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MICROSTRUCTURE AND MECHANICAL PROPERTIES OF AS CAST Al-6.5Mg-1.5Zn-0.5Fe ALLOY FOLLOWED BY COLD ROLLING AND SUBSEQUENT ANNEALING

Microstructures and mechanical properties of as-cast Al-6.5Mg-1.5Zn-0.5Fe alloys newly alloy-designed for the parts of automobile were investigated in detail. The aluminum (Al) sheets of 4 mm thickness, 30 mm width and 100 mm length were reduced to a thickness of 1mm by multi-pass rolling at ambient temperature and subsequently annealed for 1h at 200~500°C. The as-cast Al sheet was deformed without a formation of so large cracks even at huge rolling reduction of 75%. The recrystallization begun to occur at 250°C, it finished at 350°C. The as-rolled material showed tensile strength of 430 MPa and tensile elongation of 4.7%, however the specimen after annealing at 500°C showed the strength of 305 MPa and the elongation of 32%. The fraction of high angle grain boundaries above 15 degree increased greatly after annealing at high temperatures. These characteristics of the specimens after annealing were discussed in detail.

Keywords: aluminum alloy, cold rolling, annealing, microstructure, mechanical properties

1. Introduction

In recent, lots of studies on lightweight of automobile have been done because of importance of the energy saving and green environment [1-12]. Especially, the aluminum (Al) alloys for automotive body panel have been studied extensively because of their benefits such as medium strength, good formability and lightweight [13]. It is also expected that the substitution of such aluminum alloys for steels will result in great improvements in energy economy, recyclability and life-cycle cost. In the way, two different types of Al alloys of wrought and casting states are used as the automobile materials. They have different chemical composition and different fabrication methods to each other. Therefore, there are some problems such as welding and joining in manufacturing of the vehicle. Hence, it is necessary not only to enhance both strength and ductility of the conventional Al alloys but also to develop new Al alloys to satisfy the various mechanical properties needed for further applications of Al alloys to the automobile industries. In present study, a new Al alloy was designed to attain the proper balance of strength and elongation for automotive structural materials through an increase of Magnesium (Mg) and Zinc (Zn) contents and a decrease of Manganese (Mn) content, comparing to the conventional Al5083 alloy. In addition, the changes of microstructures and mechanical properties with annealing temperature after rolling of an Al-6.5Mg-1.5Zn-0.5Fe system alloy newly alloy-designed were investigated in detail.

2. Experimental

The chemical composition of a material newly alloy-designed for this study is as Table 1. The as-cast Al alloy sheet of 4 mm thickness, 30 mm width and 100 mm length was prepared for cold rolling and subsequent annealing. The as-cast Al sheet was reduced to 1mm thickness by multi-pass cold rolling, and then subsequently annealed for 0.5 h at various temperatures ranging from 200 to 500°C.

TABLE 1

Chemical compositions of an Al alloy newly designed in this study (wt%)

Al	Mg	Zn	Fe	Mn	Si	Ti	Cu	Sr	B
Bal.	6.5	1.0	0.2	0.2	0.1	0.1	0.1	0.1	0.02

Micro-texture measurements by electro-backscattering-diffraction (EBSD) analysis were performed on JSM-700F field emission scanning electron microscope (FE-SEM) equipped with a TSL-OIM EBSD analysis system. The EBSD measurements were conducted on the planes perpendicular to the transverse direction (TD) of the sheets.

The mechanical properties of the specimens were investigated by tensile and hardness test. The tensile test was performed by initial strain rate of $10^{-3}s^{-1}$ at ambient temperature with an Instron-type tensile testing machine. The test pieces were ma-

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chined so that the tensile direction was parallel to the rolling direction. The gauge length and width were 32 mm and 6 mm, respectively. The variation of Vickers hardness through the thickness of the samples was also measured with the load of 0.98 N.

3. Results and discussion

3.1. Microstructure

The as-rolled Al material showed a typical deformation structure in which the grains are elongated to the rolling direction. The specimen annealed at 200°C was also a deformation structure followed by an occurrence of recovery. However, the microstructure of the Al alloy began to change obviously from annealing at 250°C. Fig. 1(a) shows the grain boundary (GB) map, the normal direction (ND) map and the rolling direction (RD) map obtained by EBSD measurement for the specimen annealed at 250°C. The color of each point indicates the crystallographic direction parallel to ND and RD of the sample, corresponding to the colored stereographic triangle, respectively. As indicated by the arrows in Fig. 1(a), the equiaxed fine grains newly developed are observed. This means that the partial recrystallization occurred after annealing at 250°C. In addition, it was found through ND and RD maps that a rolling texture of {100}<211> (Brass-component) developed still strongly in the specimen. As shown in Fig. 1(b), the grains of about 87% consists of low angle boundaries below 15 degree, indicating that the deformation structure is still dominant. The specimen also consists of the coarse grains of which grain size is above 100 μm, as shown in Fig. 1(c). The result of EBSD measurement for the specimen annealed at 300°C is shown in Fig. 2. The wide regions have a recrystallization structure covered by clean and fine grains, even if the deformation structure indicated by the arrows still remains partially. The rolling texture still remains in the deformed regions, but the recrystallization texture did not develop in the recrystallized regions, as shown in Fig. 2(a). As shown in Fig. 2(b), the fraction of grains with low angle grain boundaries was reduced to 58%, compared to that (87%) of the 250°C annealed specimen. In addition, the grain size distribution was divided by two regions of recrystallization and deformation, shown in Fig. 2(c). Fig. 3 is the results of EBSD measurement for the 350°C annealed specimen. The specimen shows a complete recrystallization structure consisting of the equiaxed clean grains, even if inhomogeneity of grain size still exists in thickness direction. As shown in Fig. 3(c), most of grain boundaries has high angle above 15 degree, different from those of the specimens annealed at lower temperatures. In addition, the grain size distribution exhibits only one region due to complete recrystallization, as shown in Fig. 3(c).

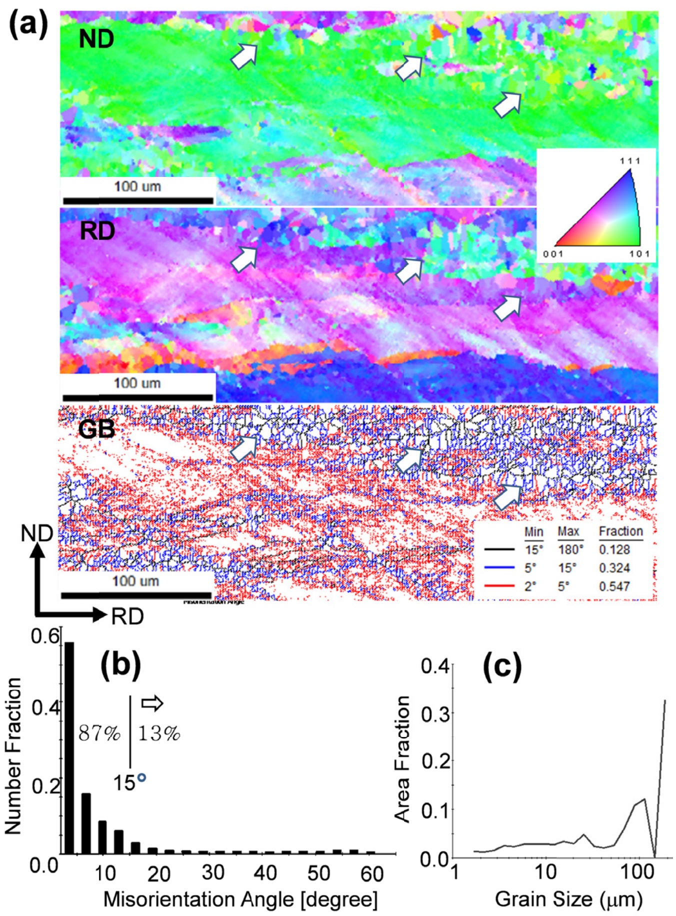

Fig. 1. ND, RD, GB maps (a), misorientation angle distribution (b) and grain size distribution (c) obtained by EBSD measurement for the specimen annealed at 250°C

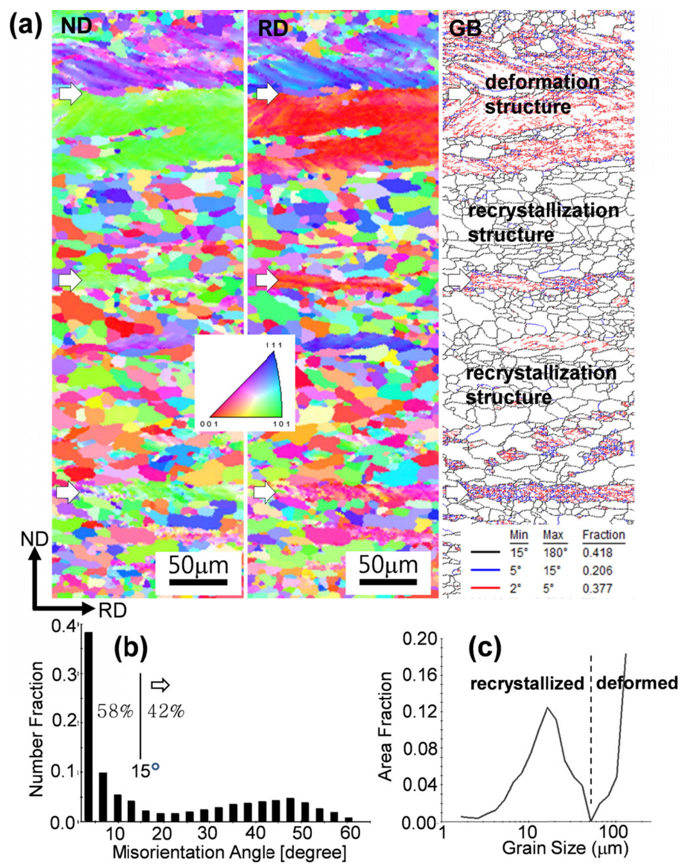

Fig. 2. ND, RD, GB maps (a), misorientation angle distribution (b) and grain size distribution (c) obtained by EBSD measurement for the specimen annealed at 300°C

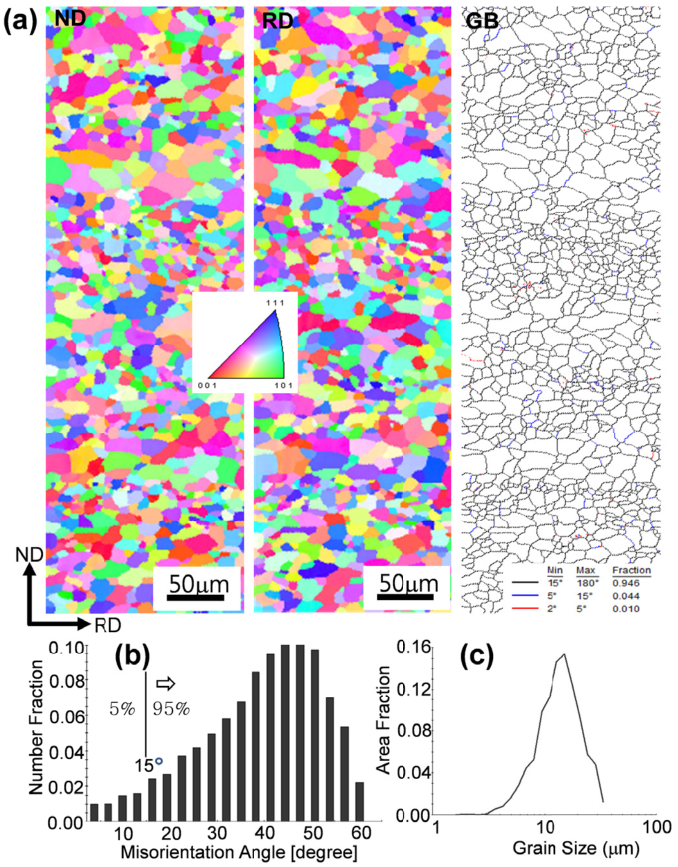

Fig. 3. ND, RD, GB maps (a), misorientation angle distribution (b) and grain size distribution (c) obtained by EBSD measurement for the specimen annealed at 350°C

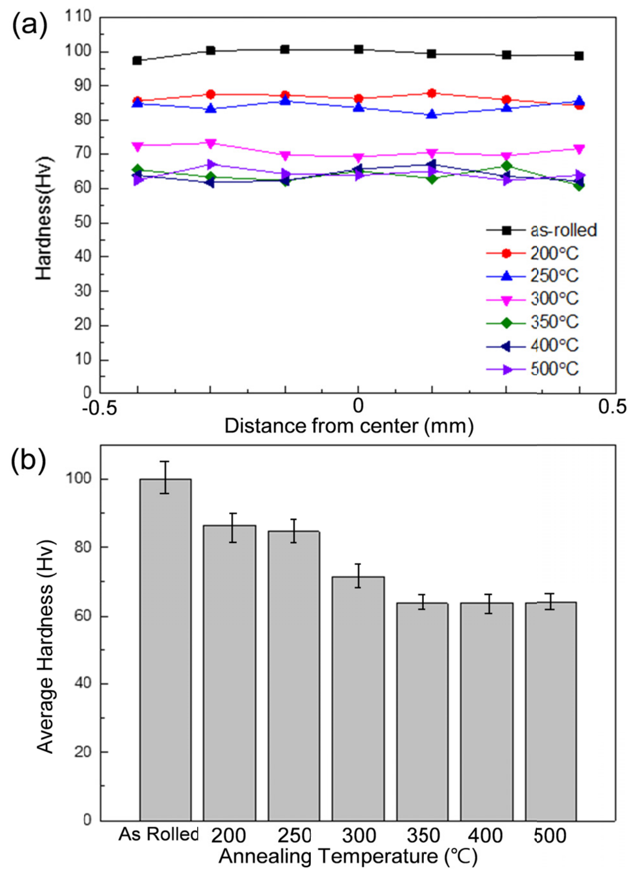

Fig. 4. Vicker's hardness distribution in thickness direction (a) and the average hardness (b) of the specimen annealed at various temperatures

3.2. Mechanical properties

Fig. 4(a) shows the hardness distribution in thickness direction of the as-rolled and annealed specimens. All specimens show relatively homogeneous hardness distribution in thickness direction. It is also found that the average hardness decreases with increasing of annealing temperature, as shown in Fig. 4(b). The drastic decrease in hardness at 200 and 300°C is due to occurrence of recovery and recrystallization, as mentioned in Fig. 3, respectively. The nominal stress-nominal strain curves and the mechanical properties of the as-rolled and annealed specimens are shown in Fig. 5. As shown in Fig. 5(a), the as-rolled specimen shows relatively high strength and low elongation due to the deformed state. For the annealed specimens, the tensile & yield strength increases and the elongation decreases, as the annealing temperature increases. The difference between the tensile strength and yield strength increased as the annealing temperature increased. This means that work hardening rate of the Al alloys increased with increasing of the annealing temperatures. The as-rolled material showed tensile strength of 430 MPa and tensile elongation of 4.7%, however the specimen after annealing at 500°C showed the strength of 305 MPa and the elongation of 32%. These values were respectively higher by 5% in the strength and 45% in the elongation, comparing to those of the commercial Al5083 alloy. As shown in Fig. 5(b), the

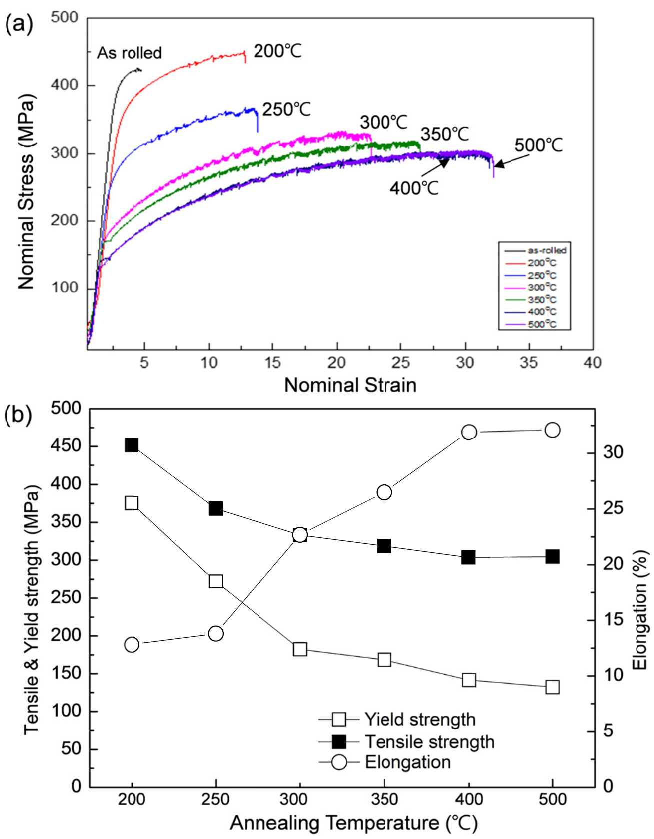

Fig. 5 Nominal stress-strain curves (a) and the mechanical properties (b) of the specimens annealed at various temperatures

500°C annealed specimen is the most favorable, in viewpoint of balance of strength and elongation.

4. Conclusions

Microstructures and mechanical properties of as-cast Al-6.5 Mg-1.5Zn-0.5Fe alloys newly alloy-designed for parts of an automobile were investigated in detail. The recrystallization begun to occur at 250°C, it finished at 350°C. The as-rolled Al alloy showed tensile strength of 430 MPa and tensile elongation of 4.7%, however the specimen after annealing at 500°C showed the strength of 305 MPa and the elongation of 32%. The fraction of high angle grain boundaries above 15 degree increased greatly after annealing at high temperatures. It is found that the 500°C annealed specimen is the most favorable, in viewpoint of balance of strength and elongation.

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