Bulk nanostructured materials processed by severe plastic deformation

New and surprising nanostructures are observed in commercial aluminium alloys processed by severe plastic deformation (SPD).

Bulk nanostructured materials (BNMs) processed by SPD have provided new opportunities for developing nanostructures in metals and alloys with unusual properties that are very attractive for various structural and functional applications. Besides having a typical grain size in the range of ~50–500 nm, these materials can exhibit unusual features.

High density hexagonal and rhombic shaped nanostructures with an average size of 4 nm are observed in commercial Al–Mg (–Si) alloys processed by both equal channel angular pressing (ECAP) and high pressure torsion (HPT) at room temperature (Fig. 1). These surprising nanostructures may have profound effects on the mechanical properties and further investigations are therefore involving collaboration with one of the top-ten materials scientists in the world (Prof. Ruslan Z. Valiev, Ufa, Russia).

Both the average grain size and the dislocation densities depend on the alloy Mg content. The average grain size in HPT Al–Mg alloys measured by x-ray line profile analysis decreased from about 120 nm to 55 nm as the Mg content increased from 0.5 to 4.1 wt% (results from the collaborator, Prof. Tamas Ungár, Eötvös University, Hungary). At the same time, the average dislocation density increased from 1.7 $x10^{14}$ to $1.3x10^{15}$ m^{-2}. However, local densities in grain boundary and triple junction areas observed by HRTEM might be as high as 1.4×10^{17} m^{-2} (see ***front page*** of Int. J. Mater. Res. (formerly: Zeitschrift für Metallkunde), 98(3), (2007) and contained article pp. 184-190).

A high density of local nano-twins and stacking faults (SFs) is detected by HRTEM within both nanocrystalline grains (Fig. 2) and ultrafine grains though the average volume twin density measured from the x-ray line profile analysis may be quite small. Most of the SFs in the SPD aluminium alloys are formed by two 30° Shockley partials dissociated from a pure screw dislocation (Fig. 3).

Hans Jørgen Roven, Manping Liu and Yingda Yu

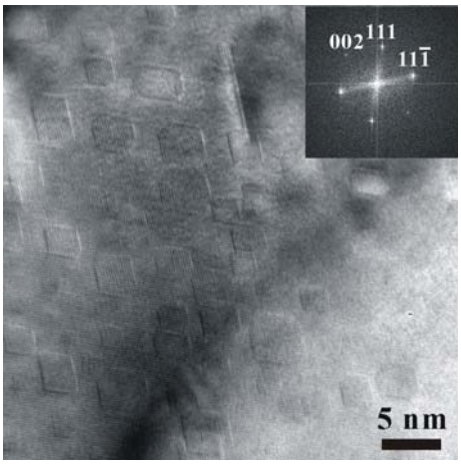


Fig. 1
HRTEM [1-1 0] image showing planar hexagonal and rhombic shaped nanostructures.

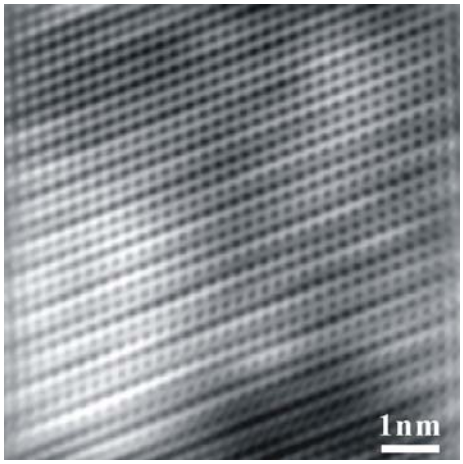
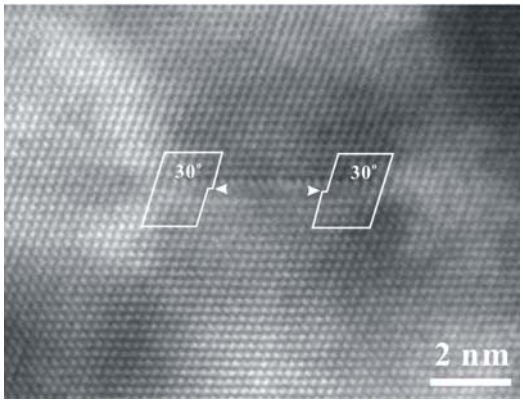


Fig. 2
A high density of nano-twins and SFs within a nanocrystalline grain.



Photos: Manping Liu

Fig. 3
A 0° screw dislocation dissociated into two 30° Shockley partials connected by an intrinsic SF.