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Short communication

Effect of rapid solid-solution induced by electropulsing on the microstructure and mechanical properties in 7075 Al alloy

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Electropulsing treatment (EPT) can make the second-phase rapidly dissolve into the matrix in the 7075 Al alloy. Although EPT has the lower degree of supersaturation compared with the traditional solid-solution treatment (SST), the combined effect of the fine precipitates and grains after artificial aging makes the slightly higher strength than that of traditional T6 treatment.

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1. Introduction

The age hardenable Al-Zn-Mg-Cu alloys are extensively used in the aerospace and automotive structural materials due to their high strength and low density [1,2]. Generally, obtaining superior mechanical properties has long been recognized as a purpose to design materials. As is known, grain refinement strengthening is recognized as an effective way to improve both the strength and ductility [3], however, although severe plastic deformation (SPD) processing is effective for producing ultrafine-grained alloys, such materials' ductility is usually inadequate for practical applications [3,4]. For Al-Zn-Mg-Cu alloys, the extremely small and uniformly dispersed precipitates were obtained after artificial ageing (AA), which can make the alloys high strength and acceptable ductility [5]. To obtain superior mechanical properties, the deformation and heat-treatment were always both used, nevertheless, they are often mutually exclusive: deformation followed by subsequent heat treatment will make the grains coarse, while the specimen fracture is difficult to avoid as the deformation after heat treatment [6,7]. Besides, the distortion and oxidation during solid-solution treatment (SST) are often inevitable.

Electropulsing treatment (EPT), as an instantaneous high energy input method, has been extensively applied in many fields [8]. Many previous studies show that the EPT has an important effect in recrystallization and phase transformations [9–12]. In recent years, it is indicated that the EPT could accelerate the precipitation phase spheroidizing and dissolution processes in the Mg alloy. The mechanism of dissolution was recognized as the decreased thermodynamic barrier in the phase transformation process [13,14]. However, few investigations have done on discussing the dissolving effect of EPT on the microstructure and mechanical properties in Al alloys, which will be studied in this paper.

2. Experimental

The commercial 7075 alloy (5.63 wt% Zn, 2.35 wt% Mg, 1.64 wt% Cu, balance Al) was provided in the form of 5.4 mm thick ingots in this investigation. The sheets were homogenized at 460 °C for 24 h, and hot rolled (HR) with a reduction thickness of $<30\%$ per pass to 2 mm thick strip at 350 °C, then were cut into pieces of 50 mm length and 10 mm width. The EPT were performed and water-quenched immediately by self-made electropulsing generator, which could generate AC pulse current with 50 Hz frequency [15]. In this study, the current density j_e was optimized to 200 MA/m^2 with a duration of 220 ms. A standard treatment (solution treated at 475 °C for 1 h and water quenching) was also carried out as a control, then the electropulsing treated and solution treated specimens were aged at 120 °C for 24 h.

The tensile tests were conducted on a servo-hydraulic materials testing system (MTS, MTS810, USA) at the strain rate of 10^{-3} s^{-1} at

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the room temperature, and at least 3 specimens were tested for each condition. The optical micrograph specimens were prepared through a conventional mechanical polishing and followed by etching with Keller reagent (2 mL HF, 3 mL HCl, 5 mL HNO_3 and 190 mL water). The specimens for transmission electron microscope (TEM) observation were prepared by the standard twin-jet electropolishing method with a voltage of 10–15 V in 80% ethanol and 20% perchloric acid at −30 °C. The TEM observations were carried out on a JEM–2100 and operated at 200 kV.

3. Results and discussion

Fig. 1 shows the optical microstructures of the HR, EPT and SST samples. It can be seen that the primary microstructures are the typical coarse and elongated α-Al grains, and the particles arounded the grains are the $MgZn_2$ phases, and a few complex eutectic phases (containing Fe and Si) and Al_2Cu phases, which are identified by EDX (not shown). After SST and EPT, recrystallization occurs in parts of the grains, and the number of the second-phases at the boundaries decreases obviously, implying that parts of the particles dissolve into the matrix. Besides, it is obvious that the EPT grains are finer, and there are more residual phases in EPT sample than that of SST. In order to better understand the microstructure, the recrystallized grain size was measured, as shown in Fig. 1d and e, the recrystallized grains induced by the EPT display a finer size compared with that of SST. It is implied that the EPT can make the finer microstructure via the rapid recrystallization and cooling. Fig. 2 presents XRD patterns of the samples at different conditions. The HR sample consists of mainly two phases, namely, α-Al and $MgZn_2$. The XRD peaks of $MgZn_2$ phase weakened and nearly vanished in SST and EPT samples. It is proved that the dissolution of secondary phases occurred, which is in agreement with the previous micrographs.

Fig. 3 shows the typical engineering stress–strain curves of the alloys with various conditions. It can be seen that the UTS (ultimate

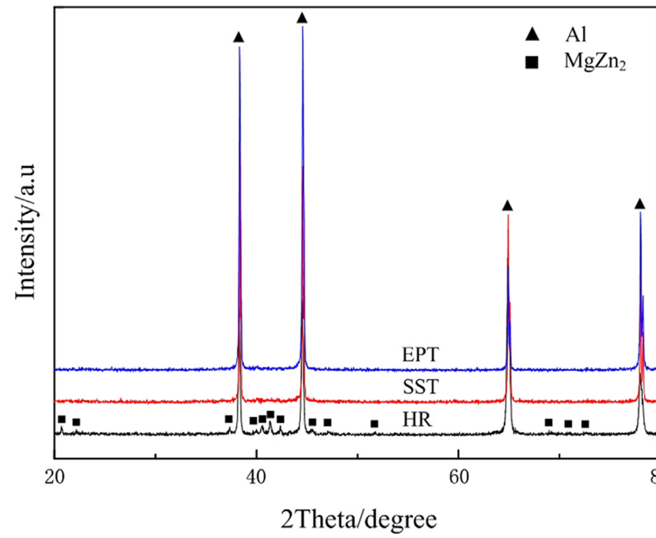

Fig. 2. XRD patterns for samples at various conditions.

tensile strength) and elongation of SST and EPT specimens are both improved compared with the HR sample. As is known, the larger degree of supersaturation makes the higher strength, and the less coarse residual phases make the better ductility. As is shown, the SST sample has better mechanical properties, which is indicated that the SST makes larger degree dissolution of eutectic phases compared with the EPT. After artificial ageing, the EPT sample has the slightly higher strength and a little decrease in elongation. Although the SST sample obtains the larger supersaturation, the finer recrystallized microstructure of EPT has an extra contribution to the strength, meanwhile, the more residual phases of EPT (Fig. 1) make the slight decrease in ductility compared with SST.

In this study, as a result of Joule heating effect during electropulsing, the temperature rise can be described as $\Delta T = \rho j_e^2 (C_\rho d)^{-1} t_c$

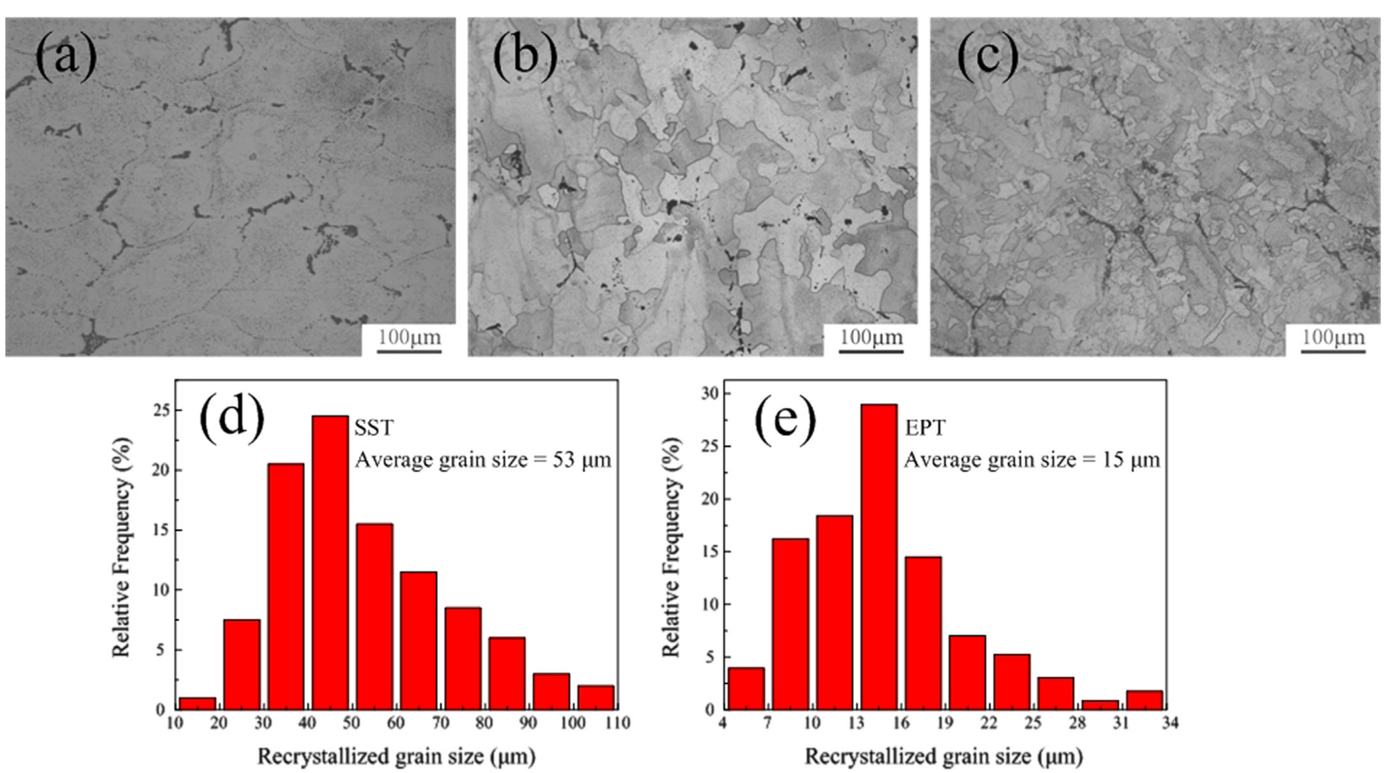

Fig. 1. Optical microstructures of (a) HR, (b) SST and (c) EPT samples, (d) and (e) recrystallized grain size distribution with different conditions.

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