Journal of Alloys and Compounds 666 (2016) 341–345

Contents lists available at ScienceDirect

Journal of Alloys and Compounds

journal homepage: http://www.elsevier.com/locate/jalcom

Annealing induced concentration of basal poles toward the normal direction of a hot rolled Mg–5.7Zn plate

Yannan Wang, Yunchang Xin*, Qing Liu**

School of Materials Science and Engineering, Chongqing University, Chongqing 400044, China

ARTICLE INFO

Article history:
Received 10 September 2015
Received in revised form
8 December 2015
Accepted 30 December 2015
Available online 4 January 2016

Keywords:
Magnesium alloys
Rolling
Texture
Recrystallization

ABSTRACT

In the present study, a Mg–5.7Zn hot rolled plate was annealed at different temperature, with the aim to study the texture evolution during static recrystallization. Our results show that the initial basal texture with two peaks of basal poles tilting from the normal direction (ND) toward the transverse direction (TD) is replaced by a single peaked basal texture and basal poles concentrate toward the ND after a complete recyrstallization. It is found that the recrystallized grains mainly appear in the shear bands containing many twins. The recrystallized grains with basal pole close to ND have much higher nucleation rate than nucleus randomly oriented and grain growth does not change the advantage of basal orientations, which is mainly responsible for the concentration of basal poles toward the ND.

1. Introduction

Magnesium and its alloys have received increasing attention for their potential applications in automotive and aerospace industries owing to their low densities, desirable mechanical properties and high damping capacity [1,2]. The limited number of independent slip systems at room temperature and the sharp textures in rolled plates or extruded products lead to a poor cold working ability and a strong mechanical anisotropy. There have been a large number of studies involving modification the texture of Mg alloy sheets to improve working capability [3–6]. It has been shown that addition of suitable elements (such as rare earth (RE)) can significantly weaken and randomize texture. Especially, some Mg–Zn–RE sheets exhibit a texture characterized by two peaks of basal poles tilting away from the ND toward the TD, which is different from those typically observed texture with a strong peak around the ND or two peaks tilting from the ND toward the rolling direction (RD) for conventional Mg alloy sheets. Our recent experiment showed that a similar double peaked TD-split texture could also appear in Mg–xZn sheets that were hot rolled from an as-cast ingot by one-single pass rolling. This type of TD-split seems to exhibit better stretch formability or cold working ability [7,8].

It is found that this TD-split texture in Mg alloys often forms after annealing [4–7,9–11]. For example, the study of Yan et al. suggested that a TD-split texture with two peaks of basal poles inclining about 48° from the ND toward the TD forms after static recrystallization [5]. Kim et al. [9] also reported the presence of TD-split texture in rolled Mg–6Zn–1Ca (ZX61). A subsequent annealing slightly weakened the texture, hardly changing its feature. It seems that annealing often benefits the formation of two peaked TD-split texture or contributes to the spreading of basal poles from the ND toward the TD. However, in the present study, it was found that the two peaked TD-split texture in a hot-rolled Mg–5.7Zn plate disappears and a concentration of basal poles toward the ND takes place after a complete static recrystallization. The corresponding mechanisms were studied and discussed.

2. Experiments and methods

Mg–5.7Zn as-cast ingot was subjected to homogenization at 320 °C for 13 h and at 400 °C for 8 h. A block with dimensions 90 mm × 70 mm × 5 mm was cut and hot rolled at 400 °C in a single pass to 39% thickness reduction. The hot rolled plate was immediately quenched in water to keep the microstructure and subjected to different annealing treatments: 300 °C/30 min, 400 °C/5 min, 400 °C/1 h, 400 °C/3 h and 450 °C/9 h in a muffle furnace.

For microstructure examination by optical microscopy, the specimens were prepared by grinding and subsequent etching in an acetic picral solution (2 ml acetic acid + 1 g picric

* Corresponding author.
** Corresponding author.
E-mail addresses: ycxin@cqu.edu.cn (Y. Xin), qingliu@cqu.edu.cn (Q. Liu).

http://dx.doi.org/10.1016/j.jallcom.2015.12.253
0925-8388/

acid + 2 ml H_2O + 16 ml ethanol). Pole figures of specimens were measured using an XRD analysis (Rigaku D/max-2500PC). The measured incomplete pole figures were analyzed to determine the orientation distribution function and the complete pole figures were reconstructed. Electron back-scattered diffraction (EBSD) mappings using a step size 0.5 μm were conducted on a FEI NOVA400 scanning electron microscope (SEM) equipped with an Oxford-EBSD system. All the EBSD data were analyzed by the Channel 5 software. The samples for EBSD mapping were mechanical ground followed by electro-chemical polishing in an AC2 electrolyte at 20 V for 90 s.

3. Results and discussion

Textures of the as-hot-rolled and the as-annealed Mg–5.7Zn plate are given in Fig. 1. The hot-rolled sample shows a relatively sharp basal texture with two peaks of the basal poles about 10° away from the ND toward the TD. This TD-tilted texture hardly changes after annealing at 400 °C for 1 h (Fig. 1b), while the basal poles concentrate toward the ND after annealing at 400 °C for 3 h (Fig. 1c). The two peaks of basal poles completely disappear after an annealing at 450 °C for 9 h (Fig. 1d), forming a strong peak of (0002) poles around the ND. However, the maximum intensity of basal poles distribution decreases after annealing.

Optical microstructures of the hot rolled plate after different annealing treatments are shown in Fig. 2. A dense network of shear bands containing much twins exist in the hot-rolled samples (Fig. 2a). There is not obvious dynamic recrystallization (DRX) taking place. The roll is cold during hot rolling. When the thin and hot plate contacts the roll, a fast drop in temperature would appear. In addition, the strain rate during rolling deformation is often very high. Both the two factors account for the presence of many twins during hot rolling in the present study. After annealing at 400 °C for 5 min (Fig. 2b), a large numbers of new and fine grains appear. However, the deformed microstructures are not completely removed even after annealing at 400 °C for 3 h, where some coarse grains containing thin twins are still observable. The annealing at 450 °C for 9 h leads to an obvious growth of the recrystallized grains and generates a completely recrystallized microstructure.

The microstructure and crystallographic orientations in the hot rolled plate with annealing at 400 °C for 1 h were further investigated by EBSD and the results are presented in Fig. 3. The subsets associated with the deformed grains and the recrystallized grains, respectively, were extracted and further analyzed. In the present study, the grains without low angle boundaries (misorientation angle below 4°) are considered as the recrystallized grains. The deformed grains have two obvious peaks of (0002) poles away from the ND toward the TD, which is in good agreement with the results determined by XRD (Fig. 1c). In comparison, the (0002) poles of the recrystallized grains are concentrated around the ND (Fig. 3b). The misorientation angle distributions in Fig. 3b show a peak around 30°, a typical feature of the recrystallized structure in Mg [12]. It is well known that tilting angle of basal pole distributes may change through the thickness of rolled plate. However, the texture by measured by XRD from the surface and that acquired by EBSD from the middle plane of the sheet show a similar tendency, concentration of basal poles toward the ND after annealing.

For example, for Zr with a c/a ratio of 1.589, much lower than the ideal value (1.633) of *hcp* structure, prismatic <a> slip is considered to have a higher activity than basal slip. A high activity of prismatic <a> slip is considered to greatly contribute to the formation of a texture with the basal poles ±20–40° away from the ND towards the TD [13]. Becerra et al. and Park et al. reported that Zn addition in the 0.2–3.1 at% range hardly reduces the c/a ratio of Mg–Zn alloy [14,15]. Increasing evidences demonstrates that the activity of non basal slips is not only determined by the axial ratio but varies with changes in stacking fault energy. As a lower unstable stacking fault energy (γ_{us}) denotes a lower energy barrier for dislocation nucleation. According to the calculations by Wang et al. [16], the γ_{us} value associated with pyramidal $\{10\bar{1}1\} < 11\bar{2}0 >$ slip decreases by Zn addition and further drops with increasing the Zn content. Therefore, the formation of TD-split texture in the present study is considered to be associated with the effect of Zn addition on stacking fault energy.

Annealing induced inclination of basal poles is closely related with the initial texture. In many cases, for the Mg alloy sheets with a typical strong peak of (0002) poles around the ND, annealing generally induces spreading of basal poles away from the ND [17–19]. For, example, Huang et al. reported that the strong

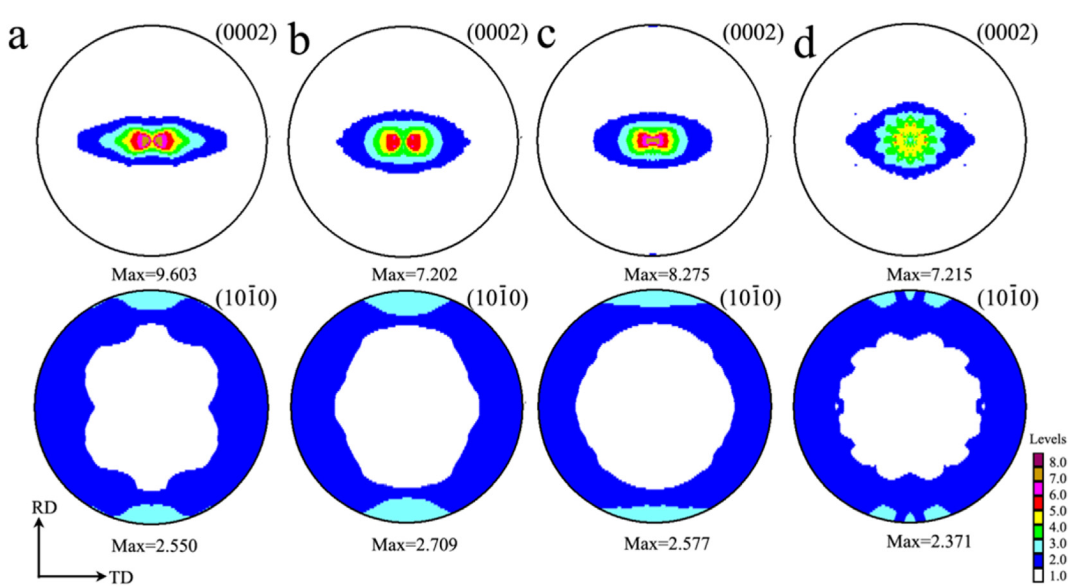

Fig. 1. Pole figures of a Mg–5.7Zn plate after hot rolling at 400 °C–39% and annealing: (a) hot-rolled (b) annealed at 400 °C for 1 h, (c) annealed at 400 °C for 3 h and (d) annealed at 450 °C for 9 h.