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Effects of annealing on texture evolution of cross shear rolled high-purity Al foils

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Abstract: The effects of annealing on recrystallization texture of cross shear rolled high-purity Al foil were investigated by orientation distribution functions (ODFs) and electron backscattered diffraction (EBSD). The results show that the intermediate annealing is beneficial to the development of the cube texture. The cube texture can be promoted by annealing, and the critical annealing temperature is about 280 °C. The cubic orientation grains firstly nucleate, and then expand into other grains with a high growth speed, and large angle grain boundary ratio increases, finally can swallow up most of the original grains, which results in the cube texture.
Keywords: high-purity Al foils; cross shear rolling; cube texture; annealing

1. Introduction

High purity Al foil is mainly used as anode materials for high voltage capacitor, whose electricity capacitance is dependent on effective surface area ratio [1-2]. The special electrochemical corrosion technology has been developed, to produce a large number of tunnels and pore pits, thus the surface area of Al foil has successfully increased [3-4]. It has been reported that Al foil erosion performance is affected by the cubic texture. The more cubic texture, the higher specific capacitance is. Several studies have focused on the cubic texture controlling by means of rolling and heat treatment [5], but few studies are about texture evolution of Al foil during the cross shear rolling and the annealing process. Therefore, on the basis of the previous research [6], cross shear rolling was chosen in the present study, to investigate the cubic texture content during the following heat treatments, and the effect of annealing on texture evolution of Al foils.

2. Experimental procedures

The chemical compositions of 2mm thickness Al foils with 99.99% purity are Fe 0.002, Si 0.002, Cu 0.007 and balance Al(mass %). The foils with or without of intermediate annealing were prepared by cross shear rolling with the speed ratios of 1.06, respectively. Then the specimens were treated by final annealing. The textures were measured at 1/4 layer of the specimen thickness with incomplete {111}, {200} and {220} pole figures using the X'pert MRD type X-ray diffractometer (XRD) with Co-Kα radiation. The corresponding ODFs were calculated by Labtex 3.0 software. The textures were also characterized by EBSD. The specimens for EBSD were electrolytic polished, using a solution(CH_3OH：HNO_3=2:1) at 25V.

3. Results and Discussion

3.1 Effect of intermediate annealing on the cube texture

The texture fractions the samples with or without intermediate annealing are shown in Fig. 1. The final annealing are at 400℃ for 5 min. The mark "1.06t" means the rolling speed ratio is 1.06; t means the sample with intermediate annealing, while w means those without intermediate annealing. It is clearly shown that the volume fraction of cubic texture with intermediate annealing is higher than that without intermediate annealing. In addition, the volume fraction of cold rolled textures, such as S, copper in intermediate annealed foil are lower than those without intermediate annealing, but the volume fraction of R texture in intermediate annealed samples is higher than those without intermediate annealing. The cube and R texture are both recrystallization textures, transformed from the cold rolled textures. That means intermediate annealing can promote the changes from the cold rolling texture to the cube texture.

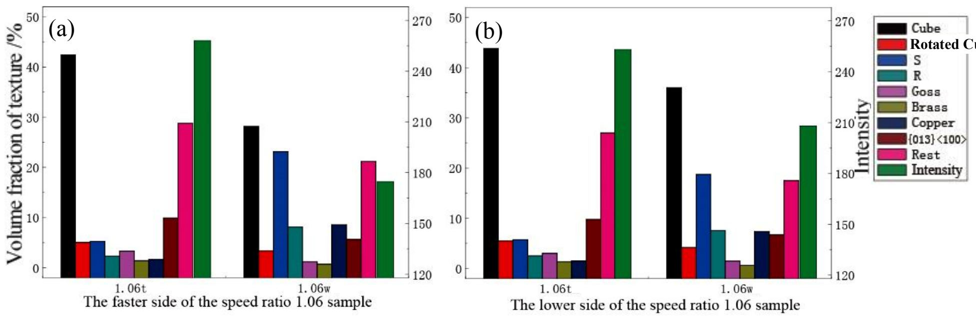

Fig. 1 Texture volume fraction in the samples with or without intermediate annealing: (a) the faster side; (b) the lower side

3.2 Effect of final annealing on the cube texture

Fig. 2 illustrates the texture volume fraction of the samples annealed at different temperatures. It shows that the increase of cubic texture is quite limited, if the samples are annealed at 250 °C for 1 h and 12h. If the annealing temperature increases to 280 °C, most of the cold rolled texture has completely transformed to the recrystallized cubic texture after 12h. It is obvious that annealing temperature dominates the recrystallization process, and the annealing times is still not enough to stimulate the development of the cubic texture if the annealing temperature is low. The critical annealing temperature is about 280 °C.

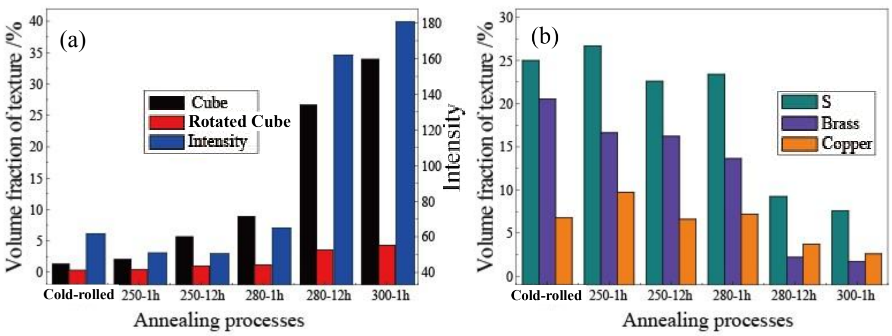

Fig. 2 Texture volume fraction of samples at low-temperature annealing: (a) cube, rotated cube texture; (b) cold-rolled texture

The effects of annealing time on the texture of Al foils with the final annealing of 300 °C are shown in Fig. 3. It is obvious that the volume fractions of recrystallization texture are still at a lower level, and the cubic texture does not illustrate the relative advantages compared with other textures, if the annealing time is within 10 min. When the annealing time prolongs to 20 min, the cubic texture gradually form. With the increasing of annealing time, the cubic texture and most other texture are kept constant, which means the effect of annealing time on the texture can be weaken, if the annealing time is higher than 20 min.

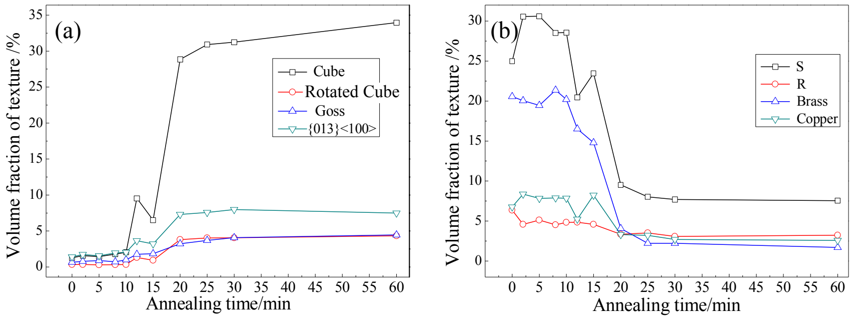

Fig. 3 Texture evolution of Al foils annealed at 300 °C: (a) cube, rotated cube texture; (b) cold-rolled texture

3.3 Texture evolution mechanism

In order to explore the texture evolution mechanism, the annealing time interval is enlarged to 2 min, and both ODF and EBSD are carried out. Fig. 4 shows the evolution of the ODF with series of annealing times at 300 °C. When the annealing time is 10 min, Brass texture is still the main part of the texture, as shown in Fig. 5 (a). If the annealing time extends to 12 min, the cubic texture starts to form and gradually develops with increasing of the annealing time. And until 20 min, they are almost cube textures.

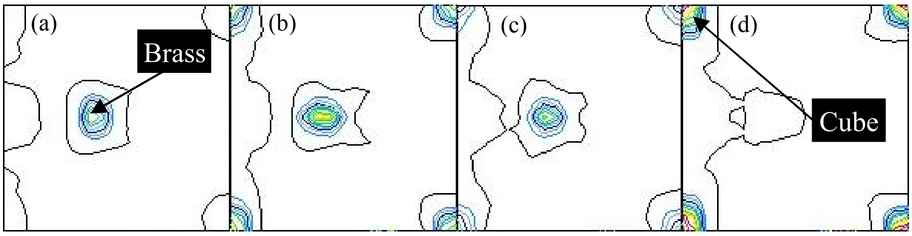

Fig. 4 Evolution of the ODF annealed at 300 °C for: (a) 10 min; (b) 12 min; (c) 15 min; (d) 20 min

Fig. 5 shows the orientation and texture map annealed at 300 °C. When the annealing time is 14min, the grain is priority to {101} orientation. When the time increases to 16 min, the red parts with cube texture increases. With the time increases, the cold rolled texture gradually disappears. It has been reported [7] that the growth of the cubic orientation ascribes to the 38°- 40° <111> axis rotation relationships between the cube orientation {001}<100> and the copper texture {112}<111>, or the 38° - 40°<111>axis rotation relationships between the cube orientation {001}<100> and S texture {123}<634>. That is why the cube texture preferentially grows, and there are almost cube textures when the annealing time is about 24 min.

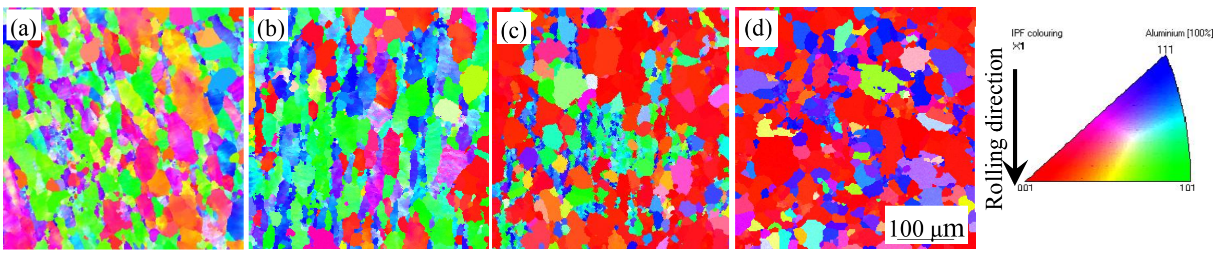

Fig. 5 Orientation and texture map annealed at 300 °C for: (a) 14 min; (b) 16 min; (c) 22 min; and (d) 24 min

In fact, the recrystallization attributes to grain boundary migration, so the grain boundary type changes with annealing can also reflect the texture transformation. The grain boundary types during annealing at 300 °C are shown in Fig. 6. It shows that when the annealing time is 14 min, the amount of small angle grain boundary is very high and almost near 6-7°, illustrating that a cold rolled texture component dominate the structure. While when the cold rolled texture starts to change to the cube texture, the large angle boundaries increase especially near 55°. Furthermore, the proportion of grain boundary orientation angle at 57° between adjacent boundaries is especially higher than that between non-adjacent ones, illustrating that part of the orientation of cold rolled grain has changes towards other orientation which is quite different and can also be confirmed to be cube orientation by ODFs and EBSD. So the grains with cube orientation gradually grow during the recrystallization, and finally, the most cube texture forms during the annealing.

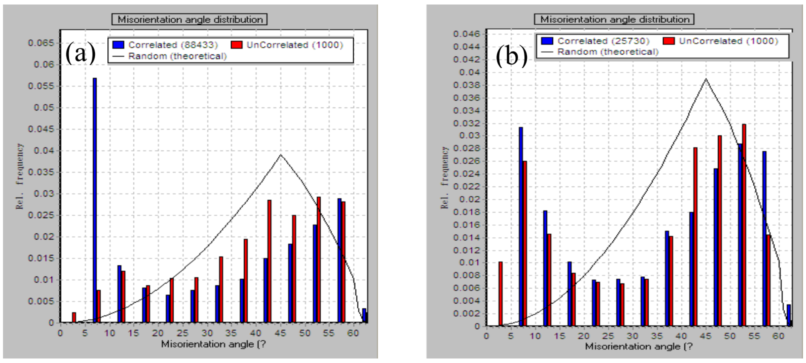

Fig. 6 Misorientations annealed at 300 °C for: (a) 14 min; (b) 24 min

Conclusions:

1. The cubic texture fraction of Al foil with the intermediate annealing is higher than that without intermediate annealing, which proves the intermediate annealing much beneficial to the development of the cube texture.
2. The critical annealing temperature of the cross shear rolled foil with the intermediate annealing is about 280 °C. Below 280 °C, the annealing temperature plays the leading role on the recrystallization process.
3. The texture transformation mechanism is as follows: Firstly, the grains with cubic orientation start to depressively nucleates, and then expand into other grains with a high growth speed, and large angle grain boundary ratio increases, finally can swallow up most of the original grains, which makes the cube texture becoming the main texture of the high-purity Al foil.

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