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EFFECT OF CARBON BLACK CONTENT ON COEFFICIENT OF THERMAL PROPERTIES OF AL/CARBON BLACK COMPOSITES

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ABSTRACT

Experimental investigation of the effect of carbon black on coefficient of thermal expansion (CTE) of Al/carbon black composites is presented for electronic packaging applications. Liquid metallurgy casting was used to fabricate Al base alloy and different wt. % of carbon black reinforced Al black composites. The CTE and thermal properties of both Al and its composites were measured between 30 and 500 °C is used NETZSCH DIL 402 E and Laser Flash Apparatus thermal analysis. The result shows that the addition of carbon black into the Al matrix was found to significantly decrease the thermal expansion. Thermal expansion increases as the function of temperature due to the softening martial phase. It has been found that thermal conductivity decreases with increase of temperature, but specific heat increases with temperature.

KEYWORDS: Metal Matrix, Al/Carbon Black, CTE, Thermal

INTRODUCTION

Al reinforced composites have high specific strength, modulus, wear and thermal conductivity but it has low dimensional stability due to its high coefficient thermal expansion at higher temperatures [1]. Metal matrix composite has several other applications, especially in automobile - piston, cylinder, and drive shaft and rotor brakes [2]. A diesel engine shows the temperature profile of the piston area where the temperature has reached the highest level in the regions of the piston [3]. The difference in the CTE between reinforcement and metal matrix has a predominant effect [4]. The linear CTE is defined as [5], some authors [6-8] have interpreted, a reduced CTE and increased thermal conductivity of metal matrix composites with addition of ceramic particles. The thermal properties such as thermal conductivity, thermal diffusivity and specific heat are important parameters for space, automotive, electronics and thermal management systems. The present work is to increase the comprehension of the thermal properties of Al/carbon black composites. The objective of the present investigation is to study the thermal characteristics of MMC reinforced with carbon black, measured between the range of 30 to 500 °C, by Thermal Mechanical Analyzer (TMA) using NETZSCH DIL 402 E.

EXPERIMENTAL WORK

The Al and Al composite castings have been prepared using a liquid metallurgy technique. The Al 6061–carbon black exhibits excellent casting properties with good base metal characteristics. The chemical composition of the Al 6061 is given in Table 1. Carbon black particles of 15µ m with a lower coefficient of thermal expansion, (4.5 X 10-6 / K) lower density and high strength (Mohr's hardness of 8 – 69) has been used in the present study.

In the present study casting has been subjected to forging and heat treatment.

Table 1: Typical Composition of Aluminium Alloy 6061

Elements	Al	Mg	Si	Fe	Cu	Zn
%	Balance	0.8-1.2	0.4 – 0.8	0.7	0.15-0.40	0.25

The specimens for CTE tests were prepared with a dimension of 11 x 5 x 5 mm and the surfaces were polished with 1µ m diamond paste. Thermal Mechanical Analyzer (TMA) NETZSCH DIL 402 E used for determining CTE. Four samples of the Al 6061-CB composite were tested under the same parameters to compare the reproducibility of the data [9]. CTE measurement has been performed from 30 (C to 500 (C at 50 °C per minute. The test has been conducted as ASTM 831 – 03. CTE test was conducted under a nitrogen atmosphere and flow rate of 50 ml / min. The expansion type probe was used with a force of 0.02N.

Thermal conductivity of Al/carbon black composites was conducted by Laser Flash Apparatus thermal analysis. This technique relies on the generation of a stationary heat flux passing through the standard specimen through composite sample, the temperature distribution through them. The heat flux is measured using

$$Q = k_s A_s \frac{\partial T_s}{\partial x_s} = k_{sa} A_{sa} \frac{\partial T_{sa}}{\partial x_{sa}}$$

k, A, δT and δx are thermal conductivity, Area of the sample, temperature difference and distance measured respectively. S and Sa are standard and specimen samples respectively. The thermal conductivity measured based on the ASTM E1225-09 standard. The sample dimensions for the thermal conductivity are 70mm x 4 mm x 25 mm.

RESULTS AND DISCUSSIONS

Based on the experimental work carried out, the following results are obtained and they are discussed

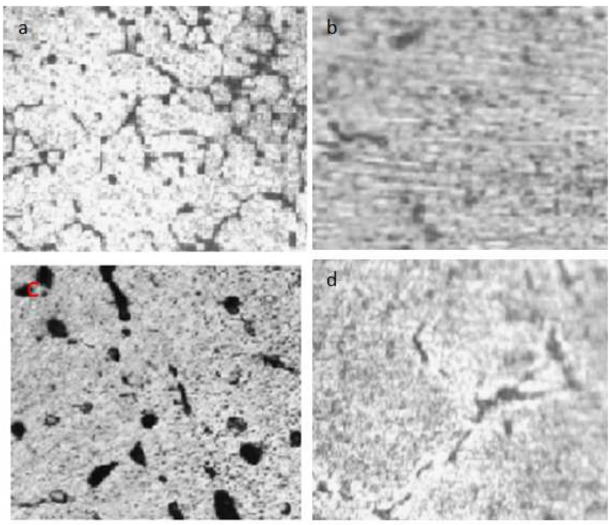

Figure 1: Microstructure of Al/Carbon Composites
a) Matrix Alloy b) 4% CB c) 8 % CB and d) 10 % CB Composites

Microstructural Study

The coefficient of thermal expansion of metal matrix composite has been expressed by different researchers [9]. Figure 1 shows the microstructure of Al 6061 with various percentages of carbon black. The base metal is cut to a size of 20 x 20 mm. The sections were prepared for optical metallography. Keller's reagent has been used. Figure 1 (a) represents microstructure of Al 6061. Figure 1 (b) shows 4% carbon black in which they are formed across the boundary line with a thin line forming. Figure 1 (c) shows 8% carbon black, in which they are uniformly distributed across the area. The difference in CTE between aluminium and carbon black has yielded low CTE in case of Al 6061-20% Carbon black. Figure 1 (d) shows 10 % carbon black, which thickens the grain boundary.

Effect of Temperature on CTE of Al/CB Composites

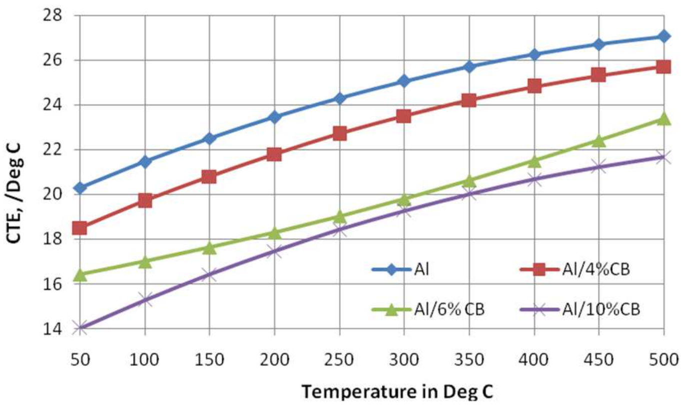

Figure 2: CTE Measurements of the Al and Al/Carbon Black Composites as a Function of Temperature

Operating at higher temperature the CTE in case of Al 6061-4% of carbon black has shown lower rates of dimensional change. As the percentage of carbon black increases to 10%, the value of CTE has decreased as shown in Figure 2. The results of the CTE of various weight percentages of carbon black reinforced composites showed that a drastic reduction in CTE of the composite in comparison with that of the matrix alloy, which indicates a good interfacial bonding due to the existence of macroscopic strain. CTE of carbon black power are lower than Al 6061, hence contributes for lower tendency of CTE in MMC.

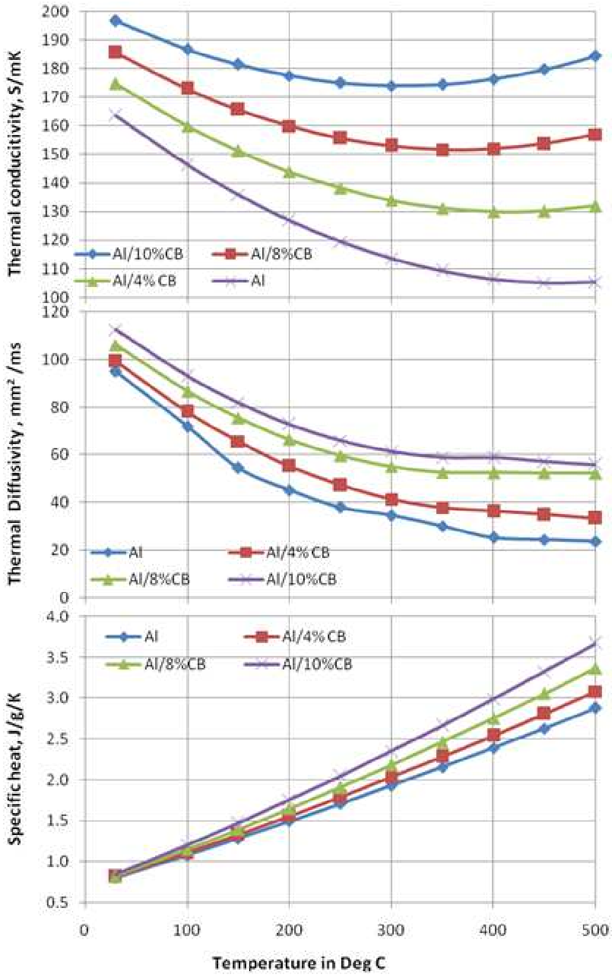

Figure 3: Results of Thermal Conductivity, Diffusivity and Specific Heat for Al and Al /Carbon Black Composites as a Function of Temperature

Effect of Temperature on Thermal Properties of Al/CB Composites

The Figure 3 (a) shows the thermal conductivity of both Al and Al /carbon black composites start to increase with increasing temperature due to radiant heat transfer and heat transported through a carbon black. Generally, all metal matrix composites decrease the thermal conductivity with respect to its base alloy. In this case, the thermal conductivity increased with increasing % of reinforcement due to good thermal conductivity. Although carbon black has a very high thermal conductivity (2-3 times), only marginal improvement is seen in composites. This may be higher porosity in the composites which leads to a reduction of thermal conductivity. There is interfacial thermal resistance formed between the flows of thermal energy. The interfacial thermal resistance of the composites influences on the thermal conductivity of the composites was observed in the graph. The same effect was observed in all % of carbon black reinforced composites, hence only a marginal amount of thermal conductivity increased. The similar results are observed by the investigations [10-11], the addition of carbon Nanotube failed to enhance in thermal conductivity of the sub composites to interface thermal resistance.

Figure 3 (b) shows the variation of thermal diffusivity as a function of temperature and various % of reinforcements. It has been inferred that the thermal diffusivity decrease with increase in temperature. It is similar to thermal conductivity but only small enhancement was seen in thermal diffusivity for composites.

The specific heat capacity increase strongly at temperatures above the room temperature and dominates the temperature dependence of thermal conductivity (Figure 3 (c)). The addition of a higher % of carbon black shows higher thermal conductivity, thermal diffusivity and specific heat as shown in Figure 3. This has proved the carbon black enhances the dimensional stability with better thermal conductivity.

CONCLUSIONS

Based on the work carried out, the following conclusions have been derived

- The distribution of the carbon black has been homogeneous with no parallel striations and detrimental pores.
- The Al / carbon black composites show CTE that increase with increase in temperature, but it decreases with decrease in % of carbon black due to lower CTE value of carbon black.
- The thermal conductivity, thermal diffusivity and specific heat of the Al/carbon black composites show higher values when compared with matrix alloy.
- Thermal properties of Al/carbon black depend on the interface thermal resistance between Al and carbon black reinforcement.

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