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# Solidified structure and solute segregation in $Al_2O_3$/A356-La alloy composites

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**Abstract:** $Al_2O_3$/A356-La alloy composites were fabricated by squeeze casting, and the effects of La on the solidified structure and the solute segregation during alloy solidification were studied. The results indicate that the structure of the matrix alloy becomes fine and small by the addition of La. La has been richened at the interface to help improve the wettability between the fiber and Al alloy, but there are no intermetallic compounds richening La found at the interface yet. There is no special influence of La on the Mg segregation in the matrix alloy. The distribution of Mg and La in the composites has been at the same position—near the interface.

**Key words:** composite; solidified structure; solute segregation; A356-La alloy

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## 1. Introduction

Because of the addition of reinforcement, the field of temperature, field of flow, field of concentration, and thermodynamics and dynamics of crystal growth during the composite solidification as well as the structural morphology of the composite are changed in processing of the fiber-reinforced Al matrix composite manufactured by liquid infiltration. The flow of solute is hindered by the fibers because the reinforcement acts as a barrier to solute diffusion ahead of the liquid/solid interface in the fiber-reinforced Al matrix composite [1-2]. Therefore, a lot of solute is segregated or some new phases are formed at the final location of solidification in the composite (e.g. fiber/matrix interface). The solute richening around the reinforcement is also a main factor to promote the interface reaction during the solidification. The solute segregation produced in the matrix will affect the final solidified structure, and moreover affect the mechanical properties of the composite. There is a need for research on solidification segregation of the fiber-reinforced Al matrix composite to improve properties of the composite and to raise the safety level of the composite. Up to now, there have been some detailed researches [1-4] on the solute segregation in foreign countries, and some literatures [5-6] in China have discussed this problem, but there are few literatures that study the solidification segregation in depth.

Sun *et al.* [7] found that the solubility of rare earths (RE) in the Al alloy is very low, and the solute redistribution in solidification can be enriched at grain boundaries. Using this characteristic of RE and the lower electronegativity of RE in comparison with that of other elements in the matrix, RE can preferentially adsorb at the fiber/matrix interface to reduce the richening of other elements, and then to bring about a decrease of solute segregation.

The solidified structures and solute segregation of $Al_2O_3$/A356-La alloy composites manufactured by squeeze casting are observed and researched by scanning electron microscope (SEM) and energy dispersive spectrometry (EDS), and the interaction between La element and solute element in solidification segregation is analyzed.

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## 2. Experimental

Alumina short fibers (3-5 μm in diameter) were used in the test, which consisted of $Al_2O_3$ (80 wt.%) and $SiO_2$ (20 wt.%). The main crystal phases of the fibers were $\alpha$-$Al_2O_3$ and mullite. The matrix alloy was prepared from A356 Al alloy and Al-La master alloy. The composition of the alloy was 7.1 wt.% Si, 0.37 wt.% Mg, 0.13 wt.% La, and the remaining, Al.

$Al_2O_3$/A356-La alloy composites were manufactured by squeeze casting. The fibers were made into preform, then dried and preheated. The preform was infiltrated by liquid Al alloy under 32 MPa. After solidifying and cooling, the ingot casting of the composite containing 15 vol.% fiber ($V_f$) was obtained. The samples, made from the composites, were polished using standard metallographic practice, etched with 0.5% aqueous solution of hydrofluoric acid and observed on a Philips XL-30 SEM. The phase structure and the composition of micro-area were analyzed on a Miniflex X-ray diffractometer and an EDAX electron probe. In addition, to determine further whether there were the richening of RE and the interaction at the fiber/matrix interface in the composite and to discover the phase structure of the reaction product, a small piece of sample was cut from the ingot. The matrix alloy in the sample was etched off with 40 wt.% aqueous solution of sodium hydroxide to leave only short alumina fiber, after separating and drying. The structure of the separated fiber was analyzed on an X-ray diffractometer and the composition of micro-area on the surface of the fiber was analyzed on an electron probe; the microstructure morphology was observed and the elements were analyzed on SEM in the form of back-scattering electron (BE) imaging.

## 3. Results

There is no shrinkage porosity in $Al_2O_3$/A356-La alloy composites, and the fibers uniformly distribute in the matrix and combine well with the matrix, as shown in Fig. 1. This indicates that liquid aluminum alloy fully infiltrates the fiber preform during squeeze casting, and the preform is not obviously deformed or displaced.

As regards the fining effect of La on eutectic silicon [8], it is seen from the structure morphologies of A356 with and without La that the number of eutectic silicon having stick-like or sheet-like morphology decreases obviously with the addition of little La to A356 alloy, and breaks into non-regulated particles.

For the composites without La, most of eutectic silicon nucleates and grows in the gap between the fibers, as shown in Fig. 2, so the strain energy is the main resistance of nuclei formation. Therefore, most of eutectic silicon shows strip-like or flake-like morphology. There is a definite restricting effect of $Al_2O_3$ short fibers on the growth of eutectic silicon, but the effectiveness, to a large extent, depends on the volume fraction of the fibers. Thus, the effect of fining and blocking of the fibers is not very evident because of the relatively small volume fraction of the fibers.

For the composites with little La, there is basically no strip-like eutectic silicon. However, the presence of $Al_2O_3$ short fibers in the matrix is more

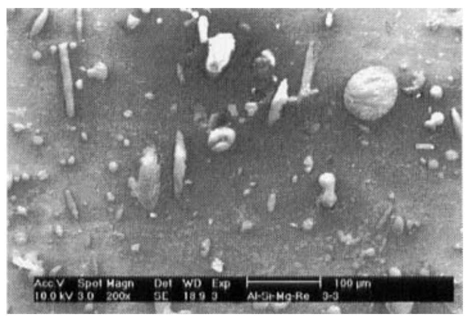

**Fig. 1. Solidified structure of the $Al_2O_3$/A356-La alloy composites.**

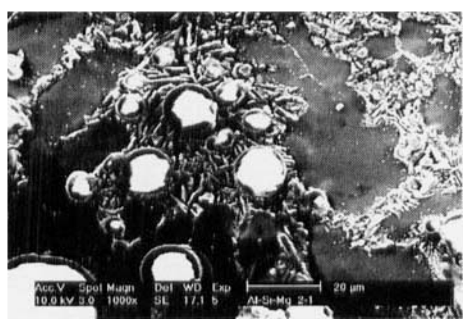

**Fig. 2. Morphology of eutectic Si in the composites without La.**