THE EFFECT OF SMALL ADDITIONS OF SILVER ON AGEING BEHAVIOR OF Al—Mg—Li ALLOYS

Z. G. Chen, Z. Q. Zheng, C. Y. Tan and D. F. Yun
Department of Materials Science and Engineering, Central—South University of Technology, Changsha, Hunan 410083, P. R. China

Abstract

The ageing behavior and microstructures of the Al—Mg—Li alloys containing silver have been studied. The results showed that small quantities of silver could modify the ageing characteristics of Al—Mg—Li alloys; the higher peak hardnesses and strengthes were achieved, and the ageing peaks were delayed by small additions of silver; And the X—Ray diffraction analysis showed that the T phase was present in the Al—Mg—Li alloy containing 0.52wt%Ag, TEM observations showed that silver prevented the growth of δ′ phase during ageing.

Introduction

It's been found that small amount of silver exerts a considerable effect on the structure and ageing characteristics of some aluminum alloys, such as Al—Zn—Mg system, Al—Cu—Mg system, etc. In a series of papers[1—3], Polmear et al reported that in Al—Cu—Mg system alloys the increased ageing hardening response caused by small addition of silver was associated with stimulating nucleation of intermediate precipitates and modification of the precipitation structure. They reported that[4] lithium additions in the range 0 to 2.5% progressively changed the precipitation processes in the Al—4%Cu—0.3%Mg—0.4%Ag alloy aged at 200°C, and three intermediate precipitates Ω, θ' and S′ contributing to the high level of age hardening in the alloy was found. Afterwards a new family of Al—Li alloys——Wedalite 049 has been developed by Pickens and his co—workers[5], they reported that the ultra high strength of these family of alloys derives from the additions of minor Ag and Mg to the Al—Cu—Li alloys. But up to now most of the investigations concentrated on the Al—Li alloys containing copper. In this paper, the ageing characteristics and microstructures of Al—Mg—Li—Zr alloys containing small amounts of silver were investigated.

Experimental Procedure

The alloys were prepared by melting and casting under argon atmosphere. The chemical compositions of the alloys tested are shown in Table 1. The ingots were homogenized, scalped, then hot rolled and cold rolled to 2 mm sheets. The specimens were solution treated and quenched into cold water, then aged at 120°C. Tensile specimens were machined from the sheets in the longitudinal directions, and the tensile tests were carried out at room temperature on Instron 8019. The X—Ray diffracton was performed on Simens D500. The specimens for the observation of transmission electron microscopy were prepared by twin-jet electropolishing in a 33 Vol% HNO_3 and 67 Vol% CH_3OH solution at −20°C. Examination was carried out in H800 with an accelerating voltage of 200KV.

Table 1. Chemical compositions of the alloys (Wt%)

Alloys	Mg	Li	Ag	Zr	Al
A1	5.10	1.56	0	0.13	Bal.
A2	5.05	1.63	0.26	0.13	Bal.
A3	5.00	1.56	0.52	0.13	Bal.

Results and Discussion

The Hardness/Ageing Time curves at 120°C for the A1, A2 and A3 alloys are given in Fig. 1. It can be seen that the form of the ageing curves of the A1, A2 and A3 alloys was similar, and only one ageing peak was observed during the whole ageing process at 120°C. The rate of overage of the A3 alloy was much slower than that of the A2 alloy. Compared with the silver—free alloy, the ageing peaks were delayed by additions of silver. It is interesting to note that there was little difference in the peak hardness value between A2 and A3 alloys although the silver contained in the A3 alloy is double to that in the A2 alloy.

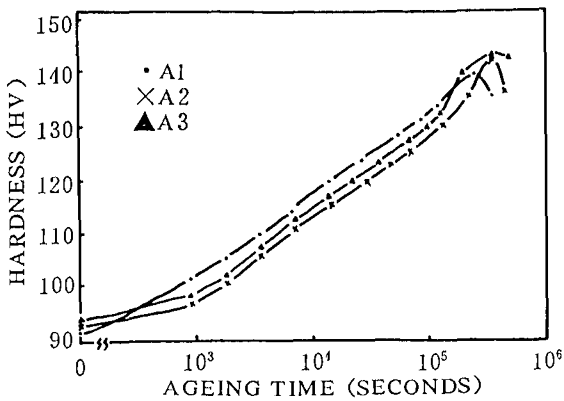
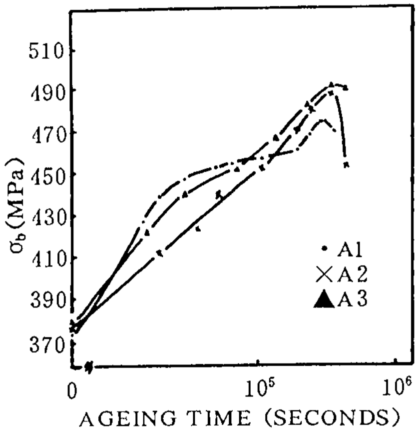
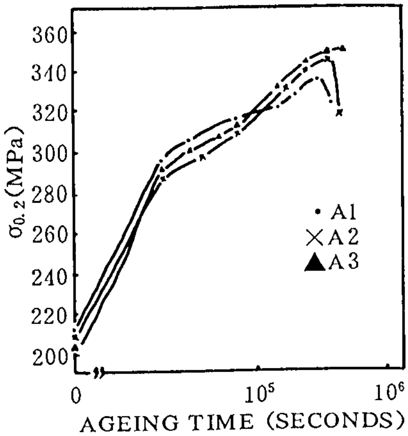


Fig. 1 Hardness/time(ageing) curves at 120°C for the A1, A2 and A3 alloys

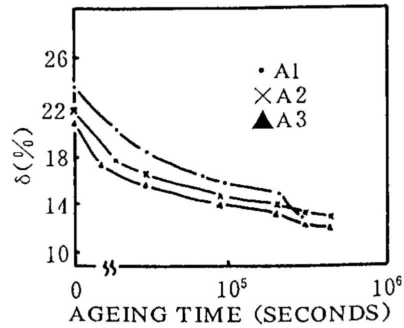
The Tensile properties/Ageing time curves at 120 C for the A1, A2 and A3 alloys are shown in Fig. 2. It's found that the form of the curves was similar to the Hardnesses/Ageing time curves. And the higher peak strength could be achieved by additions of silver.



(a)



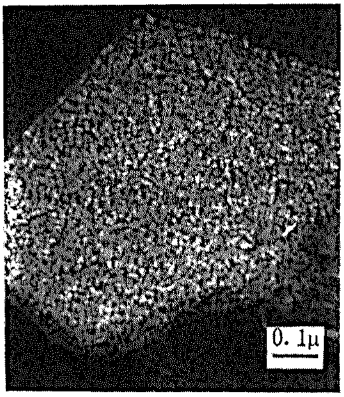
(b)



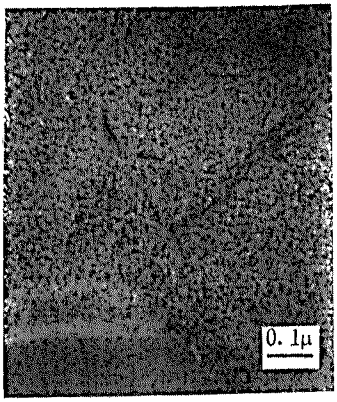
(c)

Fig. 2 Tensile properties/time(ageing) curves at 120 C for the A1, A2 and A3 alloys (a) Tensile strength (b) 0.2% Proof stress (c) Elongation

TEM investigations indicated that homogeneous distribution of δ' precipitates present in both silver—containing and silver—free alloys. There was no significant difference in the distribution and morphology of δ' particles between the silver—containing and silver—free alloys. However, in the same aged condition the size of δ' particles in the-silver—containing alloys appears to be smaller than that in the silver—free alloy, and it's seemed that the more the silver was added, the finer the δ' phase was. As for the silver—free A1 alloy, its δ' particles after ageing for 80h is even bigger than that of the A2 alloy aged for 100h(see Fig. 3). It's seemed that the existence of the silver may prevent the growth of the δ', this may lead to the delay of the ageing peak for the A2 and A3 alloys and the slow overage of the A3 alloy. The slow growth of δ' phase may be associated with the fact that the additions of silver slow the rate of the Lithium atoms diffusion. On one hand, because silver atoms and Magnisium atoms have high combining energy with vacancys[6], they may trap a lot of vacancy after quenching, consequently the number of vacancys traped by the Lithium atoms is reduced. On the other hand, as for δ' phase, in order to grow up, they either rob silver atoms and Magnisium atoms of vacancys, or get over the obstacle of the combination of silver atoms /vacancy or magnisium atoms/vacancy, thus it is difficult for Lithium atoms to diffuse, and the growth of δ' particles is slower.



(a)



(b)

Fig. 3 Central dark field image of δ' phase in (a) A1 alloy aged 80 hrs. and (b) A2 alloy aged 100 hrs. at 120℃

The X — Ray diffraction results (see table 2 and 3) showed that the S phase (Al_2MgLi) could be precipitated in A2 and A3 alloys, and only in the A3 alloy the T phase($Mg_{32}(Al,Ag)_{49}$) was present. This indicated that in the Al—Mg—Li—Ag alloy the T phase could be precipitated only when containing more silver. As Wheeler et al. [7] pointed out the Al—Mg alloys with even small additions of silver should consequently be regarded as ternary precipitation hardening alloys, here the Al—Mg —Li alloys with additions of silver could also be considered as quaternary precipitation hardening alloys. The existence of T phase in the Al—Mg—Ag alloys was reported by J. H. Auld et al. [8], which can contribute to the marked age hardening[9]. In the Al —Mg—Li—Ag—Zr alloy the δ', S phase and T phase could be precipitated, and it seems reasonable to attribute the high level of age hardening and strengthening in the alloy mainly to their presence. The precipitation of T phase may lead to the slower overage of A3 alloy, for the precipitation of T phase can compensate for the softening during the overage stage.

Table 2. The Result of X−Ray Diffraction of A2 Alloy Aged at 120°C for 100h

No.	2θ	D	INTEG. I	Phase(hkl)
1	21.753	4.1023	82	S(422)
2	23.068	3.8523	62	S(511)
3	31.263	2.8586	109	S(711)
4	38.408	2.3417	5872	S(822)
5	43.309	2.0874	84	S(931)
6	44.648	2.0278	6620	S(933)

Table 3. The Result of X−Ray Diffraction of A3 Alloy Aged at 120°C for 100h

No.	2θ	D	INTEG. I	Phase(hkl)
1	21.737	4.0851	366	S(422)
2	22.972	3.8682	280	T(321)/S(511)
3	25.050	3.5518	155	S(440)
4	35.801	2.5060	248	T(530,433)
5	36.623	2.4516	201	T(600,442)/S(733)
6	38.342	2.3456	12780	T(611,532)/S(822)
7	41.089	2.1949	186	S(842)
8	42.147	2.1422	201	T(631)/S(664)
9	44.550	2.0321	20934	T(710,550)/S(933)
10	45.910	1.9750	263	T(721,633)/S(1020)
11	64.803	1.4375	4801	T(941,853)
12	68.568	1.3674	160	T(1031,952)
13	77.843	1.2260	9078	T(1060,866)
14	81.996	1.1741	804	T(1222,1064)

Conclusions

1. Small quantities of silver may modify the ageing characteristics of the Al−Mg−Li−Zr alloys, and the higher peak hardnesses and strengthes could be achieved by small additions of silver.
2. The ageing peak was delayed by the additions of silver, and the more the silver was added, the slower the rate of overage softening was.
3. T phase can be precipitated in the Al−Mg−Li−Ag−Zr alloy containing 0.52wt%Ag.
4. The additions of silver may prevent the growth of δ' phase during ageing.

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