Mechanical properties Investigation of Cu-SiC composites using different percentage of Magnesium element

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Abstract:

The aim of this study is to produce composites of Cu –SiCp(10vol%). by using P/M method with different additions of active element like magnesium (0-10vol%) and investigating their characteristic properties..

The powders were prepared in suitable manner , blended in a ball- mill for 2 hours for good homogeneity , then pressed in uniaxial steel die with (11) mm redius to (250)MPa. The samples were sintered in electric furence to (1100°C).Density and porosity for samples were preformed. The hardness test was investigated using Vicker microhardness (HV) tester. In addition, wear resistance of specimens were also investigated by using a pin-on-disc type apparatus with a typical experimental plan of simultaneous variation of loads (5,10,15)N for (10min) .It was found that the density would be increased gradually with the Mg content. The hardness and the wear performance of the composite increased with increasing volume percentage of Mg.

1. <u>Introduction</u> :-

copper is widely used in thermal and electronic applications, i.e. electronic packaging, electrical contacts and resistance welding electrodes due to the high electrical and thermal conductivity, good corrosion resistance and high melting point.

Nevertheless, the low mechanical property at both room and high temperatures limits the extensive application of pure copper. Discontinuously reinforced metal matrix composites are a class of materials that exhibit blending properties of the reinforcement and the matrix [1,2].

The fabrication and performance of metal matrix composites are strongly influenced by the reinforcement–matrix interface. 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

[3]. A value of (ϴ = 140º) was reported for the wetting of SiC by liquid Cu at (1100 ºC) [4]. Cu–SiC system is considered to be weak for the practical application of composites. Interfacial reactions were reported in many cases when the temperature was lower than 900°C [5,6] .

Information on wettability of solids (like SiC) by liquids (like Al) is very important for the production of advanced metal-ceramic composite materials, because it has a significant influence on the properties of the final product. Wetting studies usually involve measurement of contact angles as primary data. The wettability of a solid by a liquid is characterized in terms of the angle of contact that the liquid makes on the solid [7,8].The contact angle, □, is obtained from a balance of interfacial tensions , and is defined from Young's equation, according to which [9]:

$\gamma_{sv} = \gamma_{lv}.\cos□ + \gamma_{ls}$
□□
□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□

As shown in the figure (1), Contact angle indicate the degree of wetting when a solid and liquid interact. The lower the contact angle the greater the wetting .Contact angle below 90^o indicates that the liquid wets the solid spontaneously. Contact angle θ can be decreased by increasing the surface energy of the solid γ_{Sl}, or by decreasing the surface tension of the liquid γ_{LV} [9].
One of affective ways of improving wetting is to alloy the lower melting point material with small additions of elements active at the AB interface[10].

As shown in the figure (2) the additions tend to reduce γ_{AB}, generally tend to segregate at the interface so that the additions need not normally be large. The most effective additions will be elements which react with the substrate added in quantities sufficient to form an atomic monolayer of reaction product. A minimum harm is caused by the reaction product. Generally, the addition should it self has a similar or higher surface energy than the parent metal otherwise it will also segregate to the free surface and lower γ_{AB}. Table(1) give the values of surface tension and their melting point for different elements[11].

In another way, if we combine the first and second laws of thermodynamics for the surface layer instead of the total system, we can describe surface quantities as [12][13]:-

$$dE = Tds + \gamma dA - PdV + \sum \mu_i dn_i \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2)$$

Where *dV* is the volume of the interface layer (thickness×*dA*), ds the excess entropy due to the interface, the number of moles n_i of component *i*, and dn_i the excess moles of *i* in the boundary. Integrating without change of composition, we have [12][13]:-

$$E = TS + \gamma A - PV + \sum \mu_i dn_i \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (3)$$

$$\gamma = \frac{1}{A}(E - TS + PV - \sum \mu_i n_i) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (4)$$

Thus the surface tension of a flat interface is the excess gibbs free energy per unit area. By differentiating we have:-

$$Ad\gamma = -SdT + VdP - \sum n_i d\mu_i \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$d\gamma = -SdT + VdP - \sum \Gamma_i d\mu i \qquad \text{For unit area} \qquad \ldots\ldots\ldots\ldots \quad (6)$$

Where Γ_i is the excess moles of *i* per unit area of the interface layer (or define the 'adsorption' Γ_i of component *i*) and *S* and *V* are the excess entropy and volume per unit area. For changes at constant temperature and pressure.

$$d\gamma = -\sum \Gamma_i d\mu_i \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

For two components, this becomes

$$d\gamma = -\Gamma_1 d\mu_1 - \Gamma_2 d\mu_2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

The terms $\mu_1$and μ_2 are the chemical potentials of component 1 and 2, $d\mu_1$ and $d\mu_2$ are not independent but are related through the Gibbs-Duhem equation:

$$X_1 d\mu_1 + X_2 d\mu_2 = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

Where X_1 and X_2 are the mole fraction of the two components in the phase being considered. Hence [12][13]:

$$-d\gamma = \left[\Gamma_2 - \frac{X_2}{X_1}\Gamma_1\right] d\mu_2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

This is the Gibbs adsorption isotherm and is usually written [13]:

$$-d\gamma = \Gamma_{2(1)} d\mu \approx \Gamma_{2(1)} RTd \ln C_2$$

Where $\Gamma_{2(1)}$ is a relative adsorption of component 2 with respect to component 1, its defined as.

$$\Gamma_{2(1)} = (\Gamma_2 - \frac{X_2}{X_1}\Gamma_1) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

And C_2 is the concentration of component 2 in the phase being considered and assumes that the activity coefficient is nearly constant at low concentration. The excess of component 2 in the interface is therefore related to the variation in the surface tension [13]:

$$\Gamma_{2(1)} = -\frac{d\gamma}{d\mu_2} = -\frac{d\gamma}{RTd \ln a_2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

$$\Gamma_{2(1)} = -\frac{1}{RT}\frac{d\gamma}{d(\ln C_2)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

This last relation is very important: it expresses that if the addition of component 2 to the mixture causes a decrease of the surface tension, the more it does so, the more component 2 segregates to the surface. In practice, last equation makes possible the calculation of the amount of adsorption of a component on the surface when the variation of γ as a function of the bulk activity of this component has been measured. Such an approach, which has often been practiced in the literature, can be carried out for any type of interface, as shown in fig.(3)[13].

The research of **Bedir et al[14]** was to produce composites of Al–Cu–SiC_p and Al–Cu–B_4C_p by using hot pressing method and investigating their characteristic properties. The volume fractions of the reinforced (SiC, B_4C) composites were 10, 20and 30 (vol%). The composites were treated in solution for 24 h at 530 ºC to evaluate heat treatment effect on the composites then aged in oil bath at 180 ºC for various ageing periods and hardness reached to a maximum value within 8–10 h using Brinnel hardness (HB) tester. In addition, wear resistance of the aged and unaged composite specimens were also investigated by using a pin-on-disc type apparatus under dry sliding conditions at constant speed using 100, 150 and 220 grade SiC abrasive paper under constant loads of (2-10) N at room temperature. As a result, the distribution of the reinforced particle was uniform by examining their microstructures. The hardness and the wear performance of the composite increased with increasing volumetric reinforced Particle

Liquid phase sintering is an important processing technique for metal matrix composites (MMCs) which eliminate reinforcement segregation typically occurring in the ingot metallurgy process [15,16]. 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 [17] .

The effects of magnesium volumetric percentage on the mechanical and wear properties of silicon carbide particle-reinforced copper matrix composites were investigated ..

2. Experimental procedure :-

Pure magnesium powder with particle size less than 25µm and silicon carbide particle with particle size less than 25µm and copper powder with particle size less than 53µm. All were dried by oven at 110^{o}C. Cu and (10wt%) of SiC with (0-10wt%) of magnesium; all were well-blended in steps by using a rotating mill. Mixture samples were compacted in sat 350 MPa using uniaxial hydraulic press in steel die with (11mm) diameter.. The samples were sintered at 1100^{o}C for 2 hours under pure nitrogen. The density of copper composites was determined according to Archimedes' method, and as a result the porosity percentage, (A.P%) for samples were found.

Vicker microhardness was measured by (HVS- 1000) made in Japan, Dry sliding wear tests were carried out using a pin-on-disc tester. The pins were slid against a hardened steel disc with a hardness of HRC60, within a load range of (5, 10,15N) at a constant sliding velocity of (2m/s) for (10min) and sliding radius of (70 mm). Both contact sample surfaces were polished, cleaned in acetone in an ultrasonic cleaner and dried. The sliding distance for each test was normally (1.2×10^3) m for all normal loads. The wear losses of the specimens were measured by weighting samples before and after wearing test.

3. Results and discussion :-

1. As shown in figure (4),.increasing the composite density with Mg content was a result to the bonding strength between copper matrix and SiC particle was increased by interfacial modifying

2- in figure (5), the porosity was decreased gradually with Mg content due to that Mg made as an interfacial layer , and this layer had increased gradually with Mg content, caused to close the pores between copper and silicon carbide.

3- as shown in figure (6), Hardness is a parameter that reflects the local deformation resistance of a material. As the magnesium presence reduces the micropores near the interface and increases the bonding strength, the composite can resist local deformation more effectively, and the hardness will be increased.gradually with Mg content,

4- as in figure(7), An increase in wear rate with increasing normal load is observed.. However, the magnesium-coated SiC-reinforced composite exhibits lower wear rate than the uncoated one at all the load levels .finally the wear rate will be decreased in steps with Mg percentage as a result of increasing the bonding strength,

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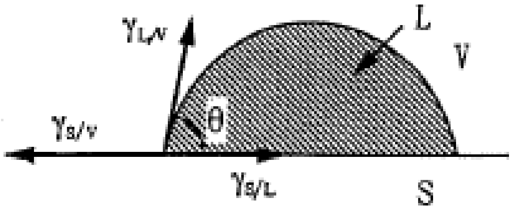


Fig(1): Shows the effect of contact angle on wetting [9].

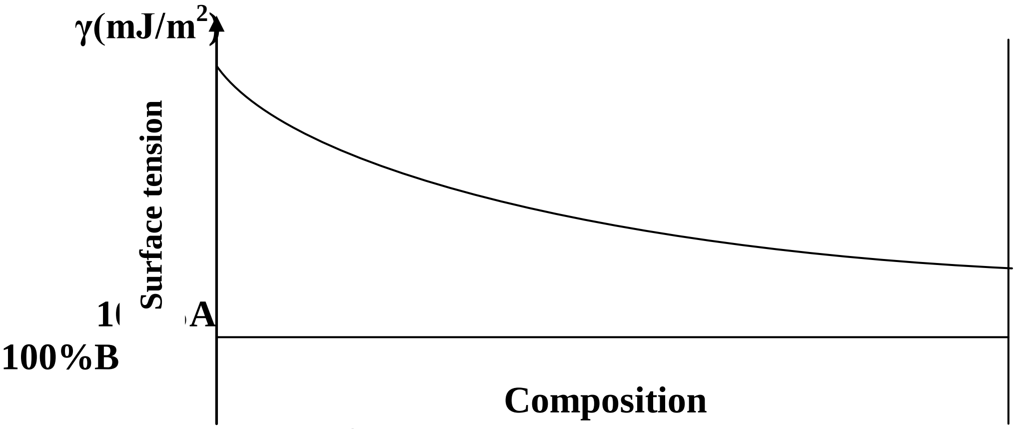
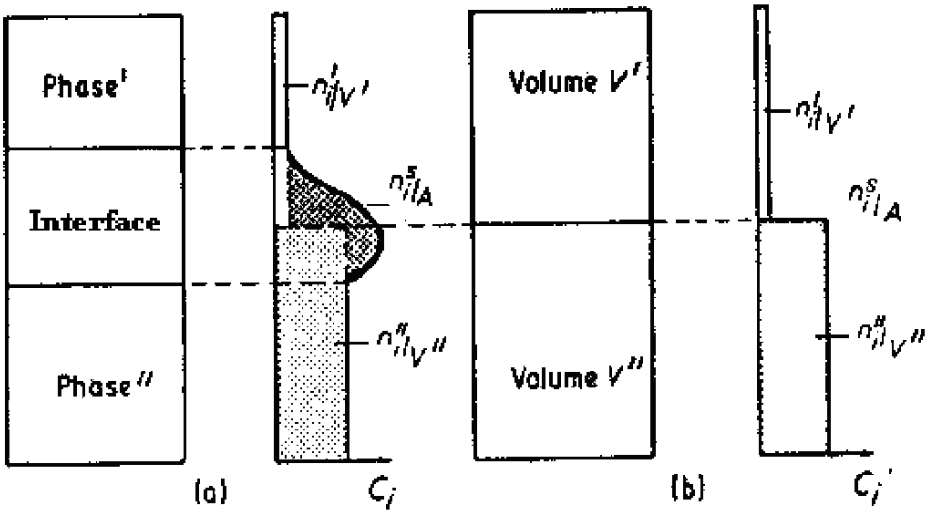


Fig (2): Surface tension in a two-component system [10].

Table (1): The values of surface energies for different elements [11].

Metal	**Li**	**Mg**	**Zn**	**Al**	**Cu**	**Ti**	**Ni**	**Fe**	**Mo**
γ_{LV}mJ/m^2	**400**	**560**	**780**	**866**	**1300**	**1650**	**1780**	**1800**	**2250**
Temp. c^o	**186**	**650**	**419**	**660**	**1083**	**1680**	**1453**	**1535**	**2620**



Fig(3): (a) real interface distribution of component i. (b) the Gibbs model of this interface [13].

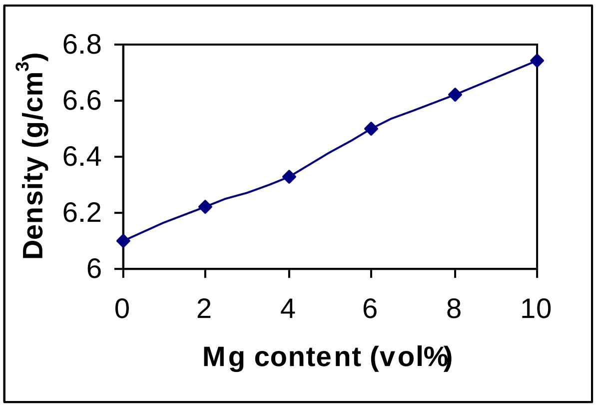


Fig (4): The variation of apparent density with Mg content (vol%)

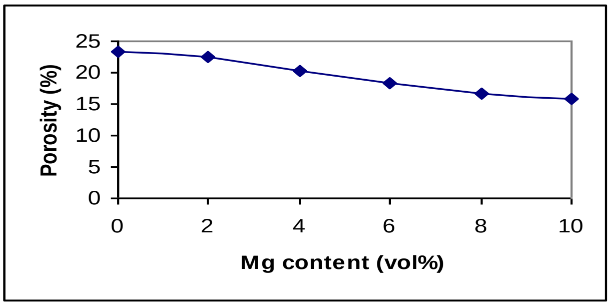


Fig (5): The variation of the porosity with Mg content

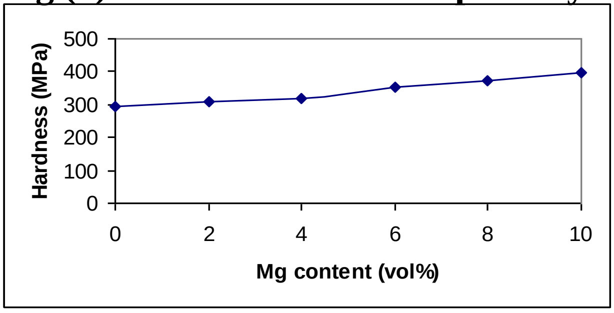


Fig (6):The variation of hardness with Mg content

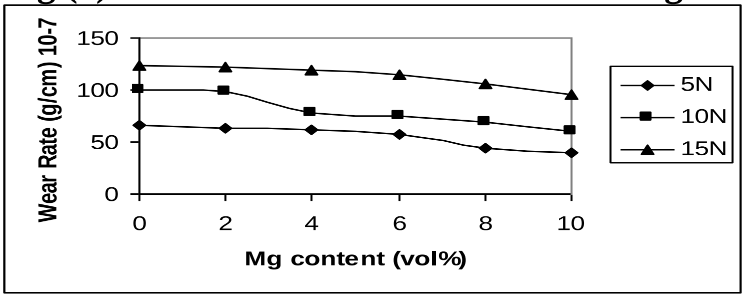


Fig (7): The variation of wear rate for 10 minute period with Mg content

دراسة الخصائص الميكانيكية لتراكب النحاس- كاربيد السليكون بأستخدام نسب مئوية مختلفة من عنصر المغنيسيوم

سمير بهجت يونس
قسم العلوم التطبيقية
الجامعة التكنولوجية

الكلمات الدليلية : البلل ، التوزيع المتجانس ، التحويل الحمل ، السطح البيني

الخلاصة :-

الهدف من البحث هو تحضير عينات من النحاس كمادة أساس المقوى بكاربيد السيلكون بنسبة ثابتة (٢٥% حجماً) باستخدام تقنية ميتالورجيا المساحيق وبوجود عنصر المغنيسيوم بنسبة(٠-١٠%حجماً) ، حيث تم تجفيف المساحيق في فرن كهربائي لمدة ساعة عند (١٠٠) درجة مئوية ومن ثم سحقها الى الحجم الحبيبي المطلوب ومزجها في طاحونة كهربائية لمدة ساعتين للحصول على التوزيع المنتظم ، وكبسها في قالب أسطواني بقطر (١١) ملمتر وتلبيدها عند (١١٠٠°C) . تم فحص الكثافة والمسامية ، ودراسة الخصائص الميكانيكية من صلادة ومقاومة اجهاد أضافة الى فحص البلى ، حيث لوحظ زيادة في كثافة العينات يقابلها نقصان ملحوظ في المسامية ، أضافة الى تحسن في الخصائص الميكانيكة ، وقلة في معدل البلى بزيادة النسبة الوزنية لعنصر المغنيسيوم كمادة بينية رابطة في المتراكب .