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# **The Effect of Binder Amount and Heat treatment on Coefficient of Thermal Expansion in High-volume Fraction Particulate Aluminium-matrix composites**

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Particulate aluminium-matrix composites with high thermal conductivities, low, tailorable coefficients of thermal expansion (CTEs), low density and low cost have been developed for use in electronic packaging<sup>[1-2]</sup>....The present investigation was undertaken with the objective of studying the effect of binder amount and heat treatment on CTEs of particulate aluminium-matrix composites.

## **Experimental Procedures**

### **Preform Fabrication**

The SiC preforms were prepared by wet forming, which involved compressing in a die a slurry containing SiC powder with a mean of 63 $\mu$ m, a liquid carrier (distilled water) and acid phosphate binder which P/Al molar ratio is 23. The die allowed excessive liquid to be squeezed out from the slurry and formed a wet cake. The preforms used in this study were cylinders, 70mm in diameter, 10mm in thick. The carrier/binder ratio is 20:3. All preforms were compressed by 60MPa pressure. Four binder SiC powder ratios of 0.15ml/g, 0.08ml/g, 0.04ml/g and 0.02ml/g were used in the preform preparation.

After removal from the die, the preforms were dried in a fume hood at room temperature for one day. Then, the preforms were treated in air furnace by: (1) heating to 1073K at a controlled rate of 15Kmin<sup>-1</sup>; (ii) holding at 1073K for 3 h; and (iii) cooling in the closed furnace. In order to study the effect of holding time on the CTE of composite, a preform was holding at 1073K for 24h.

### **Particulate Aluminium-matrix Composites Production by High-pressure Infiltration**

The high-pressure infiltration technique is a method for fabricating metal-matrix composites, where the application of a high pressure forces molten metal into a porous preform made of a particulate reinforcement. The matrix was commercial 6063Al alloy. The preform and the 6063Al alloy were heated separately to 1073K in air. The press mold was heated to 573K. When the 6063Al alloy was melted, the preform was dropped into the mold and the 6063Al alloy was poured over it. The press was then activated and the molten metal was infiltrated into the preform under 80MPa pressure. The composite was then solidified under

pressure.

### Anneal Treatment of Specimens for CET Test

Specimens for CET testing were treated in air by:(i)heating to 523K,623K,723K and 833K,respectively at a controlled rated of  $5\text{Kmin}^{-1}$ ;(ii)holding at that temperature for 3 h;and(iii)cooling in the closed furnace.

### CET Test

Specimens for CET testing,  $15\text{mm}\times 5\text{mm}\times 5\text{mm}$  in size, were machined from the prepared MMC samples. Specimen surfaces were polished with  $1\mu\text{m}$  diamond paste. More than four samples of each composite were tested under each condition to verify the reproducibility of the data. CET measurements were made using a thermal dilatometer.(model DL—1500,Japan) from 298K to 673K at  $5\text{Kmin}^{-1}$ .

## Results and Discussion

### Phase in binder and SiC blocks

#### Phases in Phosphate binder and SiC Blocks

Fig.1 shows the X-ray diffraction patterns of the acid phosphate binder and SiC blocks made with the undiluted phosphate binder baked in air furnace at 1073K for 3 hours and 24 hours. After drying of phosphate binder at 1073K for 3h, the binder formed predominantly aluminium metaphosphate( $\text{Al}(\text{PO}_3)_3$ ) and then did not change for 24h....

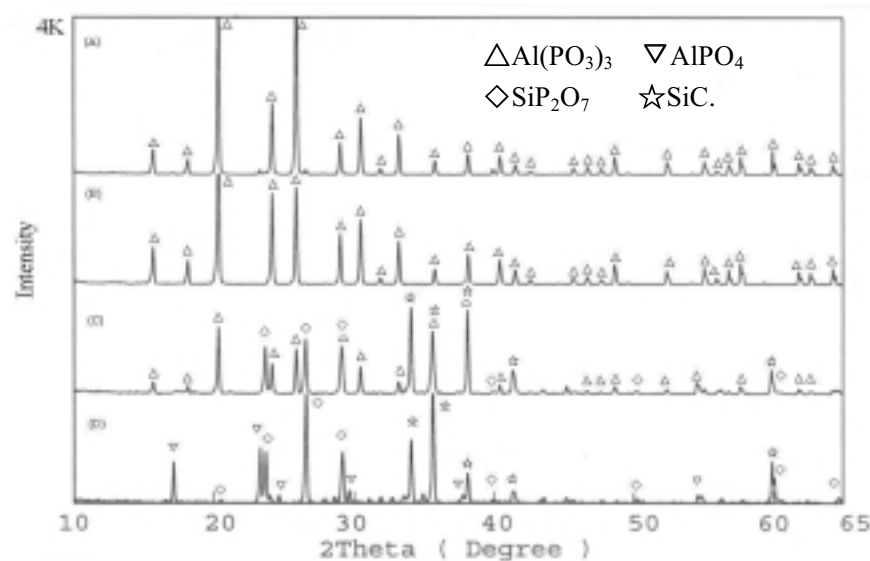


Fig1.XRD-patterns of the acid phosphate binder and SiC blocks made by using the undiluted phosphate binder baked at 1073K for 3hours(A、 C) and 24hours(B、 D).

### Coefficient of thermal expansion of composites

The mean CET of SiCp/6063Al composites in various conditions with different SiC powder binder ratios in the preforms for various temperature ranges are shown in Fig.2, which represents the average of four tests....

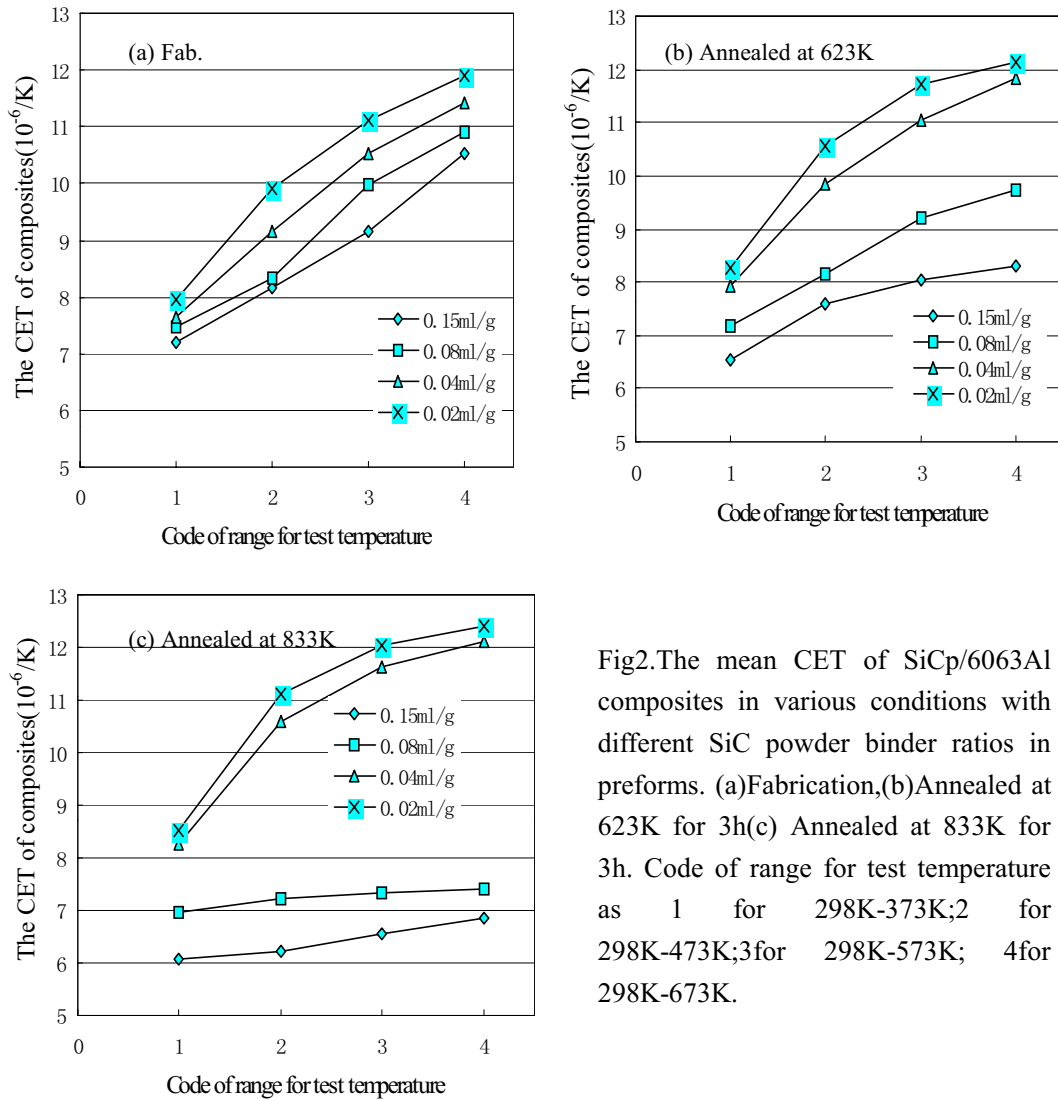


Fig2. The mean CET of SiCp/6063Al composites in various conditions with different SiC powder binder ratios in preforms. (a) Fabrication, (b) Annealed at 623K for 3h, (c) Annealed at 833K for 3h. Code of range for test temperature as 1 for 298K-373K; 2 for 298K-473K; 3 for 298K-573K; 4 for 298K-673K.

Fig.3 shows the effect of the annealing temperature on the CET of 6063Al alloy and SiCp/6063Al composites with preform baked at 1073K for 3h and 24h. The SiC powder binder ratios of the composites was 0.15ml/g. The annealing temperature have little effect on the mean CET of 6063Al alloy in the range 298K to 673K due to the CET determined by the bonding strength of atoms. When preform was baked at 1073K for 24h, the higher the annealing temperature, the higher mean CET of composite, whereas the higher the annealing temperature, the lower mean CET of composite with preform baked at 1073K for 3h....

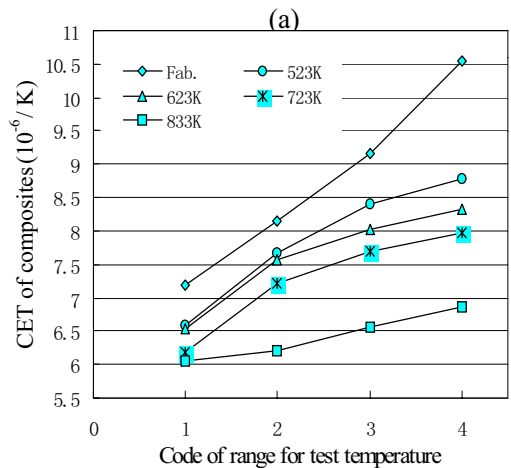
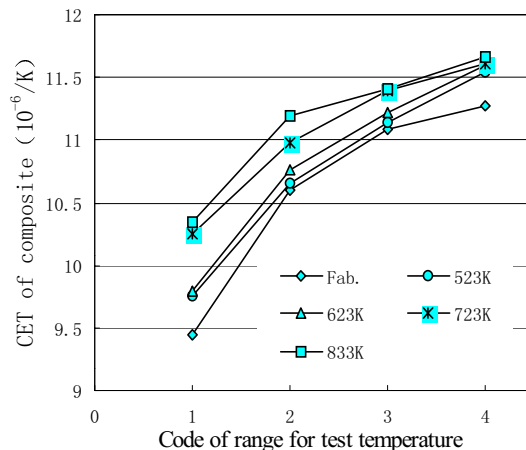
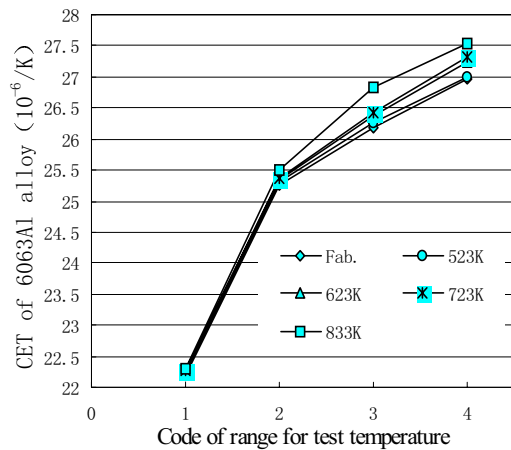


Fig3. The effect of anneal temperature on the mean CET of (a) 6063Al alloy and SiCp/6063Al composites with preform baked at 1073K for 3h (b) and 24h (c). Code of range for test temperature as 1 for 298K-373K; 2 for 298K-473K; 3 for 298K-573K; 4 for 298K-673K.

## CONCLUSION

1. The phases were different in SiC block baked for 3h and 24h. Aluminium metaphosphate may be dissociate to form aluminium orthophosphate at 1073K due to the presence of SiC particulate.
2. The effect of binder amount on CET of composites is quite evident in the composites for preform baked at 1073K for 3 hours with carrier/binder ratio of 20:3. The higher the binder amount, the lower the CET of SiCp/6063Al composite in fabrication, after annealed at 623K and at 833K for 3h.
3. The effect of heat treatment of preform on CET of composites is also quite evident. For baked at 1073K, the CET of composites with preform for 3h is lower than that of composite with preform for 24h.
4. The effect of anneal temperature of composites on CET of composite is determined by the binder amount and/or heat treatment of preform. The higher the anneal temperature, the higher CET of composite for binder amount no more than 0.04 ml/g or for preform with 0.15ml/g binder amount baked at 1073K for 24h, whereas the higher the anneal temperature, the lower CET of composite for binder amount as 0.08 and 0.15ml/g and baked at 1073K for 3h.

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