

Stability and Transformation of Quasicrystalline Phase in Transition Metal Modified Al-(Mn-Fe)-based Alloys.

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Due to environmental and economic concerns significant interest has arisen in the development of higher strength low-density Al-based alloys for aerospace and automobile applications. One notable Al-alloy strengthening approach uses fine dispersions of quasicrystalline (icosahedral) particles. These metastable phases can be formed through rapid solidification methods (e.g. melt spinning, suction casting, gas atomization), and lead to enhanced hardness (> 450 HV) and tensile strength (>1000 MPa) [1] of the obtained material. However, the high cooling rates necessary for icosahedral phase (I-phase) formation limits the final dimensions of castings to a few millimeters. Fabrication of bulk forms of quasicrystal dispersion strengthened Al alloys typically necessitates hot-compaction of melt-spun ribbon, for instance. Thus, the thermal stability of the quasicrystalline phase in these microstructures is important to retain the enhanced alloy properties after warm-extrusion or -compaction.

Ternary Al₉₁Mn₇Fe₂ alloys exhibit one of the highest tensile strengths values (1250 MPa) among the group of quasicrystal strengthened Al-Transition Metal (TM) systems [2]. Unfortunately, their thermal stability is amongst the lowest. Since the thermal stability of the icosahedral phase has been shown to relate directly to its chemical composition [3], alloying with transition metal elements characterized by high melting temperature and low diffusivity in Al, such as Mo, W, and V may offer potential for enhanced thermal stability. The main objective of this work is the determination of the influence of the alloying TM additions on the I-phase decomposition under thermal stimuli.

Al₉₁Mn₇Fe₂ and Al₉₁Mn₆Fe₂X₁ (X₁ stands for 1 at% Mo, W or V) ribbons were prepared by melt-spinning under argon atmosphere. A combination of electron microscopy, x-ray diffraction, and thermal analysis techniques were used to investigate the thermal stability of the I-phase in melt-spun ribbon and hot-compacted conditions. The microstructure in the ribbons consisted of I-phase dispersoids and FCC Al solid solution (Fig. 1a). The Mo, W and V additions are incorporated preferentially into I-phase (Fig. 1b). Differential scanning calorimetry (DSC) measurements revealed a shift of peak temperature for the exothermic peak of the I-phase decomposition towards higher temperatures (60-80 K) for the TM modified samples. The activation energies for decomposition determined using the Kissinger method exhibited an increase from 192 kJ/mol (Al₉₁Mn₇Fe₂) to 227 kJ/mol (Al₉₁Mn₆Fe₂V₁). After short term annealing near the exothermic peaks observed by DSC (Fig.2a), the I-phase decomposed into the following product phases: i) Al₉₁Mn₇Fe₂, orthorhombic Al₆(Mn,Fe); ii) Al₉₁Mn₆Fe₂Mo₁, orthorhombic Al₆(Mn, Fe) and cubic Al₁₂(Mn, Mo); iii) Al₉₁Mn₆Fe₂V₁, monoclinic Al₄₅(Mn,Fe,V)₇ and orthorhombic Al₆(Mn,Fe) (Fig. 2b). In all cases, the decomposition products formed at the interface between Al-matrix and I-phase, appearing to grow into the latter. The distributions of the alloy additions after annealing suggest that Mn and Fe diffuse to the I-phase/Al matrix interface to facilitate the decomposition (Fig. 3). Although the hot-compaction process results in a complete loss of I-phase for the Al₉₁Mn₇Fe₂ alloy, the Mo and V modified alloys still retained a significant fraction of the I-phase after consolidation. A discussion of the difference in the diffusivity of constituent elements in the quasiperiodic lattice and its effect on the thermal stability will be presented.

References:

[1] A. Inoue, H. Kimura, Sh. Yamaura, *Metals and Materials International* 9 (2003), p. 527.

[2] A. Inoue, H. Kimura, K. Sasamori, T. Masumoto, *Mater. T JIM* 37 (1996), p. 1287.

[3] R. A. Dunlap, K. Dini, *J. Phys. F.* 16 (1986) p. 11

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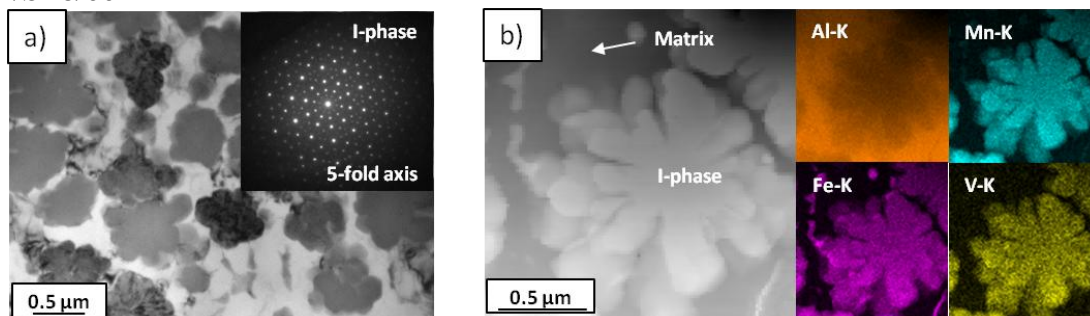


Figure 1. a) TEM bright field image of as spun $\text{Al}_{91}\text{Mn}_6\text{Fe}_2\text{V}_1$ ribbon with inserted an electron diffraction pattern form one of particles, b) STEM image with distribution of elements in the I-phase.

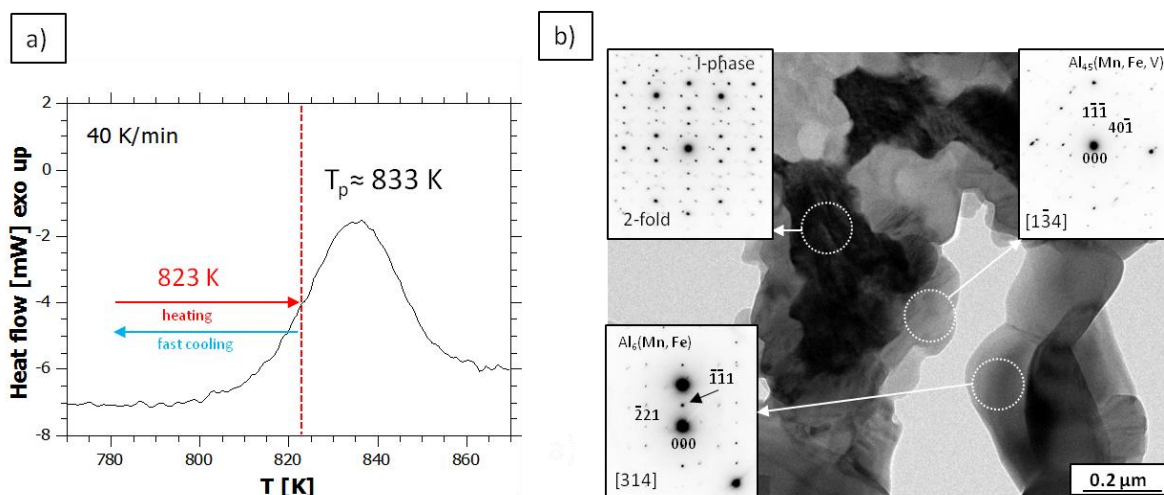


Figure 2. a) DSC curve for V modified alloy ribbon; b) TEM bright field image of sample annealed to 823K (e.g. see arrows in a)) with I-phase partially decomposed into two types of intermetallics.

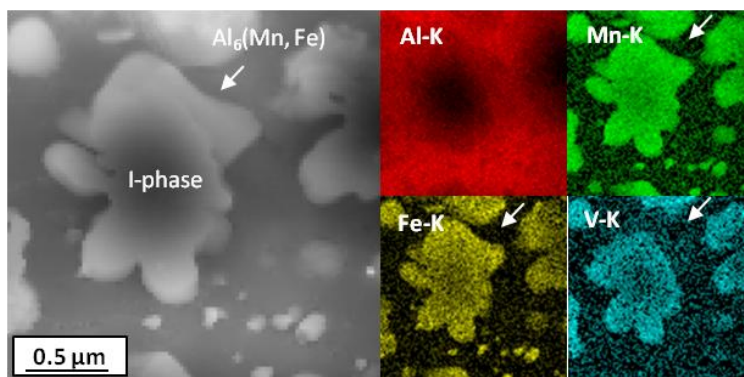


Figure 3. STEM image of $\text{Al}_{91}\text{Mn}_6\text{Fe}_2\text{V}_1$ ribbon after annealing at 773K for 30 minutes showing distribution of elements in both I-phase and orthorhombic $\text{Al}_6(\text{Mn}, \text{Fe})$.