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Recrystallization and texture evolution of cold-rolled AZ31 Mg alloy treated by rapid thermal annealing

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ABSTRACT

The recrystallized microstructure and texture of AZ31 Mg alloy after rapid thermal annealing (RTA) was investigated. A mathematical model of RTA temperature of AZ31 Mg alloy was established based on the thermal equilibrium theory. The two double-peak textures with basal poles tilted 5–10° away from the normal direction towards the rolling direction or towards the transverse direction were formed in the AZ31 alloy during RTA. The tilted basal texture was originated from recrystallized grains formed along grain boundaries for the low rolling reduction or recrystallized grains formed within the shear bands and twins for the high rolling reduction. During RTA, the recrystallization mechanism was sensitive to the previous rolling reduction and the annealing temperature, and the mechanisms of the microstructure and texture evolution of the AZ31 alloy during RTA were discussed.

1. Introduction

Magnesium alloys are potential replacements for steels and other heavier materials in the automotive and other industry due to their low density, high specific strength and good damping capacity [1]. However, the poor ductility of Mg alloys at room temperature has hindered industrial application due to the hexagonal crystal structure with less independent slip systems. It is well known that grain refinement and texture modification can significantly improve the ductility and formability of Mg alloys [2–6]. Grain refinement and texture modification can be achieved by various means. Electropulsing treatment (EPT) is one of the most effective methods to attain grain refinement and texture modification by the rapid heating and rapid cooling for improving the mechanical properties of Mg alloys [7–11]. EPT induced grain refinement and texture modification by the rapid recrystallization resulting from the coupling of the thermal and athermal effects and limited grain growth resulting from the short time of several seconds of EPT [9].

On basis of the effect of the rapid heating and rapid cooling of EPT on the grain refinement and texture modification, in the present work the rapid thermal annealing (RTA) in the furnace was conducted to the cold-rolled AZ31 alloy. The effects of the RTA on the recrystallized microstructure and texture of the AZ31 alloy with different rolling reduction were studied and the mechanism of RTA induced recrystallization was discussed, which can give a guidance for RTA inducing grain refinement and texture modification of AZ31 alloy.

2. Experimental procedures

A commercial magnesium alloy AZ31 (3.1 wt% Al, 0.9 wt% Zn, 0.2 wt% Mn, balance Mg) was used in this investigation. The ingot was homogenized at 673 K for 8 h and subsequently extruded into strip of width 2.90 mm and thickness 1.5 mm. The extruded strips were annealed at 573 K for 1 h and were then cold-rolled in a single pass down to 1.35 mm and 1.03 mm thick, corresponding to the rolling reduction of 10% and 31%, respectively. The rolling direction (RD) was parallel to the extrusion direction.

The cold-rolled AZ31 alloy strips were subjected by rapid thermal annealing (RTA). During RTA, the muffle furnace was first heated to a high temperature of 853 K, 913 K or 973 K. The samples

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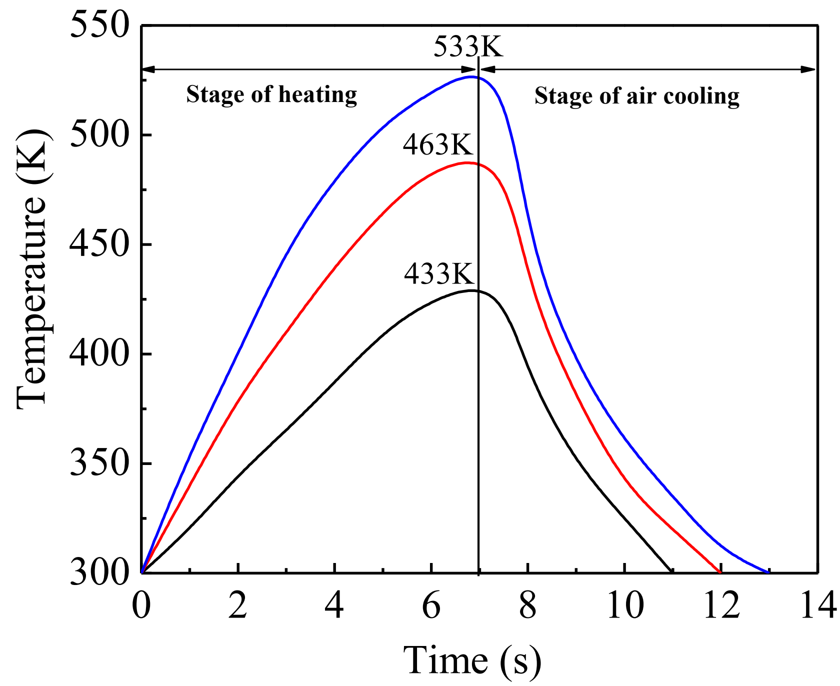

Fig. 1. Schematic view of the temperature change of the sample during RTA.

were then put into the furnace to be heated for about 7 s, finally putting the samples out of the furnace for cooling down to room temperature in air. In order to accurately measure the temperature change of the sample during RTA, a small blind hole needed to be drilled on the strip and a Φ 0.1 mm thermocouple was put into the hole and then welded to contact the sample. The temperature change of the sample during RTA was schematically shown in Fig. 1, which can be divided into the following two stages: stage of heating and stage of air cooling. The maximum temperature of the sample during RTA was defined as the temperature of RTA, and this temperature can be adjusted by changing the temperature of the furnace and the heating time, and the temperature error of the sample was ±3 K. The RTA parameters were listed in Table 1.

Prior to the optical examination, the samples were sectioned, cold mounted and polished with 6 μm and 1 μm diamond paste, and were then etched in acetic picral (5 ml acetic acid, 6 g picric acid, 35 ml ethanol, and 5 ml water) for 5 s. The average grain size was detected from the optical micrographs by the linear intercept method. The X-ray texture analysis was conducted on the cold-rolled and RTA samples. Four incomplete pole figures (up to $\psi = 70°$), namely (0002), $(10\bar{1}0)$, $(10\bar{1}1)$ and $(10\bar{1}2)$ were acquired from each sample by X-ray diffraction in the back reflection mode with Cu–Kα radiation. The pole figures showed that only the (0002) basal plane texture was developed, therefore, only the (0002) pole figure was given in this paper.

3. Results

3.1. Microstructure and texture of the cold-rolled AZ31 alloy

Our previous work indicated that the typical cold-rolled structures of prolonged crystals along the rolling direction and the basal texture existed in the AZ31 alloy after cold-rolling with 10% and 31% reduction [7], as shown in Fig. 2. For the low reduction of 10%, some deformation twins happened in the large grains, and a significant amount of the strain was accommodated in the regions near grain boundary, as shown in Fig. 2(a). For the high reduction of 31%, the number of the twin increased apparently, and the shear band and intersection between the deformation twins occurred, as shown in Fig. 2(b).

3.2. Microstructure and texture of the cold-rolled AZ31 alloy after rapid thermal annealing

The microstructure and (0002) pole figures of the cold-rolled samples with a reduction of 10% after RTA at 433 K and 533 K are shown in Fig. 3. When the RTA temperature was 433 K, incomplete recrystallization occurred and recrystallized grains formed mainly along the previous grain boundaries, accompanying some twins in the previous grains, as indicated in Fig. 3(a). This implied that the strain induced grain boundary migration (SIBM) mechanism played an important role in recrystallization. The sample had the common basal texture of (0002), as shown in Fig. 3(c).

Table 1
Experimental conditions for the cold-rolled AZ31 alloy strip under RTA.

Sample NO	Rolling reduction (%)	Temperature on the side surface (K)	Measured temperature on sample (K)
RTA1	10	853	433
RTA 2	10	913	463
RTA 3	10	973	533
RTA 4	31	853	433
RTA 5	31	913	463
RTA 6	31	973	533