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Slip-induced texture evolution of rolled Mg–6Al–3Sn alloy during uniaxial tension along rolling and transverse directions

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ABSTRACT

The microstructure and texture evolutions of a rolled Mg–6Al–3Sn (AT63) alloy were investigated during uniaxial tension along the rolling and transverse directions. Combination of experimental examination and Schmid factor analysis indicates that the texture evolution during the two tensions results mainly from dislocation slip. The texture variations in (0002) and $(10\bar{1}0)$ poles are related to basal slip and non-basal slips, respectively. The final textures exhibit the lowest SF values not only for basal slip but also for non-basal slips. Our results will be helpful in the investigation of slip mechanism based on texture examination.

1. Introduction

Due to the limited number of slip systems in the hexagonal close packed (hcp) structure, the deformation mechanism of Mg alloys strongly depends on texture [1–3]. Meanwhile, the deformation behavior of Mg alloys alters the initial texture with increasing strain [1–3]. Twinning-induced texture evolution has been extensively investigated in Mg alloys [4–8]. It is clear that extension twinning specifically leads to a drastic texture variation as it exhibits a crystal lattice reorientation of 86.3° and rapid boundary migration [5–7], whereas contraction twinning (or double-twinning) makes very small contribution to texture change due to the hindered growth of morphology [7,8]. Since slip takes place not only on the basal plane but also on the non-basal plane and induces uncertain crystal lattice reorientation, the analysis on slip-induced texture evolution is much more complex. Agnew et al. [9] suggested that dislocation slip weakened the deformation texture by increasing the plastic spin of the lattice ($\mathbf{W}_p$). Moreover, Khan et al. [10] associated the variation in basal pole distribution to basal dislocation activity.

In our previous study, we found that twinning and slip mechanisms varied significantly from plane stain compression (PSC, i.e., uniaxial compression in conjunction with lateral constraint) to equivalent uniaxial compression [11]. Extension twinning was largely suppressed during the PSC with lateral constraint along the normal direction, and texture evolution in this deformation resulted mainly from prismatic slip and directional pyramidal slip [11]. Note that the uniaxial strain path is totally different from the PSC, because of the absence of lateral constraint. However, the mechanism of slip-induced texture evolution under uniaxial strain is still not entirely clear. Generally speaking, extension twinning occurs when there is an extension strain component parallel to the *c*-axis, whereas contraction twinning takes place when there is a contraction strain component parallel to this *c*-axis [8,12,13]. Owing to the polarity of twinning, extension twinning is suppressed drastically in rolled Mg alloys during uniaxial tension along the rolling direction (RD) and transverse direction (TD), especially at quasi-static condition (strain rate range of 10^{-4}–10^{-3} s^{-1}) at room temperature [4,14]. The absence of extension twins thus gives us an opportunity to investigate the slip-induced texture evolution under uniaxial strain.

In the present study, we examine the texture evolution of a rolled Mg–6Al–3Sn (AT63) alloy during uniaxial tension along the RD and TD, and illustrate the slip mechanisms by calculating the Schmid factor (SF) systematically. The SF calculations are not merely performed on SF values, but are more focused on distributions of SF values.

2. Material and methods

The material used in this study was an AT63 Mg alloy (Mg–6.47Al–3.26Sn, wt%) plate with 5 mm thickness, which was first extruded at

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390 °C with an extrusion ratio $R=24.6$, followed by rolling at 350 °C with a thickness reduction of 38% and then homogenizing at 350 °C for 2 h. Dumbbell samples with gauge size of $10 \times 4 \times 2$ mm^3 were cut from the plate along the RD and TD. Uniaxial tension tests were conducted on an MTS-810 testing system at a constant strain rate of 1×10^{-3} s^{-1} at room temperature. The microstructure of each tensioned sample was examined by an optical microscope (Carl Zeiss-Axio Imager A2m, Germany) and X-ray diffraction (Rigaku 2500PC X-ray diffractometer with Cu Kα radiation at 40 kV and 150 mA).

3. Results and discussion

The initial material exhibits a twin-free equiaxial grain structure with an average linear intercept grain size of ~23 μm, as shown in Fig. 1a and b. The texture of the initial material is a typically rolled basal texture with most (0002) poles aligned parallel to the normal direction (ND), as shown in Fig. 1c. The $(10\bar{1}0)$ poles (Fig. 1d) are almost randomly distributed in the RD–TD plane. Since there is some spreading of the initial texture, we use the angles (α, β, θ) to simulate the spreading, where α is the angle between the (0002) pole and the RD–ND plane, β is the angle between the (0002) pole and the TD–ND plane, and θ is the angle between the RD and the projection of the $(10\bar{1}0)$ pole in the RD–TD plane. As seen from the simulation (Fig. 1e and f), the maximum spreading of (0002) poles along the RD is about 24° (i.e., $\beta_{max}=24°$) and that along the TD is about 16° (i.e., $\alpha_{max}=16°$).

To investigate the microstructure evolution, samples were tensioned along the RD to true strains of 0.01, 0.05 and 0.18. Mechanical curves and optical microstructures of these tensioned samples are shown in Fig. 2. The mechanical curves reveal a good repeatability, and the yield strength (σ_y) and ultimate tensile strength (σ_{UTS}) are about 160 MPa and 300 MPa, respectively. From the microstructures, one can see that contraction twins with thin needle-like morphology (black arrows) appear from the strain of 0.01. Extension twins presenting lenticular morphology (white

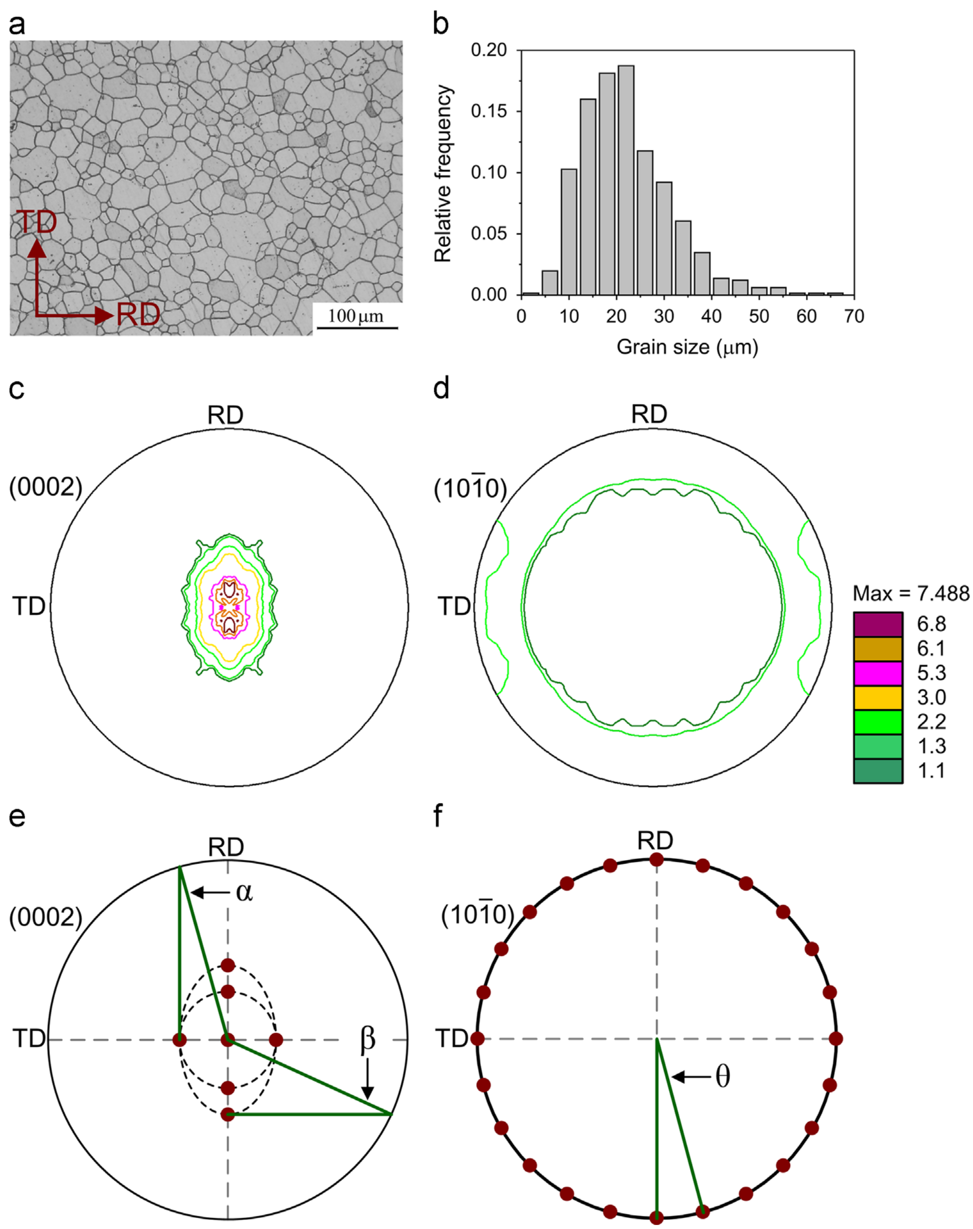

Fig. 1. (a) Optical microstructure and (b) grain size distribution of as-received plate. (c, d) (0002) and $(10\bar{1}0)$ pole figures of as-received plate. (e, f) Simulation of the pole figures in (c, d), where α is the angle between (0002) pole and the RD–ND plane, β is the angle between (0002) pole and the TD–ND plane, θ is the angle between the RD and the projection of the $(10\bar{1}0)$ pole in the RD–TD plane.