ROLES OF ORIENTATION RELATIONSHIP AND RECRYSTALLIZATION IN SUPERPLASTICITY OF SiCw/6061Al COMPOSITE①

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ABSTRACT The orientation relationship between different aluminium grains as well as that between the aluminium and the whisker during the superplastic deformation have been studied. In addition, the relation between recrystallization and orientation were examined. The results showed that during the superplastic deformation the orientation relationship between different aluminium grains and that between the aluminium and the whisker were unstable. There was also no definite orientation between the recrystal grains emerging in the process of superplastic deformation and the whisker. Only the recrystal grain produced in the end of deformation could keep definite orientation with the whisker. The recrystallization induced by superplastic deformation could coordinate the sliding of grain boundaries and the interfaces.

Key words SiCw/6061Al composite superplasticity orientation recrystallization

1 INTRODUCTION

Aluminium matrix composites reinforced with whiskers or particulates are an attractive kind of engineering materials because of their excellent mechanical properties such as high specific strength and modulus. However, the ductility of the composites is very low at room temperature. Thus an increasing interest has been shown in superplastic forming of the aluminium alloy matrix composites. Numbers of studies on the superplasticity of metal matrix composites have been carried out[1-4], but very few of them examined the elemental process of the microstructural changes during superplastic deformation. In addition, further systematic studies are still needed to provide a general understanding on the orientation relationship between aluminium matrix and whisker.

The purpose of the present work was to investigate these two aspects in details to get a further understanding of the superplastic deformation mechanism of SiCw/6061Al.

2 EXPERIMENTAL

The composite was fabricated by squeeze casting method, using β-SiC whisker (0.1~1.0 μm in diameter and 50~200 μm in length) as the reinforcement and commercial 6061 aluminium alloy as the matrix. The as-cast composite was hot extruded to a plate of 5 mm × 30 mm at 743 K with an extrusion ratio of 1∶22. Composite was 25% (mass fraction) determined by hydromatic method. The tensile sample with size of 10 mm × 6 mm × 2 mm was cut out from the plate parallel and vertical to the extrusion direction respectively. The samples were not processed with additional thermomechanical treatment for refinement of grain size[5-7]. A constant true strain-rate test for the optimum tensile condition was carried out in air at strain rate ranging from $8.33 \times 10^{-4}\ s^{-1}$ to $8.33 \times 10^{-3}\ s^{-1}$ and at temperature ranging from 773 K to 853 K. In order to study the process of superplastic deformation, some of the samples were drawn to failure and others drawn to different stages of deformation.

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The microstructure and the failured surface of the composite were examined by scanning electron microscopy and transmission electron microscopy. The changes of texture and the movement pattern of whiskers during the superplastic deformation were investigated by X-ray diffraction method.

3 RESULTS AND DISCUSSION

The results of superplastic deformation showed that the longitudinal sample had a maximum elongation of 280% at the temperature of 843 K and a strain rate of $2 \times 10^{-3}\ s^{-1}$, whereas the transversal sample had an elongation of 220% under the same condition.

The changes of microstructure and texture during the superplastic deformation were discussed in other papers[8, 9]. The present paper will focus on the orientation relationship between different aluminium as well as that between the aluminium and the whisker.

Fig. 1 shows the micrograph of the fractured surface of longitudinal specimen tensile to failure (280%) at 843K and at the strain rate of $2 \times 10^{-3}\ s^{-1}$. There are some whiskers exposed on the fractured surface. This indicates that interface sliding occurred during superplastic deformation, and it maybe a superplastic deformation mechanism of the composite as important as GBS and is consistant with the work of Nieh[10] and Imai[11].

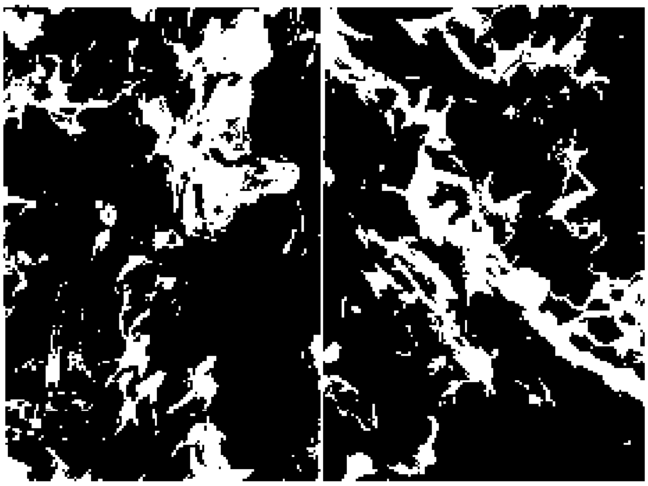

Fig. 1 The micrograph of the fractured surface of longitudinal specimen

Fig. 2 and Fig. 3 show the electronic diffraction patterns at the boundary of aluminium grains and the SiCw/Al interface in the longitudinal specimens drawn to 50%, respectively. It is evident that there are no definite orientation relationships between aluminium and whisker during superplastic deformation. This indicates that the movements of the matrix and the reinforcement are not dependent on the orientation relationship during superplastic deformation.

Fig. 4 and Fig. 5 show the electronic diffraction patterns at the boundary of aluminium grains and the SiCw/Al interface in the longitudinal specimens strained to 280%. It indicates that there are no definite orientation relationships between the aluminium grains and the boundaries are part of high-angle grain boundaries. At the interfaces, however, there are approximatively parallel orientation relationships

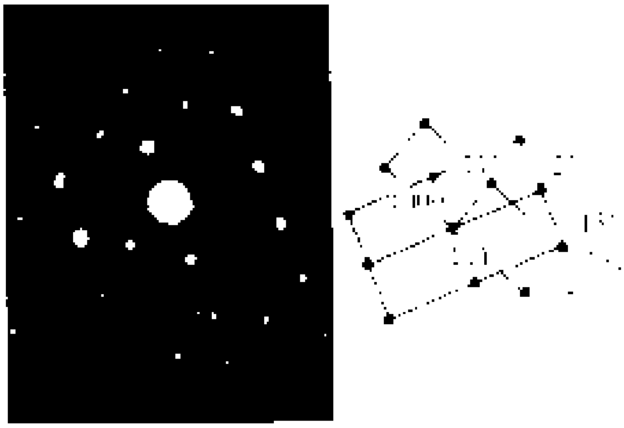

Fig. 2 The electronic diffraction patterns at the boundary of aluminium grains

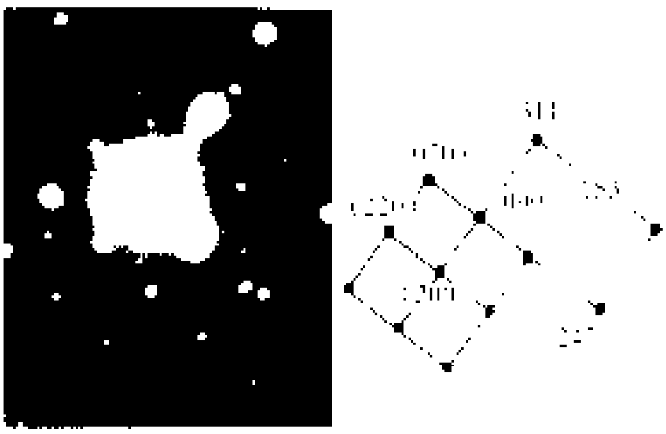

Fig. 3 The electronic diffraction pattern at the Al-SiC interface

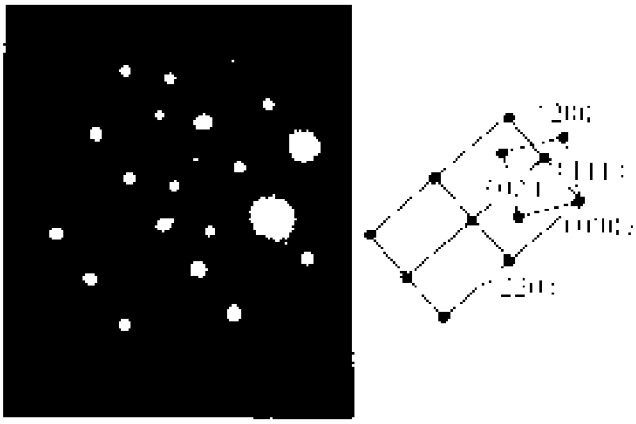

Fig. 4 The electronic diffraction pattern at the boundary of aluminium grains

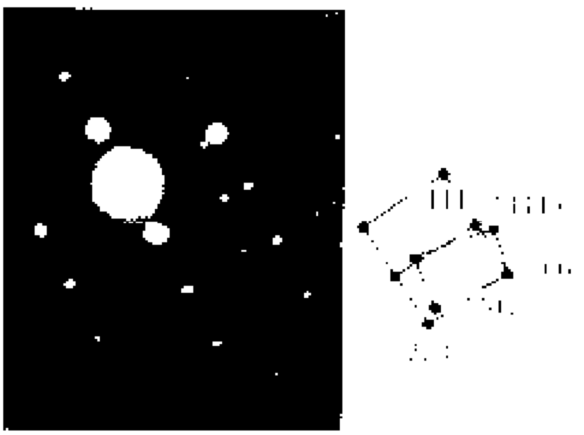

Fig. 5 The electronic diffraction pattern at the Al-SiC interface

between the crystal planes of Al and SiC with the same index. The angle between Al and SiC with the same index is about 7°. This indicates that there may be definite orientation relationship between the aluminium and the whisker in the end of superplastic deformation.

Previous studies indicated that recrystallization induced by deformation occurred during superplastic deformation[7-10]. The existence of whiskers can produce a favourable condition for the forming of cores of the recrystallization. Both crystal structures of Al and SiC whiskers are *fcc* without exception. The crystal lattice constants of Al and SiC are 0.405 and 0.435 6 nm, respectively. A semi-common lattice boundary may be formed. Thus the recrystal grains of Al may keep a definite orientation relationship with the adjacent whisker when recrystallization occurs in the matrix.

It was reported that recrystallization occurred at the beginning of superplastic deformation[9]. Thus the orientation relationship between the recrystal grains and the whisker could be observed when the sample was drawn to 50%. Inconsistency with the result in the present work indicates that the recrystal grains produced during the deformation would slide at once in the further deformation process and the orientation relationship between the aluminium and the whisker would be destroyed. The orientation relationship can remain at the SiCw-interface only at the end of superplastic deformation. Strictly speaking, because of the difference of lattice constant in the crystal Al and SiC, it is impossible to form a complete common lattice boundary and there is a little angle between the same index of crystal and whisker.

The orientation relationship formed during recrystallization is approximately parallel between the Al and SiC crystal planes with the same index. Recrystallization plays an important role in coordinating the sliding of grain boundary and SiC-Al interface during the gamut of superplastic deformation. This coordination is an important guarantee for the progress of superplastic deformation.

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