Development of Quasicrystal Morphology in Gas-Atomized Icosahedral-Phase-Strengthened Aluminum Alloy Powders

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Icosahedral quasicrystals are a metastable phase that have rotational symmetry but no translational symmetry. Interest in quasicrystals stems from their remarkable combinations of properties. They exhibit high strength, hardness and elastic modulus, as well as good resistance to wear and corrosion. The use of quasi-crystals as strengthening dispersions in an Al matrix has shown promise in the development of high-strength and high-temperature Al alloys. One of the major drawbacks to quasicrystals is that a high cooling rate (~10^{-6} K/s) is necessary to form them, which has limited their production. Our group has successfully developed an Al-Cr-Mn-Co-Zr alloy that exhibits a nano-composite FCC Al plus I-phase microstructure in gas-atomized powder. This microstructure is retained during consolidation of the powder to form bulk material or cold-sprayed coatings, and the materials exhibit a remarkable combination of mechanical properties and pitting corrosion resistance that out-performs conventional Al alloys [1-3].

Here we report a study on the morphological development in a series of three more dilute Al-Cr-Mn-Co-Zr alloys prepared via the same route (Fig. 1). The powders were characterized by X-ray diffraction, scanning electron microscopy (SEM), and transmission electron microscopy (TEM). It is shown that the powders contain the same phases as the original alloy, but there are three distinct I-phase morphologies or microstructures in the powder particles. These are: (1) equiaxed dispersoids, (2) surface growths, and (3) radial growths (Fig. 2). The equiaxed dispersoids were approximately 10-100nm in diameter and distributed uniformly throughout the volume of the powder particle. The surface growths were larger (100-500nm in diameter) and approximately equiaxed. The main difference was that they were present only at the surface of the powder particles. The radial growths were similar to the equiaxed dispersoids in that they were distributed throughout the volume of the particle, but they differ in that they were much larger (0.5-5µm in diameter) and have elongated arms that appear to radiate from a common origin. The selected area diffraction patterns (Fig. 3) show that each morphology exhibits the five-fold [000001] and three-fold [110000] zone axis patterns that are characteristic of the I-phase.

The dominant microstructures/morphologies are found to vary with particle size (and hence cooling rate) and alloy composition. We are investigating the possibility that this transition arises due to a change from homogeneous to heterogenous nucleation as a function of cooling rate.

References:

[1] T.J Watson *et al*, Scripta Mater 123 (2016), p. 51-54.
[2] T.J Watson *et al*, Corros Sci 121 (2017), p. 133-138.
[3] T.J Watson *et al*, Surf Coat Tech 324 (2017), p. 57-63.

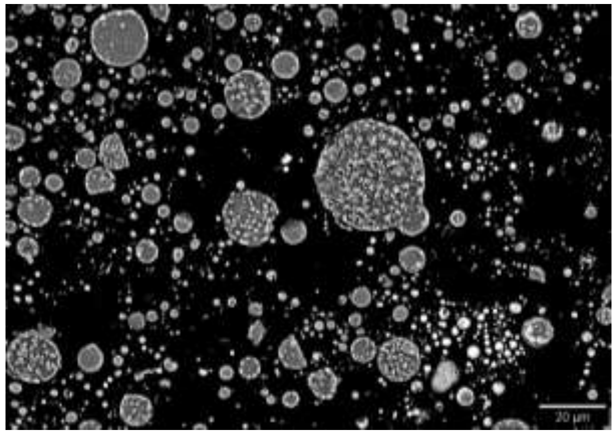

Figure 1. Backscattered electron SEM images from a metallurgical cross section of one of the alloy powders. The wide particle size distribution is a characteristic feature of gas atomized powder.

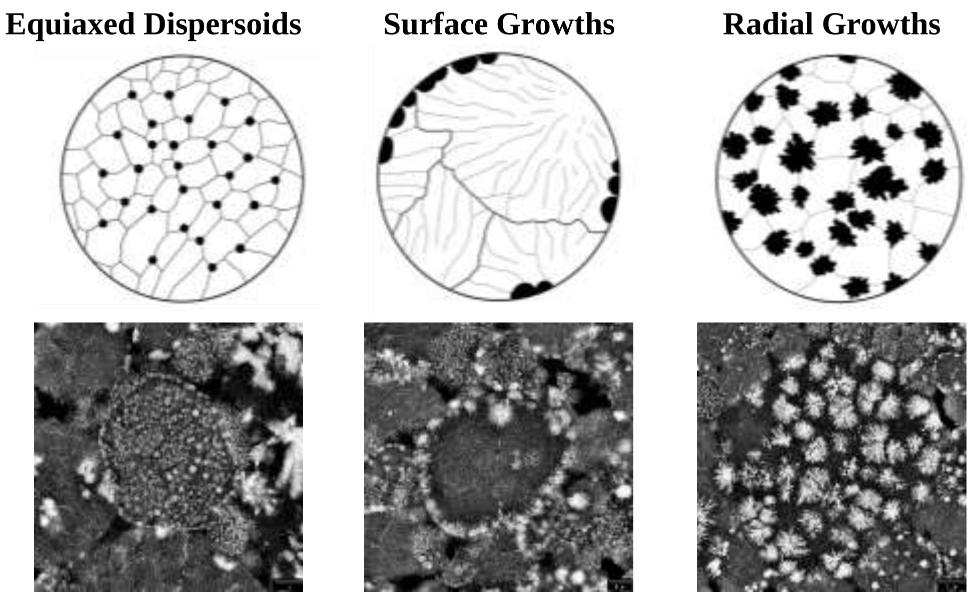

Figure 2. Schematic diagrams depicting particles with each of the characteristic I-phase morphologies, and backscattered electron SEM images showing examples of each type in the consolidated alloy.

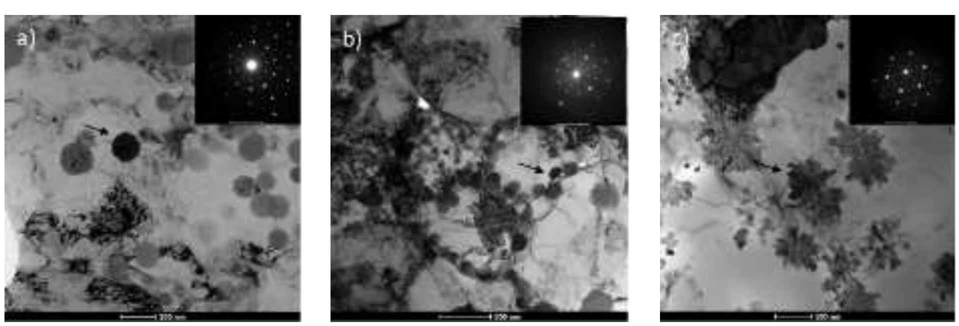

Figure 3. TEM images with selected area diffraction patterns inset for each of the three morphologies; (a) equiaxed dispersoids, (b) surface growths, and (c) radial growths.