Some Observations on Precipitation in a Al-Si-Cu-Mg Alloy with Al_2O_3 Particles

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1. INTRODUCTION

Recently, the ageing of a powder-metallurgical Al-20at%Si-1.5at%Cu-1.1at%Mg (ASCM) alloy with 10 vol% aluminium oxide (Al_2O_3) particles was studied. The alloy, made available by Dr. J. Duszczyk (Laboratory of Materials Science, Delft University of Technology) and manufactured by Showa Denko, Japan, combines the presence of two reinforcing components (silicon and Al_2O_3 particles) with the possibility of age hardening of the Al-rich phase. For instance, during ageing at 453 K, the maximum hardness is reached after 4 hours. This maximum in hardness is related with Q-phase ($Al_5Cu_2Mg_8Si_6$) precipitation. It is noted that the hexagonal Q phase is incoherent with the Al-rich matrix phase. Hence it is unlikely that hexagonal Q-phase precipitates are directly responsible for the increase in hardness. Therefore it was decided to perform a TEM study of the Q-phase precipitation in the ASCM alloy with Al_2O_3 particles.

2. TRANMISSION ELECTRON MICROSCOPY STUDY

Transmission Electron Microscopy (TEM) samples were prepared by ion milling using a commercially available GATAN line of devices. A JEOL 200CX microscope was used together with an EDAX analyzer.

The base alloy was rapidly solidified by gas atomisation, yielding fine powder (sizes range from 1 to 100 μm, with a median size of 25 μm). The powder was mixed with Al_2O_3 particles, in order to obtain a mixture with 10 vol.% Al_2O_3 particles (sizes range from 1 to 6 μm with an average of 2 μm), the sizes of the silicon particles range from 2 to 10 μm (average about 4 μm). This mixture was extruded at about 670 K, yielding round bars of about 20 mm diameter. Specimens were cut from the extrudate and observed in TEM. Si, Al_2O_3, Q, Al_7Cu_2Fe and θ particles were found. Subsequently, specimens were encapsulated in quartz, solution heat treated for 10 min at 763 K, quenched in water and observed in TEM. After quenching no indication for θ particles was generally found.

3. PRECURSOR PHASE PRECIPITATION

Hardness measurements have shown that during room-temperature ageing directly after quenching the hardness increases within a few hours (Starink, Jooris and Van Mourik (1992)).

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DSC measurements confirmed that this increase in hardness is related to an exothermic reaction, i.e. the formation of precipitates (Van Mourik and Starink (1993)). During 4 hours of ageing at 453 K the hardness of the ASCM alloy increases to its maximum, while the lattice parameter of the Al-rich phase stays approximately constant. As it can be shown that Q-phase precipitation has very little effect on the lattice parameter of the Al-rich phase (contributions from Cu, Mg and Si precipitation balance (Starink, Abeels and Van Mourik, (1993))), this indicates that in this stage of ageing a hardening, semi-coherent precursor of the Q-phase precipitates.

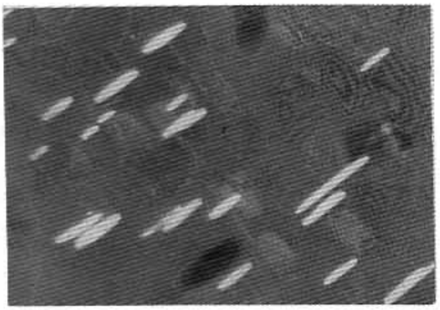

Fig. 1 Dark field micrograph of semi-coherent Q precipitates after 1 hr at 453 K (40 000x)

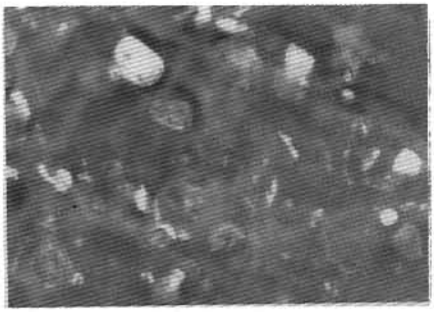

Fig.2 Dark field micrograph of incoherent Q precipitates after 4 hr at 453 K (40 000x)

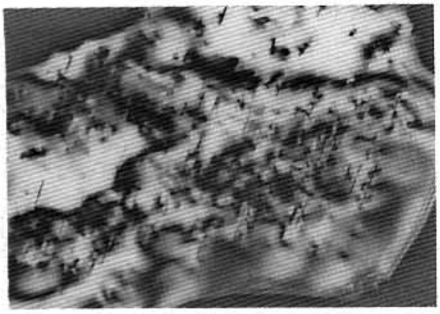

Fig.3 Dark field micrograph of semi-coherent θ' precipitates after 8 hr at 453 K (40 000x)

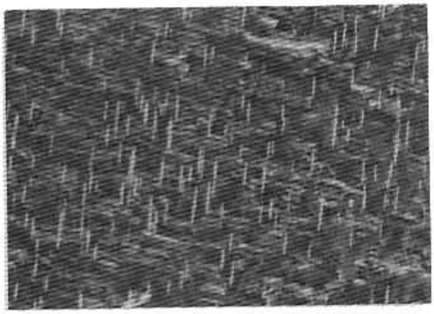

Fig.4 Dark field micrograph of semi-coherent θ' precipitates after 16 hr at 453 K (40 000x)

In line with this disc-shaped semi-coherent precipitates were observed abundantly throughout the entire matrix (Figure 1). The sizes of these precipitates (about 70 nm) are similar to those for other semi-coherent precipitates in aluminium at the stage of maximum hardness. These hardening semi-coherent precipitates evolve into incoherent Q phase precipitates (Figure 2). Hence its semi-coherent precursor will tentatively be indicated as Q' precipitate. In Figures 3 and 4 clear evidence of θ' precipitation is observed.

Starink M.J., Abeels V., Van Mourik P. (1993) *Mater.Sci.Eng.* **A163**, 115-125.
Starink M.J., Jooris V., Van Mourik P. (1992) Proc.1st ASM Heat Treatment and Surface Eng. Conf., Amsterdam (Trans Tech Publications, Zürich) pp 85-98.
Van Mourik P., Starink M.J. (1993) ATTT 93, Gand (PYC Edition, Ivry sur Seine) 293-307.