Ultrafine Aluminium After Back Pressure Equal Channel Angular Consolidation and Deformation

X. Wu, K. Xia *Department of Mechanical and Manufacturing Engineering and ARC Centre of Excellence for Design in Light Metals, University of Melbourne*

T. Honma, S. P. Ringer *Australian Key Centre for Microscopy & Microanalysis and ARC Centre of Excellence for Design in Light Metals, University of Sydney*

Introduction

Ultrafine and nanostructured materials have attracted enormous attention for their potential mechanical properties being significantly enhanced compared to their micro-structured counterparts. Such materials may be obtained from synthesising nanoparticals or refining coarse structured materials through severe plastic deformation (SPD). One of the most effective methods of SPD is equal channel angular deformation (ECAD). ECAD has been used for consolidating particles of various alloys into bulk materials [1]. However, pre-canning and compacting were required and full density might not be achieved even after multiple passes. In this work a back pressure was applied to consolidate particles in a process named back pressure equal channel angular consolidation (BP-ECAC) [2]. The resulting materials were fully dense with good mechanical properties.

Experimental

Pure Al particles and pure Al ingot were used. The set-up of BP-ECAC/ECAD is shown in Fig.1. Before ECA processing, the Al powder or ingot Al sample was wrapped with Al foil. The specimen was inserted in the entrance channel with graphite lubrication.

Experiments were conducted at 100°C with constant speed of 0.2 mm/min and back pressure of 50 MPa. The Bc route was used for multiple passes.

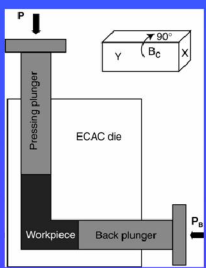

Fig. 1 The BP-ECAC/EACD set-up: a vertical entrance channel with a forward pressing plunger and a horizontal exit channel with a back plunger providing a constant back pressure. The angle between the two channels was 90°. The cross section of each channel was 9 x 9 mm.

Results

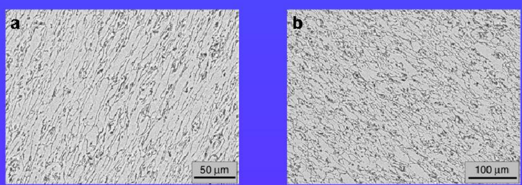

Fig. 2 SEM microstructures of the PM Al after BP-ECAC at 100°C for 1 pass showing (a) the longitudinal section and (b) the cross section.

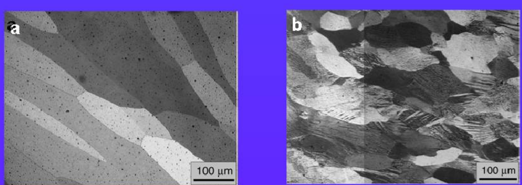

Fig. 3 OM microstructures of (a) the as-cast Al and (b) the cross section of the IM Al after BP-ECAC at 100°C for 1 pass.

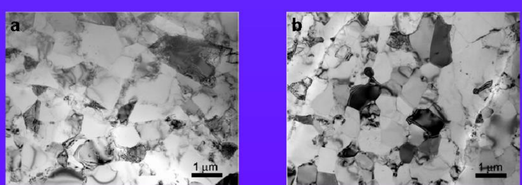

Fig. 4 TEM microstructures of the PM Al after BP-ECAC at 100°C for (a) 1 pass and (b) 4 passes.

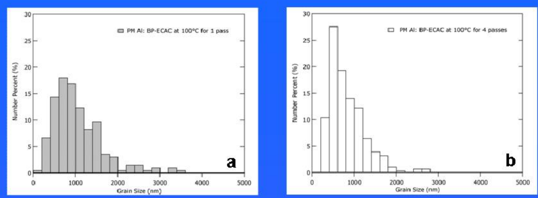

Fig. 5 Grain size distributions in the PM Al after BP-ECAC at 100°C for (a) 1 pass and (b) 4 passes.

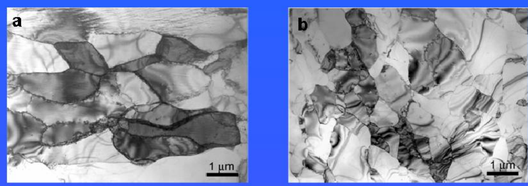

Fig. 6 TEM microstructures of the IM Al after BP-ECAD at 100°C for (a) 1 pass and (b) 4 passes.

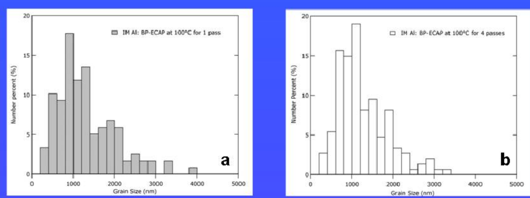

Fig. 7 Grain size distributions in the IM Al after BP-ECAD at 100°C for (a) 1 pass and (b) 4 passes.

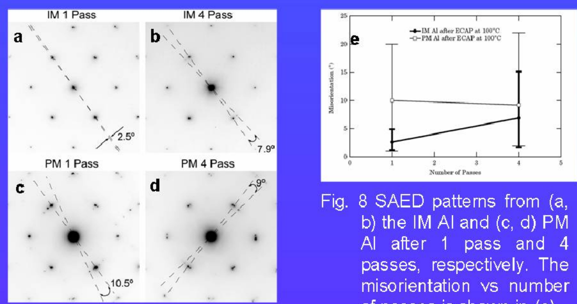

Fig. 8 SAED patterns from (a, b) the IM Al and (c, d) PM Al after 1 pass and 4 passes, respectively. The misorientation vs number of passes is shown in (e).

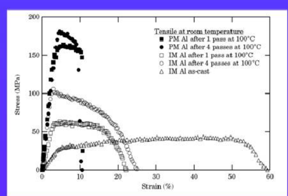

Fig. 9 Tensile curves of the as-cast, PM and IM Al after ECAC/ECAD at 100°C for 1 and 4 passes.

Conclusions

1. Pure Al particles were consolidated into fully dense materials using BP-ECAC.
2. The PM Al after 1 pass consisted of ultrafine grains of ~1 µm in size and equiaxed in shape with many high angle boundaries. After 4 passes, the PM Al was further refined to have equiaxed grains of ~0.8 µm with slightly decreased misorientation.
3. The IM Al contained elongated subgrains with small angle grain boundaries after 1 pass. Further deformation to 4 passes produced equiaxed grains with increased misorientations although the average grain size (~1.3 µm) was little changed.
4. The strength of the PM Al was significantly higher than that of IM Al, whereas the ductility of the PM Al was halved compared to that of the IM Al.
5. Tensile curves showed that a steady state deformation was reached for the PM and IM Al after 1 pass, while work softening occurred in both materials after 4 passes.

References

1. M. Haouaoui *et al.*, Metall. Mater. Trans. A, 35A (2004) 2935.
2. K. Xia and X. Wu, Scr. Mater., 53 (2005) 1225.