

# Revealing the precipitation in Al-Cu based alloys with Sc addition

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## Introduction:

Al-Cu based alloys have important applications in the automotive and aerospace industries because of their high specific strength for the weight reduction and better fuel economy. However, their hot tearing tendency hampers their wider applications. Sc addition into Al-Cu based alloys has been found to be effective to refine the grain size, reduce the hot tearing tendency, enhance the precipitation hardening and finally improve the performance of Al-Cu based alloys.

Grain refinement can be directly correlated to the enhanced heterogeneous nucleation of primary  $Al_3Sc$  or  $Al_3(Sc,Zr,Ti)$  phase for  $\alpha$ -Al. While, enhanced precipitation hardening can be mainly attributed to different precipitates formed during heat treatments. Therefore, the main aim of this investigation is to characterize the precipitates formed along grain boundary and / or within the matrix in Al-4.5Cu-0.2Sc (wt.%) alloys after T6 heat treatment using advanced electron microscopy.

## Experimental methods

The investigated Al-Cu based alloy was cast into a sand mould at about 720 °C. The specimens for TEM investigation were mechanically ground, polished and dimpled to about 30  $\mu$ m, and then ion-beam milled using a Gatan Precision Ion Polishing System (PIPS, Gatan model 691). TEM was performed using a Philips CM12 microscopy operated at 120 kV, a JEOL-2100F with a Cs-corrected microscopy operated at 200 kV (Figure 1a), and a monochromated and probe corrected FEI Titan<sup>3</sup>TM G2 60-300 (S/TEM) microscope operated at 300 kV (Figure 1b).



Figure 1: (a) JEOL-2100F with a Cs-corrected microscopy (left) and (b) Titan<sup>3</sup>TM G2 60-300 (S/TEM) microscope (right).

## Results:

### 1. Sc segregation into $Al_2Cu$ phase

Sc was found to partition into the  $Al_2Cu$  phase (Figure 2), which was believed to improve the thermal stability of  $Al_2Cu$  phase.

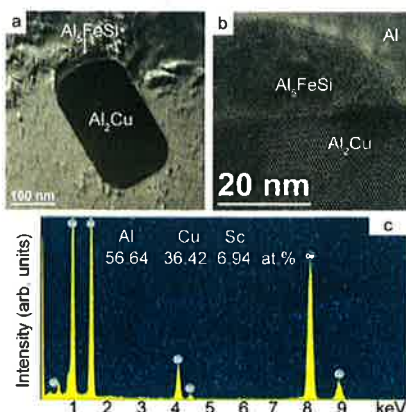


Figure 2: Sc was found to partition into the  $Al_2Cu$  phase.

## Results (continued)

### 2. Sc addition decreases the size, but increases the number density of precipitate

Compared with Al-4.5Cu (wt.%) based alloys (not shown here), the size of the precipitates decreases, however, the number density of the precipitates increases (Figure 3).

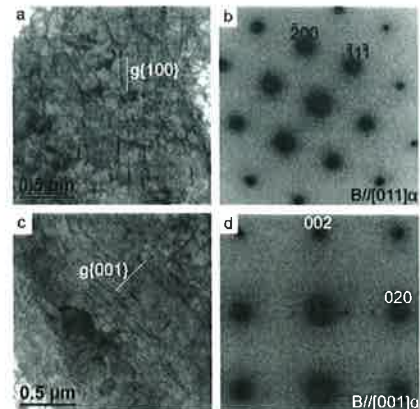
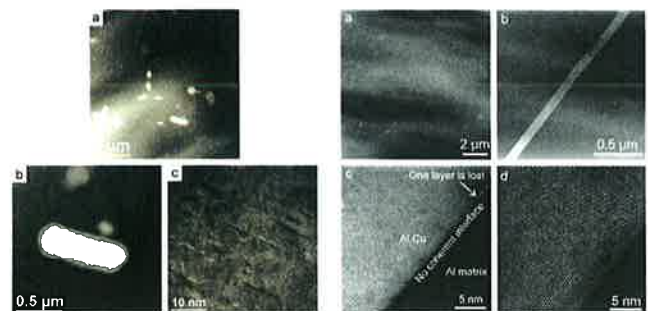


Figure 3: Sc addition increases the number density of the precipitate.

### 3. The interface between $Al_2Cu$ precipitates and $\alpha$ -Al matrix

Furthermore, high resolution STEM was employed to characterize the  $Al_2Cu$  precipitates and the interface between  $Al_2Cu$  precipitates and  $\alpha$ -Al matrix (Figures 4 and 5). The  $Al_2Cu$  precipitates appear to be no-coherent with  $\alpha$ -Al matrix when viewed from  $\{011\}_{\alpha-Al}$  (Figure 4c) and  $\{001\}_{\alpha-Al}$  (Figures 5c,d). The loss of coherency indicates that the precipitation process may be in the stage of peak ageing or over ageing. At this stage, the precipitation microstructure becomes more stable, and the mechanical properties is enhanced. However, it should be also noted that one lost atomic layer (step) was observed at the interface between  $Al_2Cu$  precipitate and  $\alpha$ -Al matrix, as shown in Figure 5c. Although this observation could be due to the beam damage, it also strongly demonstrates that advanced electron microscopy is of great necessity to reveal the mysteries (i.e. the precipitate interface structure and composition) in conventional research fields, e.g. solidification and / or precipitation.



The interface between  $Al_2Cu$  precipitates and  $\alpha$ -Al matrix viewed from  $\{011\}_{\alpha-Al}$  (Figure 4, left) and  $\{001\}_{\alpha-Al}$  (Figures 5, right).

## Conclusions:

Sc was found to partition into the  $Al_2Cu$  phase, and thereby improve the thermal stability of  $Al_2Cu$  phase. Sc addition decreases the size, but increases the number density of precipitate. The  $Al_2Cu$  precipitates appear to be no-coherent with  $\alpha$ -Al matrix. The loss of coherency indicates that the precipitation process may be in the stage of peak ageing or over ageing. This investigation demonstrates that full characterization on the precipitates from micro to atomic scale is of great importance to optimize conventional Al-Cu based alloys in service and develop new Al-Cu based alloys.



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## Research partners:



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