THE UNIVERSITY OF MELBOURNE

ARC Centre of Excellence Design in Light Metals

Mechanical property tailoring in Al-based composites and pure Mg by microstructure control through severe plastic deformation

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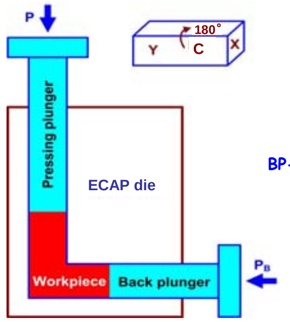
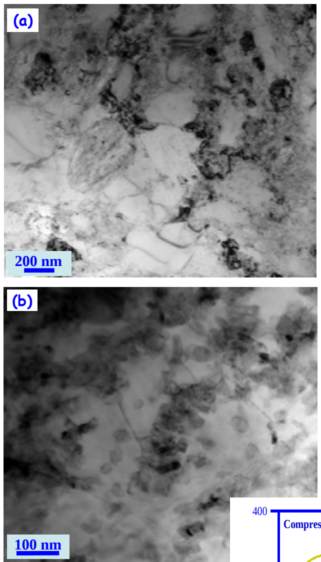
Al-based nanocomposites containing various amounts of C or Al2O3 nanoparticles were developed by ball milling and back pressure equal channel angular pressing (BP-ECAP). Well dispersed nanoparticles as individual particles in the Al matrix was achieved. The distribution of C nanoparticles was improved with increasing number of BP-ECAP passes, and this is demonstrated by the remarkable increase in compressive plastic strain to fracture from 10% for the 8-pass sample to 20% for the 24-pass sample. The Al-Al_2O_3 nanocomposites possessed lower strength but higher ductility compared with their counterparts in the Al-C nanocomposites.



BP-ECAP set up

BP-ECA consolidation of Al-based composites containing 2-10 wt.% carbon and Al_2O_3 at 400 °C from ball-milled particles

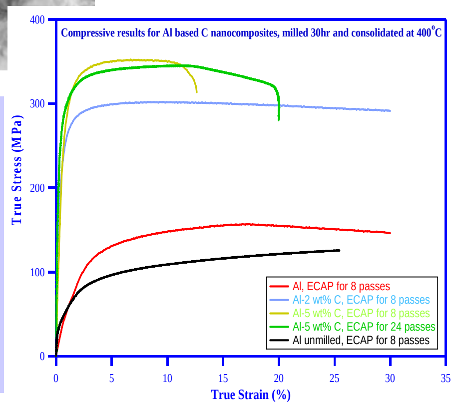
(Carbon particles were pre-milled for 50 h before mixing with Al)

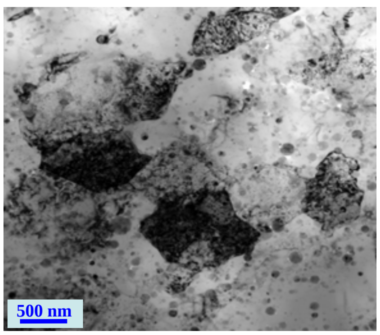


TEM microstructures in the Al-5 wt% (7 vol%) C material after BP-ECAP for (a) 8 passes and (b) 24 passes, at 400 °C.

The grains in Al matrix refined significantly from ~1 μm to ~300 nm with increasing the ECAP number of passes from 8 to 24, respectively. More homogeneous dispersion of nano C particles formed in Al matrix with increasing ECAP number of passes to 24, and individual C particles as fine as ~20 nm were dispersed in Al. This improvement in C particles dispersion resulted in the significant increase in compressive strain of nanocomposite materials.

The Al-2 wt% C composite exhibited good combination of strength and ductility with true yield strength over 250 MPa and compressive fracture strain reaching 30%. In Al-5 wt% C material, the ductility increased from 10% to 20% with increasing the number of passes from 8 to 24, with a moderate reduction in yield strength from 260 MPa to 245 MPa.

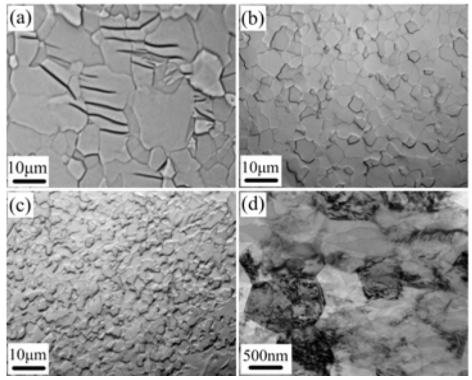




TEM microstructures in the Al-10 wt% (7 vol%) Al_2O_3 material after BP-ECAP for 24 passes, at 400 °C.

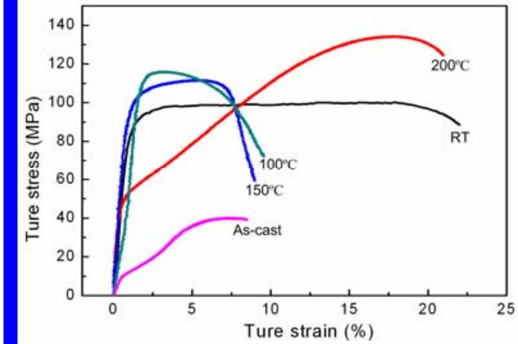
Homogeneous dispersion of nano Al_2O_3 particles formed in Al matrix with, and individual Al_2O_3 particles as fine as ~40 nm were dispersed in Al. The Al grain size is larger than their counterpart in Al-7 vol% C material at the same ECAP conditions.

- Mg and its alloys are very attractive for automotive, aerospace and electronic industries. However, their applications have been restricted because of their low ductility.
- Grain refinement may to improve their ductility to some extent while retaining or enhancing their strength, refining their gain structures has been an objective in recent studies.
- The lower pressing temperature, the finer grain size can be got. Back-pressure (BP) assisted ECAP for Mg and its alloys has been used to avoid cracking at low temperature.



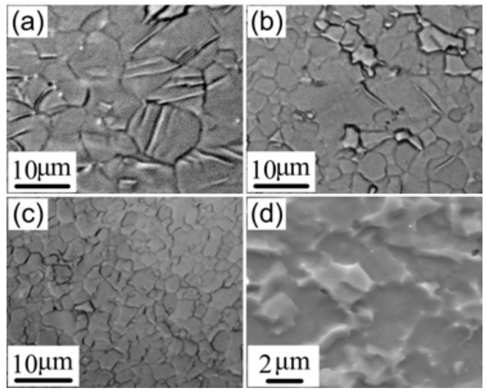
The microstructure of pure Mg: (a) 200 °C; (b) 150 °C; (c) 100 °C; (d) room temperature.

The grain size drastically decrease as pressing temperature decrease. The grain size in pressing at room temperature refined significantly from 980 μm in cast ingot to ~700 nm.



The mechanical properties for as-cast and ECAPed with 4 passes at different temperatures.

The yield stress have a significantly increase compared with the sample of cast ingot. Moreover, the sample pressed at room temperature has higher strength and much larger uniform deformation.



The microstructure of compressive deformed samples: (a) 200 °C; (b) 150 °C; (c) 100 °C; (e) room temperature

The mechanical twinning mainly appears in the grain size larger than 3 μm. When the grain size smaller than 3 μm, the deformation mechanism changed from twinning to dislocation slipping.

Summary

1. Fully dense Al based nanocomposite materials were successfully consolidated by BP-ECAP.
2. Nanoscaled carbon and Al_2O_3 particles were homogeneously dispersed in Al matrix, which resulted in a significant increase in Al strength.
3. Increasing ECAP number of passes improved the compressive strain in Al-5 wt% C materials.

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