Electron Tomography of Simple Solids in Aluminium Alloys

Zhang, Z.[1], Weyland, M.[1,2], Rosalie, J.M.[3], Medhekar, N.V.[1] and Bourgeois, L.[1,2]

[1] Department of Materials Science and Engineering, Monash University, Australia, [2] Monash Centre for Electron Microscopy, Monash University, Australia, [3] Erich Schmid Institute of Materials Science, Austria

Ancient Greek philosophers valued simple solids with high symmetries. A Platonic solid is defined as a regular, convex polyhedron with the same number of congruent faces (identical in shape and size) at each vertex. There are only 5 Platonic solids, and Plato associated them with the 5 classical elements in his dialogue Timaeus [1]. Archimedes built on this idea by allowing two types of regular facets meeting at each vertex, leading to 13 distinct Archimedean solids. In this study, we use electron tomography to reveal the existence of nanometre sized Platonic and Archimedean solids embedded in aluminium alloys. These simple solids are generated as precipitates develop during thermal treatments of the alloys. The complicated microstructures they form are associated with result from solid-state phase transformation, and they are expected to influence the mechanical properties of alloys.

Figure 1 shows γ' (HCP Ag_2Al phase) precipitate assemblies in an Al-Ag alloy. Most of these assemblies have the form of seven precipitate plates on {111} planes, constructing a truncated bi-tetrahedron geometry [2]. This geometry can be visualised as a combination of two truncated tetrahedra (one of the 13 Archimedean solids) with one shared facet and a relative rotation of 60°between them. In addition, there is are also small tetrahedrons (Platonic solids) composed by four precipitate plates, labelled as T in Fig.1(b). Figure.2 shows voids embedded in Al-enriched clusters in an Al-Ag alloy. A void is essentially an empty space enclosed in the matrix. Electron tomography shows that the void has a truncated octahedral geometry (another Archimedean solid) with 8 {111} facets and 6 {001} facets. The evolution of truncated octahedral voids in pure Al during *in situ* annealing was studied in our previous work [3].

The tilt series experiments were performed on a Tecnai F20 in the HAADF-STEM mode (high angle annular dark field scanning transmission electron microscopy). A Fischione 2020 single-tilt high-tilt holder was used to access high angles, with a tilt range of $\pm$70° and a step size of 2°. Image stacks were aligned and volume data were reconstructed using the code programmed in IDL 6 [4]. The reconstructed 3D data was segmented and visualised in Amira 6.

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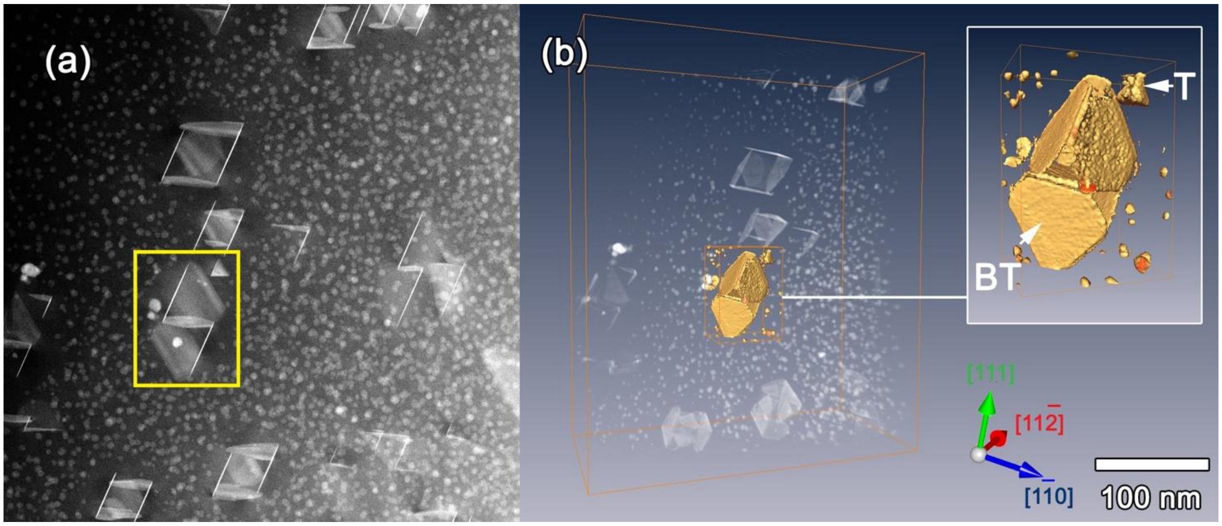

Figure 1 γ' precipitate assemblies in an Al-Ag alloy. (a) A HAADF-STEM image in the tilt-series image stack. The yellow framed precipitates correspond to the enlarged view in the reconstruction. (b) The reconstructed microstructure. The precipitate assemblies in the centre of the reconstructed volume are highlighted by rendering the isosurface, showing a truncated bi-tetrahedron assembly, labelled as BT, and a tetrahedron assembly, labelled as T.

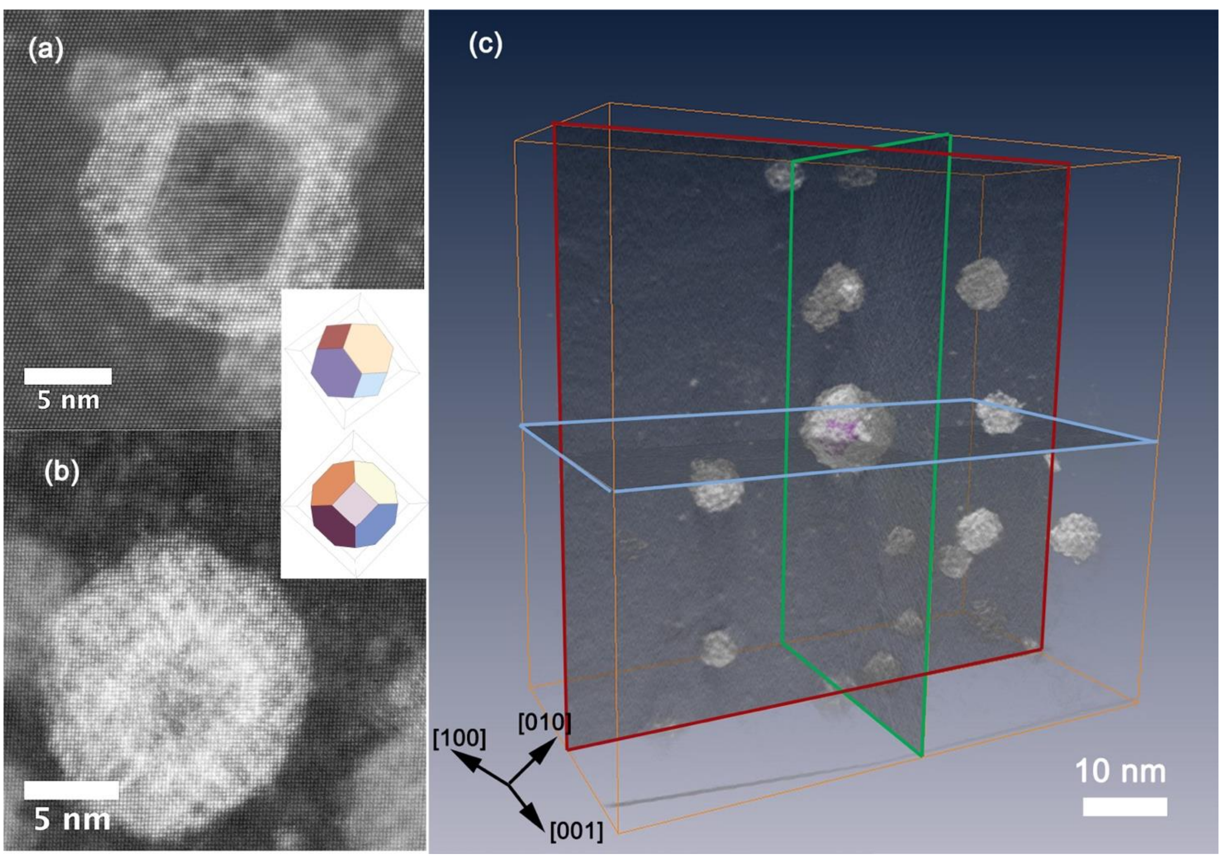

Figure 2 Atomic resolution HAADF-STEM images of voids embedded in an Ag-enriched clusters in (a) <110> and (b) <100> directions. (c) The reconstructed microstructure.