Nucleation and growth crystallography of Mn-bearing intermetallics in magnesium alloys

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Most automotive magnesium alloys contain a small manganese addition to combat impurity iron. For AZ91 (Mg-9Al-0.7Zn in wt%), sufficient Mn is added to give an Fe:Mn ratio less than 0.032 which gives the alloys acceptable corrosion resistance for most automotive applications.

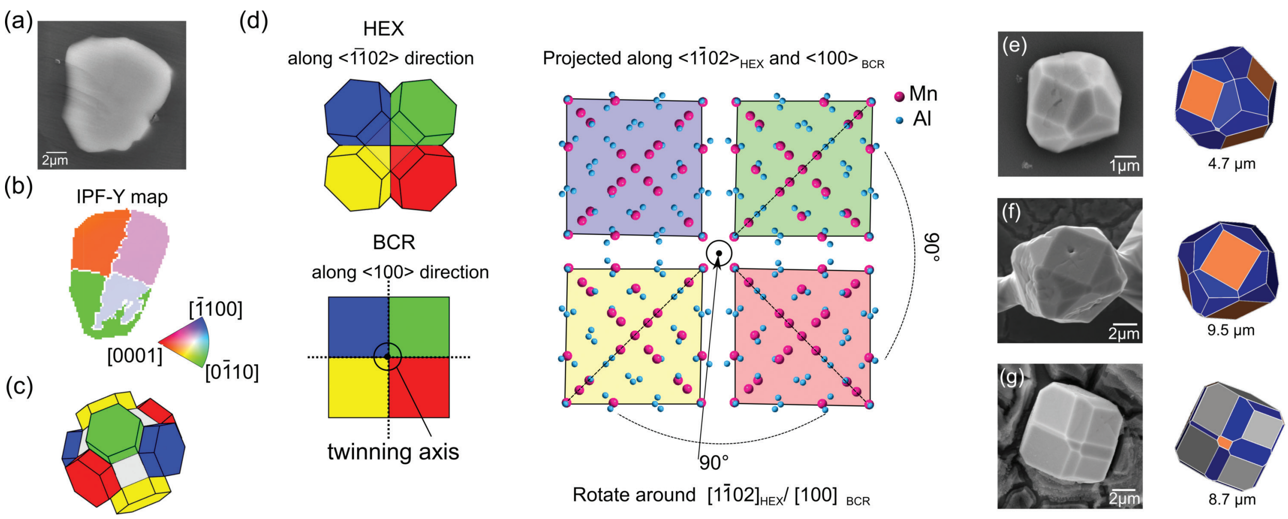

FIGURE 1. (a) to (c) a typical Al_8Mn_5 particle containing four orientations; (a) SE-SEM image of a cross section; (b) EBSD orientation map with colour key of the particle in (a); (c) graphical representation of the orientation relationship between the four orientations in (b) using a RGBY colour scheme. (d) Four-fold cyclic twinning model of particles similar to (a) to (c). (e) to (g) SE-SEM images of extracted Al_8Mn_5 particles and polyhedron models based on {100}-orange, {110}-grey and {112}-blue facets using a pseudo-cubic Al_8Mn_5 cell [1].

Both Mn and Fe are almost insoluble in α-Mg, do not form intermetallic compounds (IMCs) with Mg, and instead react with solutal Al to form $Al_x(Mn,Fe)_y$ IMCs. The main Mn-bearing IMC in AZ91 after gravity casting or high-pressure die casting is Al_8Mn_5, which can dissolve some Fe as $Al_8(Mn,Fe)_5$. At typical Mn and Fe levels, Al_8Mn_5 begins to form above the α-Mg liquidus temperature as a primary phase and can be removed to some extent by gravitational sedimentation which gives some control of the Fe content of melts. However, $Al_x(Mn,Fe)_y$ particle settling also creates sludge in die casting pots and can block filters in the launders of direct chill (DC) casting units. For a given IMC density, the size and shape of the primary IMCs determines their settling behaviour as well as their packing and clumping behaviour.

This work is being conducted to understand the nucleation and growth crystallography of Al_8Mn_5 and to use this understanding to control the size and shape of primary IMCs in Mg-Al-based alloys.

Electron backscatter diffraction (EBSD), focussed ion beam (FIB) tomography, and selective etching techniques are being combined with thermodynamic calculations and polyhedron models to extract new insights into IMC nucleation and growth crystallography.

It has been found that Al_8Mn_5 often nucleates on Fe-rich B2-Al(Mn,Fe) particles and an incomplete peritectic transformation results in a B2-Al(Mn,Fe) core enveloped by a low-Fe Al_8Mn_5 shell. A reproducible orientation relationship (OR) is measured that is linked to the group-subgroup relationship between these phases [1].

As shown in Figure 1a to d, it has been found that most rhombohedral Al_8Mn_5 particles are cyclic twinned, consisting of four orientations related by ~90° rotations around three common <1102 >, which are the pseudo-cubic <100> axes of the Al_8Mn_5 rhombohedral gamma brass when considered with a body-centred rhombohedral (BCR) cell. The three twin planes are $\{2\text{-}201\}_{Hex}$ or $\{100\}_{BCR}$ and the twin obliquity is ω=0.9.

Primary Al_8Mn_5 particles grow with an equaiaxed polyhedral habit that has been measured by combining EBSD with FIB-tomography. Figure 1e to g show that Al_8Mn_5 crystal growth can be explained by polyhedron models based on {100}, {110} and {112} facets of the pseudo-cubic Al_8Mn_5 cell.

The results indicate that, at low Fe:Mn ratio, most impurity Fe is dissolved in B2 particles that are encapsulated by low-Fe Al_8Mn_5 which may be important for corrosion resistance.

REFERENCES:
[1] G. Zeng, J.W. Xian and C.M. Gourlay. Nucleation and growth crystallography of Al_8Mn_5 on B2-Al(Mn,Fe) in AZ91 magnesium alloys. *Acta Materialia*. Accepted 2018. DOI: 10.1016/j.actamat.2018.04.032.

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