Phase transformation of b-AlFeSi to a-Al(FeMn)Si phase during homogenisation of 6xxx Al alloys

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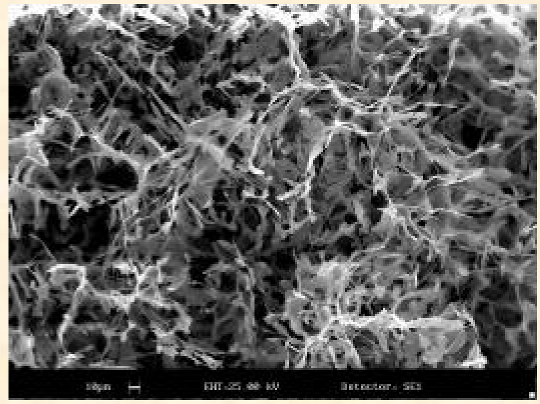
1. Introduction

The figure on the right shows the isolated intermetallic skeleton of *b*-Al_5FeSi, from an as cast 6005A series aluminium alloy, where the Al is dissolved by the Sibut method. The *b*-particles have a thin plate like shape, which adversely influence the extrusion properties of the aluminum. Therefore the material is homogenised, where the *b*- intermetallics transform to the more favorable *a*-$Al_{12}(Fe_x,Mn_{1-x})_3Si$ particles. To understand the nature of this transformation, the changes have been investigated by optical microscopy, SEM and Energy Dispersive Spectrography (EDS).



b-Al_5FeSi *plates in as cast material*

2. The kinetics of the phase transformation

(Optical microscopy pictures on polished samples)

As cast

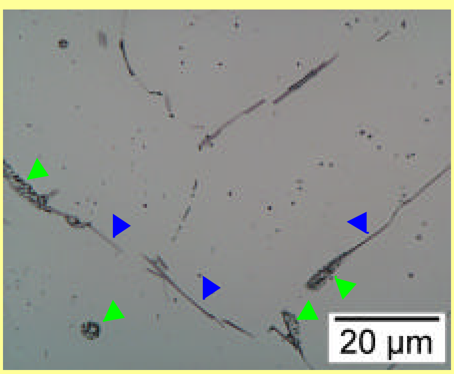


Plate like *b*-Al_5FeSi particles (▼) inside and on the grain boundaries.

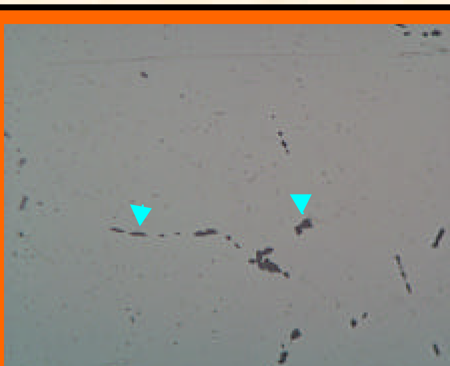
(Mg_2Si precipitates (▼) are nucleated near the boundary of the *b*-particles and in clusters.)

Intermediate transformation: 2 hours homogenised (540 °C)

Nucleation of *a*-$Al_{12}(Fe_xMn_{1-x})_3Si$ particles (▼) on the *b*-Al_5FeSi particles.

(Mg_2Si precipitates are dissolved in the Al matrix)

32 hours homogenised (540 °C)



b-Al_5FeSi particles are completely transformed to the more rounded *a*-$Al_{12}(Fe_xMn_{1-x})_3Si$ particles(▼)

Alloy composition of 6005 series aluminium in wt%

Mg	Si	Fe	Mn	Ti,Cu,Zn,other
0.69	0.88	0.29	0.18	<0.03

3. Quantitative measurements

The transformation is measured quantitatively by automatic SEM and Energy Dispersive Spectrography (EDS) measurements. To accomplish this, 300 intermetallics taken at random are analysed on each polished sample.

3.1 EDS measurements

Figure 1 shows the EDS measurements on particles in cast material, where the particles with Mg are ignored. The measured aluminium concentration varies because in general a part of the Al-matrix was also measured by EDS. However, this figure shows that the iron to silicon ratio of the intermetallics was approximately unity, which corresponds to the expected *b*-Al_5FeSi stochiometry.

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b-Al_5FeSi is the main phase of intermetallics in the cast structure.

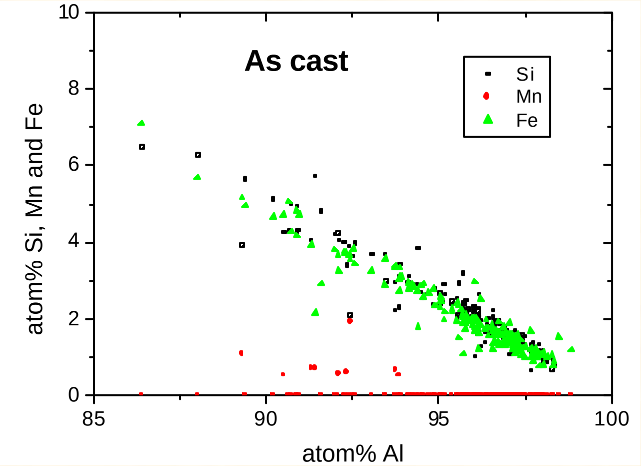

Figure 1, assembly of EDS measurements.

The data collected from EDS measurements (see Figure 2) on samples which have been homogenised for longer times (32 hours at 590 ºC) shows that the [Fe]:[Mn]:[Si] ratio is ~2:1:1

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a-$Al_{12}(Fe_x,Mn_{1-x})_3Si$ was the main phase of inter-metallics after homogenisation.

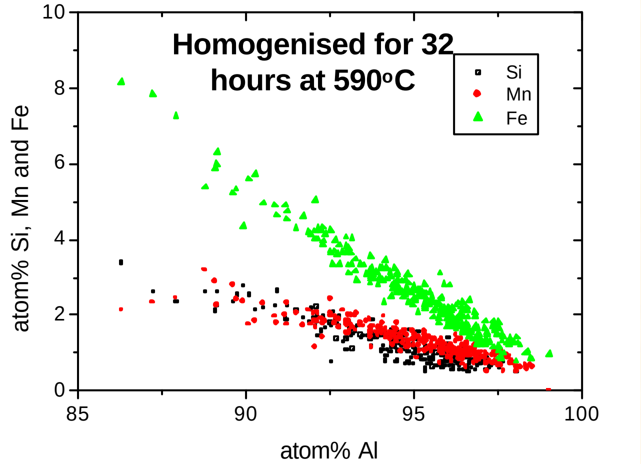

Figure 2, assembly of EDS measurements.

3.2 Transformation rate

Figure 3 shows the relative volume% as function of time of *a*-Al_5FeSi and *b*-$Al_{12}(Fe_x,Mn_{1-x})_3Si$ particles, as measured by the automatic SEM and EDS.

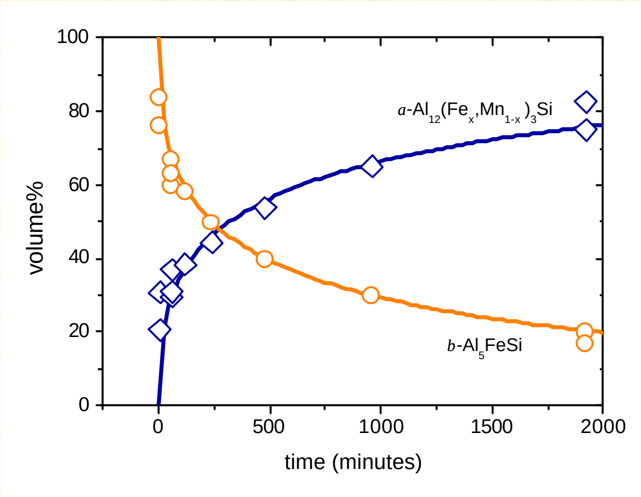

Figure 3. The relative volume% of a and b as a function of time.

The line fitted through the experimental data for volume% of *a* in Figure 3 is a plot of the Avrami equation:

$$x_a = 1 - \exp\left(-kt^n\right)$$

Where *k* is a constant and *n* in this case is *n*≈0.5, which indicates that the transformation is controlled by diffusion over the observed time range. Other measurements indicated that the transformation rate was significantly accelerated when the temperature was higher (565 ºC and 590 ºC).

4. Discussion and conclusion

Optical microscopy

Nuclei of *a-$Al_{12}(Fe_x,Mn_{1-x})_3Si$* particles are found on *b-Al_5FeSi* particles

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at the very beginning of the transformation, the transformation rate is nucleation controlled.

SEM and EDS measurements

Avrami plots

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the transformation kinetics for higher times (>60 minutes) is diffusion controlled.