A Heterogeneous Magnesium Extrusion Alloy with Ultra-High Plasticity

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Abstract: Understanding the relationship between the actuate of the slip system and dynamic recrystallization (DRX) during thermo-mechanical processing is vital for developing high-performance Mg-based alloys. In this work, we investigate the effect of slip initiation on DRX behavior of 250 °C hot-extruded. It results that at a temperature of 250 °C, larger sized non-DRX grains undergo continuous dynamic recrystallization (sub-grain growth) with the activation of basal <a> slip. Small-size non-DRX grains incur discontinuous dynamic recrystallization (stress-induced grain boundary migration (SIBM)) with activation of the pyramidal < c + a > slip. In addition, heterostructures contributes to the improvement of the work-hardening of materials and to eliminate localized stress concentrations in small-sized grains. Achieving the synergistic improvement of alloy strength-plasticity.

Keywords: dynamic recrystallization, slip system, heterogeneous magnesium alloy, hot-extruded.

1 Introduction

Mg alloys as the lightest structural metal, which has a wide range of applications [1]. Despite the emerging and critical significance of Mg alloys as a class of engineering materials, magnesium alloys as engineering structural components still have a lot of problems that need to be solved [2]. Thus, how to improve the plasticity of magnesium alloys at room temperature has become a popular research topic today. Hot mechanical methods such as rolling, extruding, forging, etc. are often used to improve the room temperature formability and plasticity of magnesium alloys [3]. Therefore, how to maximize the activation of slip during deformation is the key to preparing highly plastic magnesium alloys. In this work, a heterogeneous structural magnesium alloy is successfully prepared using the extruded process with artificial cooling. The highest plasticity recorded to date has been achieved due to the successful activation of the pyramidal < c + a > slip.

2 Experimental procedure

The original AZ31B alloys are prepared by using pure Mg (99.99%), Al (99.98%), and Zn (99.98%). The as-cast alloys are subjected to a homogenization treatment at 420°C for 12 hours. The extrusion angle is set at 30°. The extrusion ratio is set to 25:1 and the extrusion speed is set to 0.2 mm/s.

3 Result and discussion

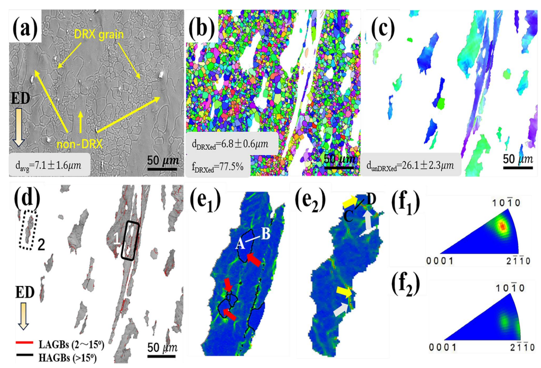

Fig.1 (a) SEM map; (b, c) EBSD maps of DRXed and non-DRXed grains, respectively; (d) the distribution of OIM pattern quality (IQ) facets with superimposed grain boundary orientation differences; (e) KAM map; (f) IGMA analyses of the corresponding magnification of (b).

Fig.1 (a) shows that the average grain sizes of the total are 7.1 ± 1.6 µm. Fig.1 (b, c) show that the average grain sizes of the DRXed grains and the non-DRXed are 6.8 ± 0.6 µm, and 26.1 ± 2.3 µm, respectively. Simultaneously, the volume fractions of non-DRXed grains are statistically 22.5%. Fig.1 (d) shows the corresponding distribution of grain boundaries of non-DRXed grains. It should be noted that some of LAGBs are mainly distributed inside the non-DRX grains with large size, while some of LAGBs are concentrated nearby the grain boundaries of the grains with small size. Therefore, different recrystallization mechanisms exist in non-DRX gains with different sizes. Fig.1 (e) shows the blue grains (strain-free) formed inside the large-size non-DRX grains (red arrows in Fig.1 (e_1)). Similarly, blue grains (strain-free) formed nearby the small-size non-DRX grain boundary are observed (yellow arrows in Fig.1 (e_2)). This indicates the formation of recrystallized grains located inside the grains or nearby the grain boundary. Fig.1 (f_1, f_2) shows that in the early stages of deformation, the activation of the basal < a > slip in large-sized non-DRX grains leads to new grain formation from within their grains. This suggests that a sub-grain growth mechanism (belonging to continuous dynamic recrystallization (CDRX)) is responsible for the recrystallization process in large-sized non-DRX grains. Differently, activation of pyramidal < c + a > slip in small-sized non-DRX grains leads to the formation of new grains at grain boundaries. This shows that the SIBM mechanism (belonging to discontinuous dynamic recrystallization (DDRX)) is responsible for the recrystallization process in small-sized non-DRX grains.

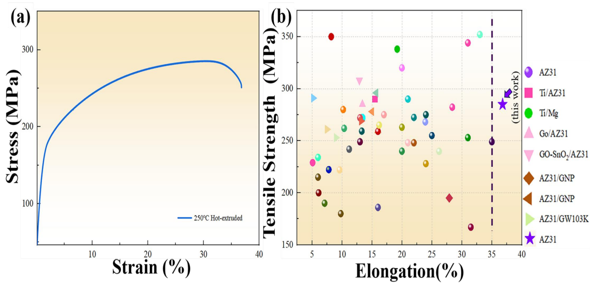

Fig.2 (a) Engineering stress-strain curves of the hot-extruded AZ31B at 250 °C; (b) Comparison of the UTS and El of the hot-extruded AZ31 alloys in this work and other AZ31 alloys.

The unique recrystallization mechanism in the heterogeneous structure leads to excellent mechanical properties. Fig.2 (a) show that the hot-extruded temperature is 250 °C and the ram speed is kept at 0.2 mm/s, the ductility is significantly increased to 36.8 ± 0.3 % in the tensile test, which is a record of extruded AZ31B (Fig.2 (b)). Moreover, the high-ductility AZ31B has a balanced strength of about 285 ± 2.5 MPa.

4 Conclusion

(1)The hot-extruded AZ31B alloys are composed typical bimodal microstructure containing fine DRX grains and coarse non-DRX grains. Significant size differences are also present in the coarse non-DRX grains at a hot-extruded temperature of 250 °C.

(2)When the temperature of 250 °C, larger sized non-DRX grains undergo continuous dynamic recrystallization (sub-grain growth) with the activation of basal <a> slip. Small-size non-DRX grains incur discontinuous dynamic recrystallization (stress-induced grain boundary migration (SIBM)) with activation of the pyramidal < c + a > slip.

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