

# SOLIDIFYING STRUCTURES OF $\text{Al}_2\text{O}_3$ SHORT FIBER/Al-Si ALLOY MATRIX COMPOSITE PREPARED BY SQUEEZE CASTING<sup>①</sup>

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**ABSTRACT**  $\text{Al}_2\text{O}_3$  short fiber/Al-Si alloy matrix composite was prepared by squeeze casting. Solidifying structures of the composite were investigated. Results showed that primary silicon and eutectic silicon grains in the composite are obviously refined.

**Key words** composite short fiber Al-Si alloy solidifying structures squeeze casting

## 1 INTRODUCTION

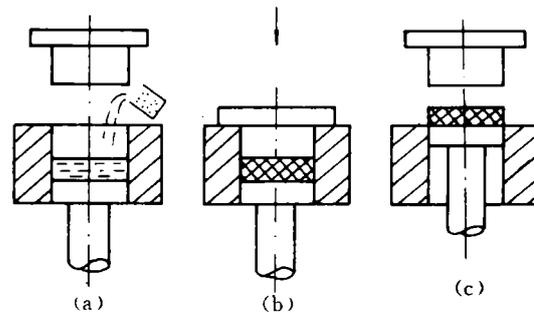
The squeeze casting is an important method to produce metal matrix composite. To investigate the solidifying characteristic of this composite is of great importance to the control of its solidifying process and structures, and to the improvement of its mechanical properties. Mortensen *et al.*<sup>[1]</sup> have investigated the solidifying process of SiC and  $\text{Al}_2\text{O}_3$  fiber/Al-Cu alloys matrix composites. Clyne *et al.*<sup>[2, 3]</sup> have investigated the effect of  $\delta$ - $\text{Al}_2\text{O}_3$  fiber on the solidifying structures of aluminium alloy matrix composite and found silicon precipitate on the surface of  $\delta$ - $\text{Al}_2\text{O}_3$  fibers in the composite.

The main purpose of this work is to examine the reasons of silicon grain refinement in  $\alpha$ - $\text{Al}_2\text{O}_3$  short fiber/Al-Si alloy matrix composite.

## 2 EXPERIMENTAL

$\text{Al}_2\text{O}_3$  short fiber used in this work mainly consists of  $\alpha$ - $\text{Al}_2\text{O}_3$  containing 15%  $\text{SiO}_2$ . The ratio  $L/D$  (Length/Diameter) of the fiber is 7 to 15. The matrix is an Al-11 Si-0.8 Cu-0.7 Mg-0.9 Ni alloy. The short fibers were made

into preforms, then  $\text{Al}_2\text{O}_3$ /Al-Si alloy matrix composite was prepared by squeeze casting. The squeeze casting process is schematically shown in Fig. 1. The short fiber volume fraction  $V_f$  is 24% in the composite. Fiber distribution, silicon phase size and distribution in the composite were observed by optical microscope and SEM. The hardness of reinforced field and unreinforced field in the composite was measured.



**Fig. 1 schematic diagram of squeeze casting process**

- (a)—pouring;
- (b)—mould assembling and pressing;
- (c)—mould unloading

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### 3 RESULTS AND DISCUSSION

The macrostructures of the composite are shown in Fig. 2, which indicates that the combination of the preform with the matrix alloy is good, but the interface between reinforced field and unreinforced field is distinct.



Fig. 2 Macrostructures of the composite  
above unreinforced field;  
below reinforced field

The hardness of the composite is shown in Table 1. Comparing the hardness data, it can be found that the matrix alloy is obviously reinforced by the fiber.

Table 1 Hardness of the composite

| hardness    | reinforced field | unreinforced field |
|-------------|------------------|--------------------|
| Hv(α-phase) | 97.0             | 80.5               |
| HBS5/250/60 | 147.0            | 100.5              |

Solidifying microstructures are shown in Fig. 3 and Fig. 4. Fig. 3 shows that solidifying structures of the matrix alloy in the reinforced field and the unreinforced field mainly consisted of α-phase, primary silicon and eutectic(α+Si), and primary silicon and eutectic silicon grains are obviously refined in the reinforced field. Fig. 4 indicates that silicon is precipitated on the surface of the fibers, which agrees with the reported results in refs. [2,3]. Fig. 4 also indicates that the surface of some fibers becomes rough, which would be proof of the reaction of Al and Mg in the matrix with SiO<sub>2</sub> in the fibers. From the viewpoint of thermodynamics, the following reactions can occur:

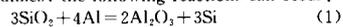
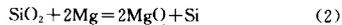


Fig. 3 Optical micrographs of the composite, ×200  
(a) reinforced field; (b) interface field; (c) unreinforced field



Fig. 4 SEM micrograph of the composite



Reduced silicon is conserved on the surface of the fibers or moves from the surface of the fibers to the matrix alloy melt with the help of the melt convection. In the case that pouring temperature is suitable, the silicon is not resolved or not all resolved. Reduced silicon may act as nuclei of silicon crystals. This is one of the important reasons for grain refinement of the primary silicon and the eutectic silicon in the reinforced field.

Some primary silicon grains and eutectic silicon grains are observed around fibers (Fig. 3 (a) and (b)). Occurrence of this phenomenon has three possible reasons. As above, the reduced silicon on the fiber surface acts as nuclei of the primary silicon and the eutectic silicon, and grows around the fibers. Silicon crystals may immediately be precipitated from the matrix alloy melt and grow until they contact with the fibers, i. e. the fiber may prevent silicon grains from growing. In

addition,  $\alpha$ -Al<sub>2</sub>O<sub>3</sub> structure is rhombohedral, its lattice parameters are  $a = 5.13 \text{ \AA}$ ,  $\alpha = 55^\circ 17' 41''$ . Silicon structure is face-centered cubic, its lattice parameter is  $a = 5.43 \text{ \AA}$ . The lattice misfit between  $\alpha$ -Al<sub>2</sub>O<sub>3</sub> and silicon is less than 6%. Therefore, there is coherent interface between  $\alpha$ -Al<sub>2</sub>O<sub>3</sub> and silicon, which is beneficial to the nucleation of silicon crystals with  $\alpha$ -Al<sub>2</sub>O<sub>3</sub> as the substrate; these are also the reasons of grain refinement of the primary silicon and eutectic silicon in the reinforced field.

#### 4 CONCLUSIONS

Solidifying microstructures of the matrix alloy in the  $\alpha$ -Al<sub>2</sub>O<sub>3</sub> short fiber/Al-Si alloy matrix composite prepared by squeeze casting mainly consist of  $\alpha$ -phase, primary silicon and eutectic ( $\alpha$ +Si). Primary silicon and eutectic silicon grains in the reinforced field are obviously refined.

Al and Mg in the matrix alloy react with SiO<sub>2</sub> in the fibers, leading to precipitate silicon on the surface of the fibers and increase the quantity of silicon nuclei; silicon crystals nucleate and grow with  $\alpha$ -Al<sub>2</sub>O<sub>3</sub> as the substrate. The fibers prevent the growth of the silicon crystals. These are possible reasons for the refinement of silicon grains in the composite.

#### REFERENCES

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