AN INVESTIGATION ON HIGH TEMPERATURE AGEING OF COMPLEX Al-Cu-Mg-Ag-Zn ALLOYS

S. Abis[1], P. Mengucci[2] and G. Riontino[3]
1. Federal Mogul-Glyco - Via Trione 5, I-10082 Cuorgnè (TO), Italy
2. Dipartimento di Scienze dei Materiali e della Terra - Unitá INFM, Università di Ancona, Via Brecce Bianche, I-60131 Ancona, Italy.
3. Dipartimento di Chimica Inorganica, Chimica Fisica e Chimica dei Materiali - Unitá INFM, Università di Torino, Via Giuria 9, I-10125 Torino, Italy.

Abstract

The precipitation sequence of an Al4Cu0.35Mg0.7Ag1Zn AVIOR alloy at 190°C has been investigated by coupled DSC/TEM analyses.
It is found that the alloy shows a different precipitation sequence with respect to the the well known K0-1 alloy of the same family without the Zn addition, namely:

$$\alpha sss \rightarrow GPZ \rightarrow \Omega + \theta' + S'.$$

The role of Zn seems to be linked out with a decrease of the activation energy for Ω precipitation, giving as a result a more dense precipitation of this phase with respect to the Zn-free alloy.

Introduction

Silver modified Al-Cu-Mg alloys having a Cu content of 4÷5 wt% and a high Cu:Mg ratio have been widely investigated in the past years for at least two reasons:

- they are quite interesting from a basic metallurgal standpoint, since the addition of silver promotes a massive precipitation of the well known Ω-$CuAl_2$ phase; the structure and genesis of this latter have been the subject of a number of papers; (see references in [1]).
- they are also attractive from an application standpoint as premium casting alloys, being able to reach quite high values of YS and UTS (say 500 MPa) in the T7 temper. Such a high values have been related to the presence of the Ω-$CuAl_2$ phase.

At least two commercial foundry alloys based on Ω strengthening have been proposed on the market in the past: the well-known K0-1 alloy in the USA (Al4Cu0.35Mg0.35Mn0.7Ag) and the AVIOR composition (Al4Cu0.35Mg0.7Ag1Zn) [3] in France; this latter having an addition of about 1%wt Zn.
Another composition has been recently proposed for application requiring a good thermal stability [4].
Many papers have been devoted to the study of the precipitation sequence in AlCuMgAg alloys;

recent results have shown that the following sequence:

$$\alpha_{sss} \rightarrow \Omega' + GPZ \rightarrow \theta'' + \Omega' \rightarrow \theta' + \Omega + S'$$

takes place during high temperature ageing at 190 °C after solution treatment and quenching in a K0-1 alloy [1]. Ω' is a precursor of the Ω-$CuAl_2$ phase and its structure has been proposed to be a distorted hexagonal Al_xCu_yMg.
On the contrary few papers have been devoted to the study of the precipitation phenomena in Zn-additioned AlCuMgAg alloys, even if it is generally accepted that the AVIOR composition should have a precipitation path similar to that of the K0-1 alloy.
This paper reports some preliminary results about the precipitation sequence at 190 °C in an AVIOR AlCuMgAgZn alloy after solution treatment, quenching and room temperature annealing. Differential Scanning Calorimetry (DSC) together with TEM/SADP examinations have been used to investigate the formation of the hardening phases during the ageing process. A Zn-free K0-1 alloy has been used as a reference sample in order to investigate the influence of the zinc in the precipitation sequence.

Materials and Methods

Samples of AlCuMgAg and AlCuMgAgZn alloys were cast in permanent die and prepared for DSC/TEM examinations according to the method elsewhere described [1]; the chemical composition is reported in Tab I. Samples were homogeneized and aged according to the data reported in Tab II.

Table I. Chemical composition of the investigated alloys (wt%).

Alloy	Cu	Mg	Zn	Ag	Mn	Ti	Fe	Si
K0-1	4.46	0.33	-	0.68	0.34	0.20	0.07	0.03
AVIOR	4.70	0.36	1.20	0.67	0.52	0.28	0.08	0.03

Table II. Ageing treatments performed on the investigated alloys.

Alloy	Homogeneizing	Quenching	T4	T7
K0-1	3h /500°C+3h /515°C+22h /530°C	water r.t.	24h at r.t.	600' / 190°C
AVIOR	3h /500°C+3h /515°C+22h /525°C	water r.t.	24h at r.t.	600' / 190°C

DSC analysis was performed by a DuPont 910 thermal analyzer at a scanning speed of 30 K/min in argon atmosphere; pure Al was used as reference. TEM/SADP observations were taken using a Philips CM12 at 120 kV.

Results and Discussion

Thermograms referring to the investigated tempers are reported in fig 1 and 2; they are compared with the corresponding traces detected for the Zn-free K0-1 alloy.

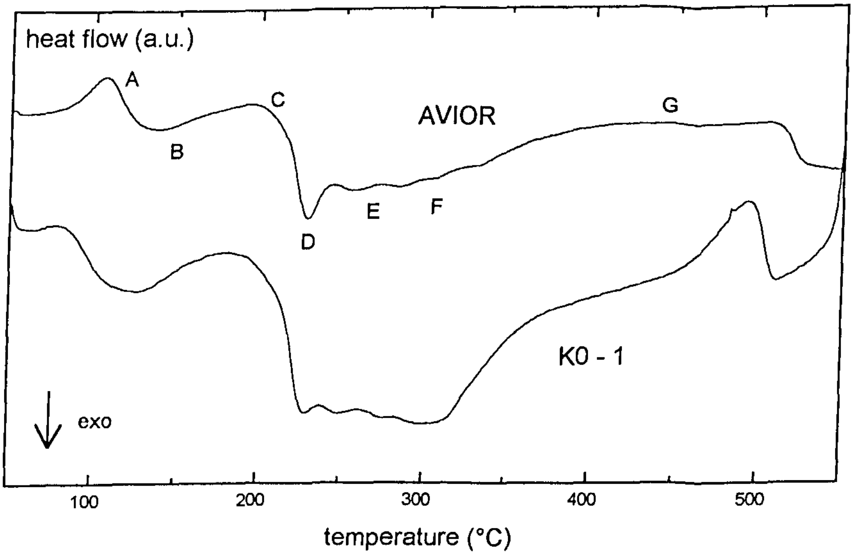

Fig 1 - DSC traces obtained for the AVIOR and K0-1 alloys in the T4 temper.

Detected curves show essentially the same trend for both the alloys:
T4-temper: a first endothermal peak 'A' at lower temperature, an exothermal effect 'B' and then a further endothermal peak 'C'. A complex exothermal effect comprising three different peaks 'D', 'E' and 'F' is then placed in the temperature range $200 \div 350$°C followed by a broad endothermal effect between 350°C and the solutioning temperature.
According to the results elsewhere published [1] for the K0-1 alloy, the first peak 'A' is the result of the dissolution of Cu-GPZs formed during r.t. annealing after solution treatment and quenching. During the scan θ" particles form giving place to the exothermal peak 'B'; they then dissolve (peak 'C'), while Ω, θ' and S' precipitate at higher temperature giving as a result the 'D', 'E' and 'F' exothermal effects. The last broad endothermal effect 'G' is due to the complete solutioning of all the precipitated phases.
SADP patterns were taken from two different zone axes, namely: <001> and <111>. Streaks along [100] in the <001> zone axis indicate the presence of Cu Guinier Preston Zones (fig 3a). An examination of the <111> pattern does not show the presence of extra spots which could be attributed to the presence of the Ω' phase as in the K0-1, but faible extra spots at ½(220) can be assigned to the presence of θ' precipitated particles. A further examination taken from the <233> zone axis which was claimed to be the Ω' precipitation plane, confirmed the absence of this phase.

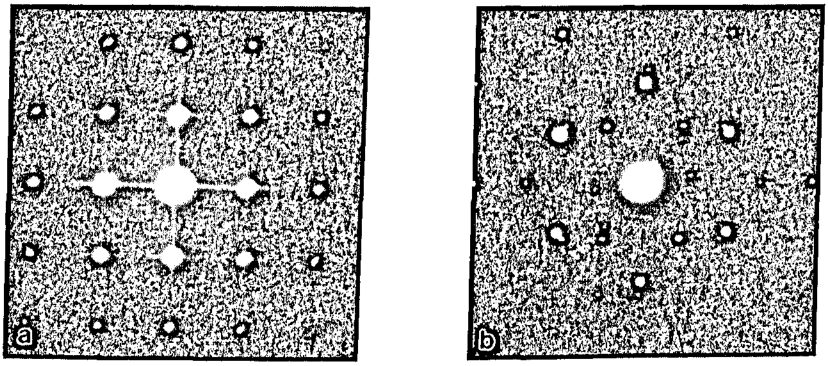

Fig 3 - T4; SADP patterns from <001> (a), and <111> (b) zone axes.

T7-temper: thermograms in the T7 temper are characterized by a broad endothermal effect where the peak 'C' can be easily detected (fig 2). This latter must be assigned to θ" dissolution as in the T4 temper, and the increased size of precipitates due to the aging at 190°C justifies its increased peak temperature with respect to the T4 trace.
SADPs taken from the same zone axes considered in the T4 temper are reported in fig 4. Reflections can be indexed on the basis of θ"/θ', S' and Ω precipitates as found in the K0-1 Zn-free alloy[1].

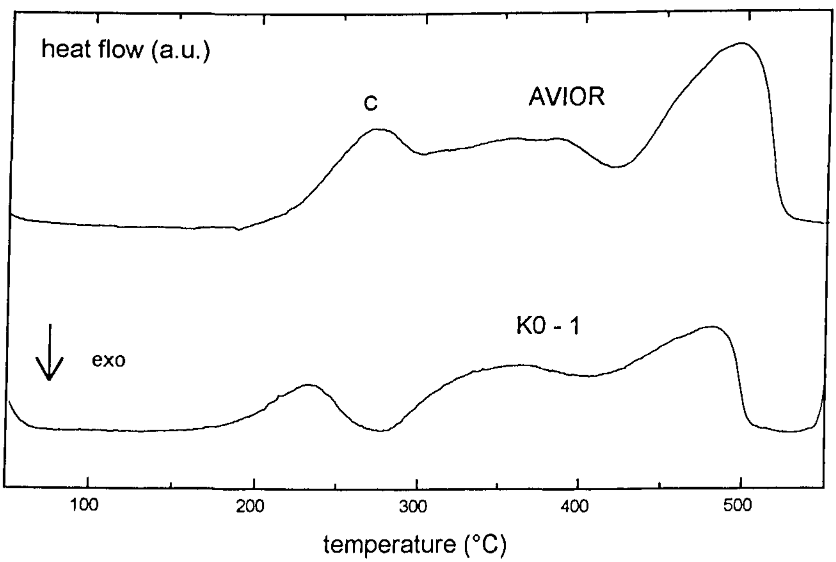

Fig 2 - DSC traces obtained for the AVIOR and K0-1 alloys in the T7 temper.

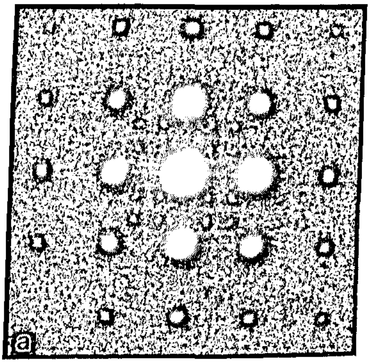

Fig 4 - T7; SADP patterns from <001> (a), and <111> (b) zone axes.

The TEM observation revealed the presence of a dense distribution of Ω precipitates; few θ' particles can be also observed and S' precipitates are present inside the grains. A comparison with the A201 Zn-free alloy shows that a higher density of Ω particles is present in the AVIOR alloy (fig 5, left).

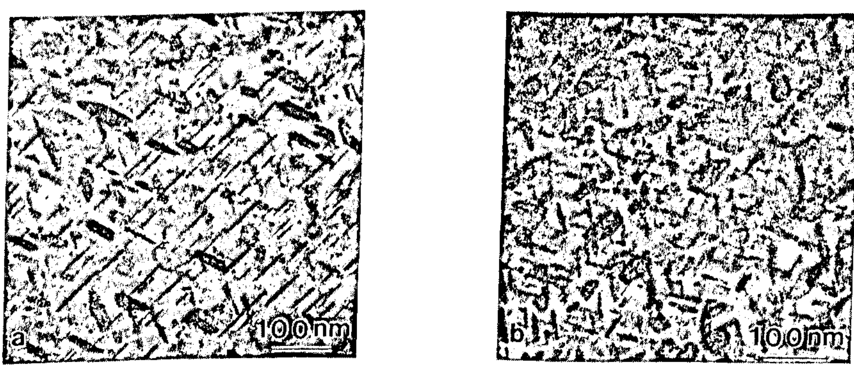

Fig 5 - TEM pictures obtained for the AVIOR (a) and K0-1 (b) alloys in the T7 temper.

Results here described indicate that the precipitation sequence in the AVIOR alloy is different from the K0-1 composition. In the T4 temper a pattern of GPZs and θ' particles is found; GPZs evolve according to the well known sequence:

$$GPZs \rightarrow \theta''\text{-}CuAl_2 \rightarrow \theta'\text{-}CuAl_2$$

while the pattern Ω'→Ω found in the A201 alloy seems to be absent in the Zn modified AVIOR composition and a different mechanism must be invoked for Ω nucleation.

The addition of Zn modifies therefore the precipitation sequence; it moreover influences the density of Ω precipitates in the T7 temper, reducing also the density of θ' particles. As a matter of fact, the activation energy for Ω precipitation calculated for the peak 'D' by the Ozawa plot [5] gives a result of 74 kJ/mole [6] which is significantly lower than the value of 115 kJ/mole found for the Zn-free K0-1 alloy [7].

References

1. Abis, S., Mengucci, P. and Riontino, G., 1993, *Phil. Mag.* B, **67**, 465.
2. Iler, A.J., 1969, *Mod. Casting*, **55**, 55.
3. Speidel, M.O., 1975, *Proceedings of the Sixth International Light Metals Congress*, (Leoben: Aluminium-Verlag), pp. 67-71.
4. Polmear, I.J., Couper, M.J., 1988, *Metall. Trans.* A, **19**, 1027.
5. Ozawa, T., 1970, *J. Thermal Analysis*,**2**,301
6. Abis S., Mengucci P. and Riontino G., Unpublished data
7. Abis S., Mengucci P. and Riontino G., *Phil. Mag.* in press