Consolidation of pure Mg particles into bulk materials by back pressure equal channel angular processing

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Introduction

Refined microstructures in metallic materials can, generally, enhance their mechanical properties, especially strength. Severe plastic deformation (SPD) has increasingly been used to obtain such a material with ultrafine or even nanostructures. As one of the most effective SPD techniques, equal channel angular pressing (ECAP) has been widely used to produce refined microstructures in various bulk materials including Al, Mg, Ti, Fe, Cu and Zr alloys. ECAP with the application of a back pressure (BP-ECAP) has shown its significant advantage in processing materials which are less ductile, and in consolidating micron and nano sized particles into fully dense bulk materials displaying significantly enhanced strength.

Current work has been carried out to consolidate the hcp structured pure Mg particles into fully dense bulk material. Mechanical properties of the consolidated Mg (PM Mg) were compared with those of pure Mg ingot (IM Mg) which has been ECA processed under the same conditions.

Experimental materials and procedures

Pure Mg particles and a commercial pure Mg ingot were used with the purities of >99.5 and >99.9 wt%, respectively. The particles were of irregular shape with an average size of ~60 μm.

BP-ECA processing was performed using a die with an internal angle Φ of 90º. The Mg powder was wrapped in Al foil before being placed in the entrance channel of the die with graphite lubrication. A rectangular billet was machined from the Mg ingot to fit the cross section of 9 x 9 mm channel. The experiments were conducted at 200° C with a constant speed of 2 mm/min and back pressure of 100 MPa following the C route.

After BP-ECAP, the density and the Vickers hardness were measured. Microstructures were examined using optical microscopy (OM) and transmission electron microscopy (TEM). All these measurements were conducted on the cross section of the BP-ECAPed materials. Compressive properties were tested at room temperature along the longitudinal direction.

Results and comments

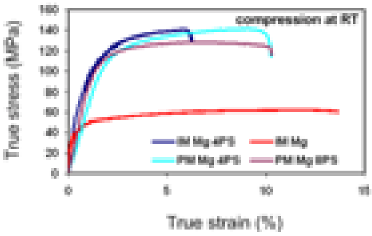

Fig. 1. True stress versus true strain curves for the PM and IM Mg after BP-ECAP at 200ºC for different passes.

Material	Density (g/cm^3)	HV (kg/mm^2)	$\sigma_{0.2}$ (MPa)	σ_{US} (MPa)	Strain to Fracture (%)
PM Mg 4ps	1.78	54.3	110	142	9
PM Mg 8ps	1.78	53.9	100	120	9
IM Mg 4ps	1.74	38.6	58	140	6
IM Mg	1.74	35.5	25	62	14

Table 1 Properties of PM Mg and IM Mg after different BP-ECAP passes.

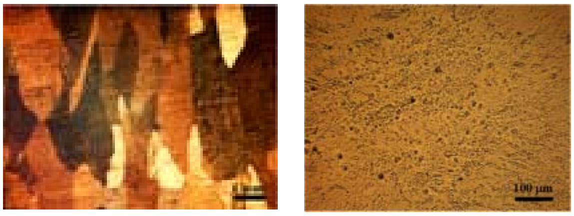

Fig. 2. Comparison of OM microstructures of (a) the as-received pure Mg cast ingot with an average grain size of ~1200 μm and (b) the IM Mg billet after 4 passes showing the mixture of small and large grains although they were much refined.

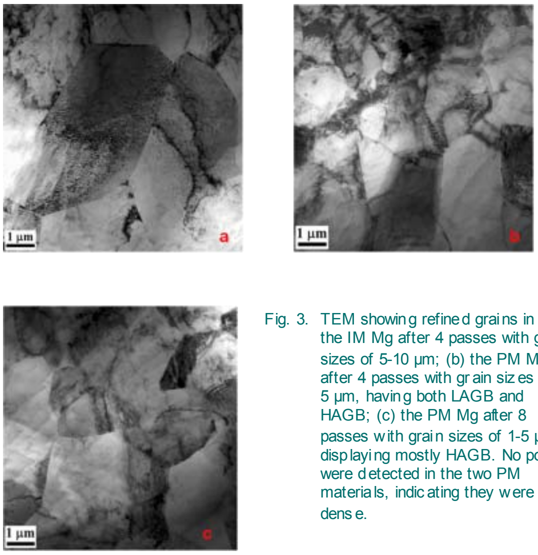

Fig. 3. TEM showing refined grains in (a) the IM Mg after 4 passes with grain sizes of 5-10 μm; (b) the PM Mg after 4 passes with grain sizes of 1-5 μm, having both LAGB and HAGB; (c) the PM Mg after 8 passes with grain sizes of 1-5 μm, displaying mostly HAGB. No pores were detected in the two PM materials, indicating they were fully dense.

Conclusions

1. Pure Mg particles with average size of ~60 μm were successfully consolidated into fully dense bulk materials using BP-ECAP.
2. The consolidated materials after 4 and 8 passes showed similar yield strengths although greater work hardening rate in the material after 4 passes resulted in a higher ultimate strength.
3. The PM Mg after 4 passes appeared to possess higher hardness and yield strength, as well as a better ductility, compared to the IM Mg after 4 passes.