-Al-SiC composite is a promises one, that is increasingly used for automotive , aerospace, and structural applications. Moreover it can be used as heatsink in electronic applications like power supplies.

Due to the high electrical and thermal conductivity, good corrosion resistance and high melting point, copper is widely used in thermal and electronic applications, i.e. electronic packaging, electrical contacts and resistance welding electrodes[l]. Nevertheless, the relatively low mechanical property at both room and high temperatures limits the extensive application of pure copper. The room temperature mechanical strength can be improved dramatically by addition of small amount of elements such as Ag or A1. to form precipitation-hardened alloys. However, these copper alloys lose their high strength at higher temperature (usually 500 °C) generally related to the structural instability caused by the coarsening of precipitation particles [1,2]. Furthermore, low wear resistance and conductivity are the other two limitations of these alloys 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. In other words, particulate-rein- forced copper matrix composites may have many prominent advantages that the copper alloys do not possess. Therefore, these kinds of materials are considered to be promising candidates for applications where high conductivity, high mechanical property and good wear resistance are required [3].

The PM route consists of several processes like blending, compacting, and sintering. Blending is one of the crucial processes in PM where the metallic powders are mixed with the ceramic reinforced particles. Good blending produces no agglomeration of both the metallic and ceramic particle powders. To achieve this, several parameters such as particle size, blending speed and duration should be taken into consideration. Conventional melting and casting has distinct limitations due to the poor wettability between ceramic particles and molten copper, leading to agglomeration of dispersoids [4].

Moreover, the difference in the densities and the reinforcements can also cause segregation in the melts[5]. Therefore, the PM route is ideal to prepare copper matrix composites because of its efficient dispersion of fine particles [7]. Powder metallurgy is an important processing technique for metal matrix composites (MMCs) which eliminate reinforcement segregation typically occurring in the ingot metallurgy process [8,9]. Segregation can adversely affect the properties of MMCs and therefore a homogenous distribution of the reinforcement is essential for improving mechanical and other properties of the composite [10] .

Proper bonding at the interface can attain good load transfer between phases. In some composites, the intrinsic lack of wetting between the matrix and the reinforcement causes difficulties in production and even debonding of interface during the service life. In this case, adhesion promoters are needed to modify the interface structural model. Studies of the Cu-SiC system indicate poor wettability between them [4].

A value of (θ= 140°) was reported for the wetting of SiC by liquid Cu at 1100 °C [5]. Interfacial reactions were reported in many cases when the temperature was higher than 900 °C [6,7],

In this investigation, the effects of adding silicon carbide particle-reinforced copper matrix composites on the mechanical properties were studied.

Pure copper and its composites reinforced with SiC particles were prepared by Tjong et al (2003) [11], using hot isostatic pressing (HIP) process. The tribological behaviour of copper and composites was studied on a pin-on-disc tester. The pins were slid against a hardened steel disc under dry ambient conditions. In two-body abrasive wear measurements, the disc surface was bonded with a SiC abrasive paper of 240 grit size. The abrasive wear measurements showed that soft copper exhibits an extremely high wear loss. However, additions of SiC particles up to 20 vol.% appeared to improve the abrasive wear resistance of copper significantly under the applied loads of 15-55 N. Dry sliding wear tests also indicated that the composite with 20 vol.% SiC _ exhibits a lower wear loss compared to pure copper. This was due to the reinforcing SiC particles being effective to reduce the extent of wear deformation in the subsurface region during sliding.

A composite of copper powder and SiC particle reinforcement was prepared by K Gan, and Gu (2006) [12], using mechanical ball milling and subsequent sintering. Microstructure, powder morphology and mechanical properties of the composite were investigated as a function of milling time. With increasing milling time. the dentritic copper powder became flattened, which subsequently became spherical shaped. Mechanical properties of the composites change with the distribution of SiC.

EXPERIMENTAL AND RESULTS

Copper powder (99% Purity), 53 μmin diameter, SiC particles (95% purity); 25 μm in diameter,. and Aluminum(99% purity), 25 μm in diameter were commercially available . The composites with Cu as a matrix SiC reinforced (0, 2, 4,6 ,8 and 10 wt.%), and Al (2 wt%) powders were mixed mechanically by electric mill . and the blended powders were compressed in cylindrical steel die(12 mm diameter , 90mm height) using uniaxial hydraulic press to (350) MPa . making (4g) for each sample. The samples were sintered at (900 °C) in electric furnace in argon atmosphere for two hours. The procedure is illustrated in fig (1). The density of copper composites was determined according to Archimedes' method. In this technique, density is determined by measuring the difference between the specimen's weight in air and when it was suspended in distilled water at room temperature, using the equation [86]:

$$\rho_A = \frac{W_D}{W_S - W_I} \times \rho_W \qquad \ldots\ldots (1)$$

W_D: the weight of samples after dried in oven.
W_S: the weight of samples immersion in water.

W_I: the weight of samples rise from water and wiped by clothes.
ρ_w : the density of tested water at this temperature.

The results showed that the density of composites tends to decrease with increasing SiC content. This is due to the density of SiC particles being much smaller than that of copper as in fig. (2). The porosity can be determined by the equation:

$$A.P\% = \frac{W_s - W_D}{W_s - W_I} \qquad \ldots\ldots (2)$$

It can be noticed that porosity was increased gradually with increasing SiC content.

Optical microscope was used to study the Micro structural changes at the differtant SiC additions. The samples were ground with 500. 800. 1200 grit silicon carbide paper, cooled with water, then polished with diamond paste of 3 µm. 1µm. The samples were Then degreased by ethanol and dried. Computerized optical microscopy was used to examine the microstructure of sintered samples. The analysis was conducted at the top of selected samples. The photographic picture converted to a digital image using scanner device and using the computer program VID CAP 32 and the digital image was saved as jpeg-image. The images are shown in fig (4).

Copper matrix integrates with the reinforcement closely, and impurities can hardly be found. Adding (Al) to the composite cause impurities on the SiC particle surface were eliminated by the activation and sensitization processes to get a high bonding strength between the Aluminum and the reinforcement. Since the preparation temperature of the composites (900 °C) is high enough for the Cu and Al atoms to diffuse to form a film of Cu-Al alloy at the interface, the composition of this film changes continuously from the copper side to the Aluminum side. The bonding strength of this SiC-Al-Cu interface is high enough to transfer load from the matrix to the reinforcement effectively.

Debonding of the interface is more difficult to take place. In other words, the Aluminum layer on the SiC reinforcement improves the strength and ductility of the composite by lowering the extent of interfacial debonding. The microhardness testing results is expected that composites exhibit higher hardness than pure copper and the hardness increases markedly with SiCp content, since SiCp with high hardness can contribute positively to the hardness of the composite.

The enhancement in hardness is attributed to the SiCp—copper interfaces which can resist the dislocation motion in the matrix and constrain the local plastic deformation. The more interfaces in the matrix, the more resistance to plastic deformation. Therefore, the hardness increases as SiCp content increases as in fig. (5).Identification of the phases in the (stir-cast and powder metallurgy) samples was done by using X-rays diffraction unit with the following specifications. The target of the X-ray tube was copper with wavelength Cuk ∝ equal to 0.15405nm. Type (philips pw-1840). Power (Voltage 40KV). (Current 20 mA).

scanning speed: 3° per minute / 6° per minute for (2θ). diffraction angle ($2\,\theta$): 10-90° (Scanning range), filter type: Nickel (Ni). average wavelength = 1.5405 A°. By using Bragg law, the d-values can be determined as follows [90]:

$$n\lambda = 2\,d\,sin\theta \qquad .... (3)$$

Where n= order of reflection 1, 2, 3,.....

λ = Wave length of X-ray = $0.15405A^{o}$
d = interplanr distance in (A^{0}).
G = angle of incidence or reflection of X-ray beam.
From interplanar distance, the intensity of the X-ray present, and by the standard files, the phases can be defined.
Fig. (6) Shows the XRD pattern of the Cu-Al-SiC (10 wt%) composite particles, indicative of the presence of Cu . Cu_20 and SiC. The inherent Cu_20 is formed due to the possibility instantaneous oxidation of Cu during the sintering process. This type of XRD device could not recognize Al cause the minimum level of detection is (5 wt%). while Al content is (2 wt%).

CONCLUSIONS

1. The addition of SiCp is beneficial to the hardness of the material and the hardness of the composite increases as the SiCp content increases. This is obviously occured after (4 wt%) reinforcement.
2. Increasing hardness is due to the higher value of SiC hardness, so the hardness will be increased with SiC content in spite of the porosity increase.
3. Decreasing the composite density with SiC content is due to the fact that density of SiC is smaller than Cu matrix.

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Table (1): Properties of Cu-Al-SiC composite samples

SiC content (%)	Density (g/cm)	Porosity (%)	Hardness (Kg/mm")
0	8.1	9.2	59.4
2	7.4	11.5	63.6
4	7.12	12.7	64.5
6	6.9	13.8	84.7
8	6.85	16.6	99.1
10	6.4	19.72	103

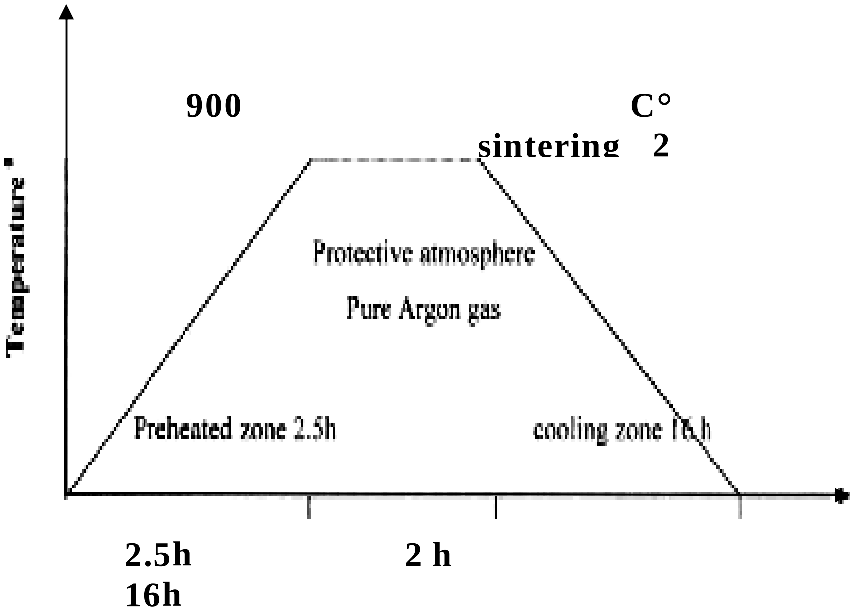

Figure (1): schematic diagram represent sintering

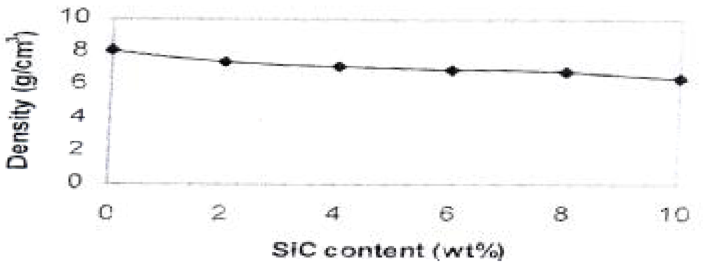

Figure (2): illustrate density value with SiC content.

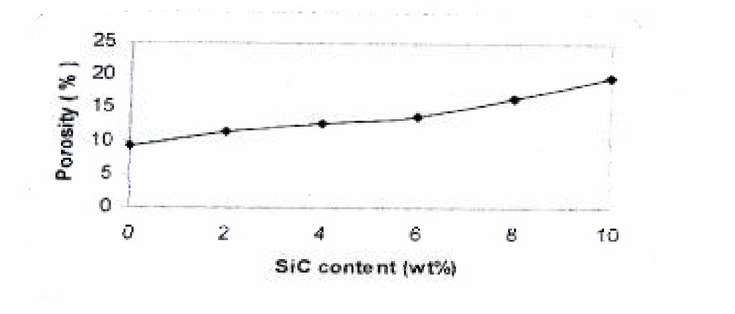

Figure (3) illustrate porosity percentage with SiC content

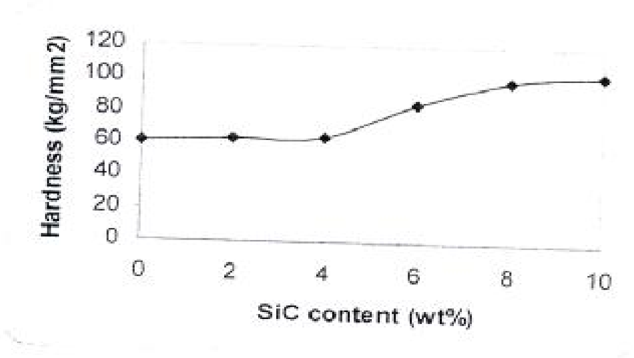

Figure (5) illustrate the measured hardness value with SiC content

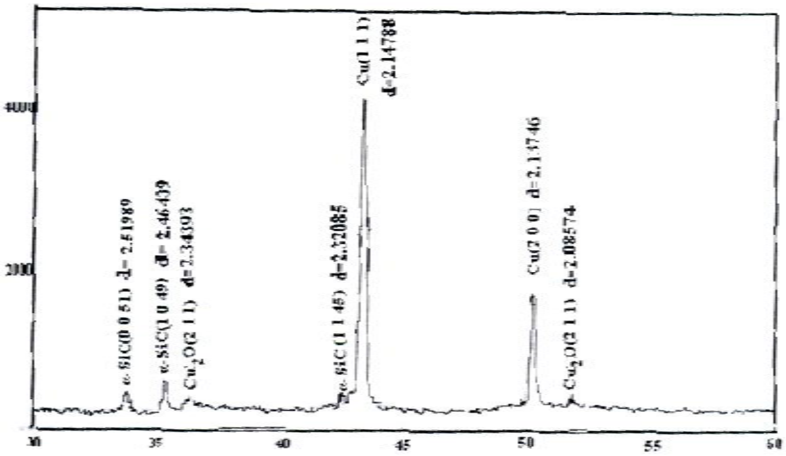

Figure (6) The XRD pattern of Cu-Al-Sic(10wt%s) composite