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Rapid projection of crystal grain orientation distribution in aluminium alloy sheets by synchrotron X-ray diffraction

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An investigation of the primary recrystallization and the grain growth process of aluminium alloy sheets has been carried out using a method for rapid projection of the crystal grain orientation distribution. It is found that the projected pattern is continuous in the cold-rolled state. When the sheet is annealed, tiny diffraction spots or small grains appear. The addition of Mg greatly alters the sizes and number of grains, and the orientation of the grains in sheets.

Keywords: crystal grain orientation; X-ray diffraction; aluminium alloy; recrystallization; grain growth.

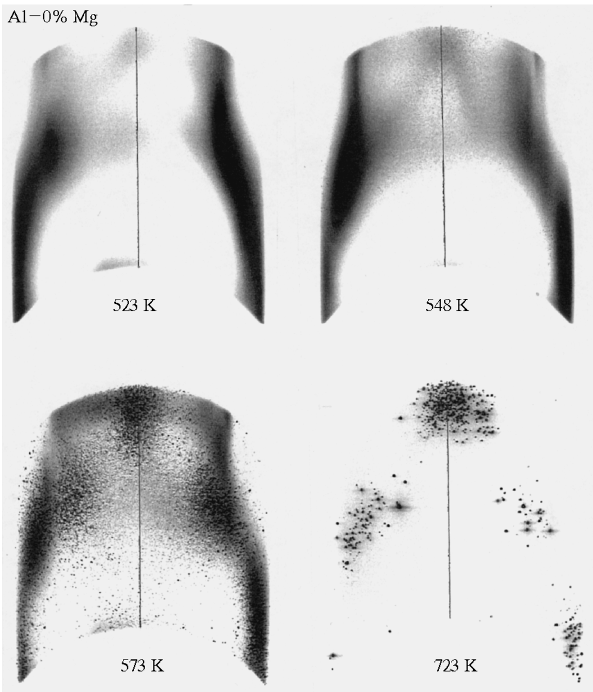

Figure 1
A series of crystal grain projection patterns of the {100} poles of pure aluminium sheets (Al–0% Mg) during the primary recrystallization and grain growth process.

1. Introduction

A new method for rapid projection of the crystal grain orientation distribution in polycrystalline materials, the pole figure, has been developed by Kawasaki & Iwasaki (1995). The great advantage of this method is that in every area of a grain orientation space, the grain size and the number of grains can be determined from the size (or integrated intensity) and the number of diffraction spots. An investigation of the primary recrystallization and the grain growth process of mild steel sheets has been carried out using this method (Kawasaki *et al.*, 1995). Recently, rapid projection patterns of the crystal grain orientation distribution of the primary recrystallization and the grain growth process of pure aluminium sheets were recorded (Kawasaki *et al.*, 1996). In this paper, the effect of the addition of Mg is examined in an Al–5% Mg alloy and the results are compared with those already reported for pure aluminium.

2. Experimental

Cold-rolled aluminium alloy sheets were heated isochronally for 1800 s at every stage of the primary recrystallization and the grain growth process at the Shonan Institute of Technology. Measurements were made at the normal-bending beamline BL-3A at the Photon Factory, KEK, Japan. Details of the experimental apparatus are described elsewhere (Kawasaki & Iwasaki, 1995). The beam size was 3 × 4 mm. The photon flux at the sample position was 1.3×10^{10} photons s^{-1} mm^{-2} at a wavelength of 0.06 nm with a beam current of 250 mA. {100} pole patterns were measured in transmission set-up at room temperature with an angle range of α (radial angle) from -5 to $+51^\circ$, β (circumferential angle) = $\pm 45^\circ$, within a time period of 110 s. Orientation distribution functions (ODFs) were measured at the Shonan Institute of Technology.

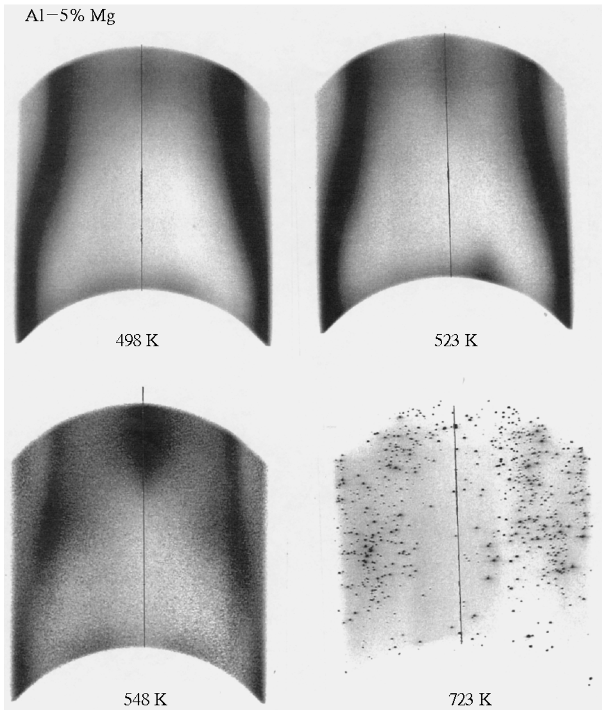

Figure 2
A series of crystal grain projection patterns of the {100} poles of Al–5% Mg sheets during the primary recrystallization and grain growth process.

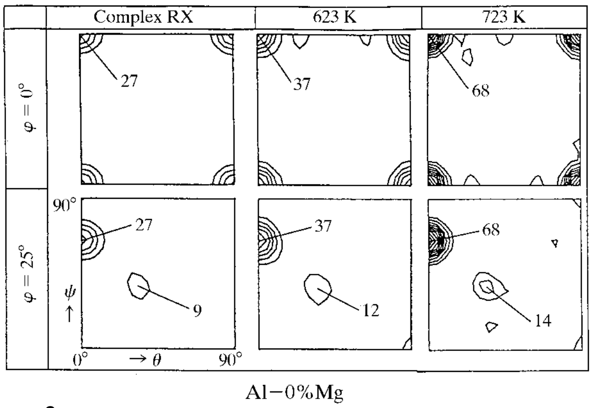

Figure 3
A series of ODFs of the same specimens as shown in Fig. 1 (pure aluminium sheets). 'Complete RX' is the completion of recrystallization. The peak intensity values are relative to those of a random orientation specimen.

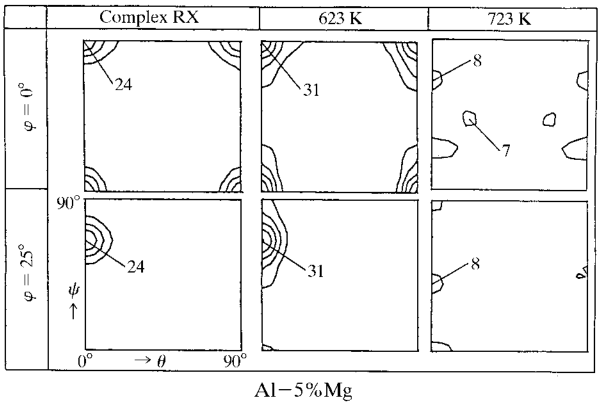

Figure 4
A series of ODFs of the same specimens as shown in Fig. 2 (Al–5% Mg sheets). 'Complete RX' is the completion of recrystallization. Peak intensity values are relative to those of a random orientation specimen.

3. Results and discussion

When the pure aluminium sheets were annealed, tiny diffraction spots or small grains appeared in the continuous pattern of the cold-rolled state. Step-by-step growth of the crystal grains was seen as an increase in the size and integral intensity of the diffraction spots, shown in Fig. 1. At 723 K, many grains are concentrated at the top of the pattern. The center point of this main area has cube orientation {(100)[001]}, and the center points of the two sub-areas have *R* orientation {retained rolling orientation: (123)[634]}.

When 5% Mg was added, tiny diffraction spots or small grains also appeared in the continuous pattern of the cold-rolled state. Step-by-step growth of the crystal grains was observed as an increase in the size and integral intensity of the diffraction spots, shown in Fig. 2. However, the peak of the cube orientation became weaker as grain growth progressed. In the pattern at 723 K, no grain concentration was observed at the cube orientation.

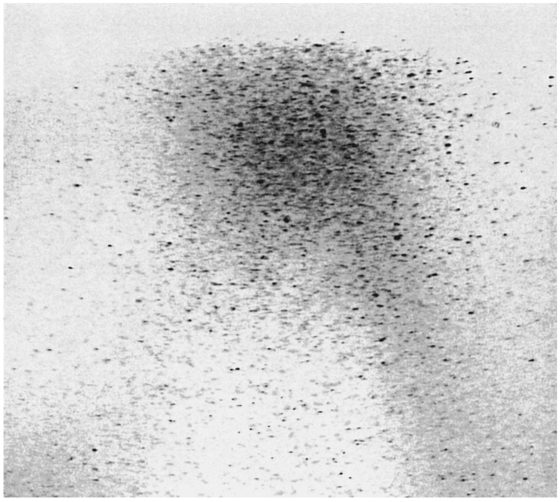

Figure 5
An image of the grains around the cube orientation in Fig. 1 at 548 K magnified four times.

The ODFs for the pure aluminium specimens showed peaks of crystal orientation (Fig. 3). The main peaks were observed in both the φ (Euler angle) = 0 and 25° sections (with intensity 27–68), corresponding to the cube orientation, and sub-peaks in the φ = 25° section (with intensity 9–14), corresponding to the *R* orientation. The ODFs for the aluminium alloy (Al–5% Mg) specimens shown in Fig. 4 clearly illustrate the weakening and disappearance of the cube orientation as observed in Fig. 2 by the rapid projection method. The cube orientation peak intensity observed in both the φ = 0 and 25° sections was initially 24, but decreased to almost zero at 723 K.

In Fig. 5, the image of the grains around the cube orientation in Fig. 1 at 548 K is magnified by a factor of four. It is very important that the appearance of tiny diffraction spots or small grains can be observed clearly in the continuous pattern of the cold-rolled state at the starting stage of recrystallization.

The difference in the projection patterns of pure aluminium and Al–5% Mg sheets is clear. These projected patterns correspond well to the ODFs. It can be concluded that the rapid projection method is useful for metallurgy studies such as recrystallization and grain growth. In a future study, the heating process will be observed directly.

References

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