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Effect of Additional Elements on the Age Harding Behavior of Al-Zn-Mg-Si Alloys

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Al-Zn-Mg alloy has been known as one of the aluminum alloys with the good age-hardening ability and the high strength. The mechanical property of the limited ductility, however, is required to further improvement. In this work, three alloys, which were added Cu or Ag into the Al- Zn- Mg- Si (base) alloy, were prepared to compare the effect of the additional elements on the aging behavior. Zr was also added to three alloys. The age-hardening behavior, tensile properties and microstructures of those six alloys were investigated by hardness measurement, tensile test and transmisssion electiron microscope (TEM) observation. Ag or Cu added alloys showed higher peak hardness and tensile strengh, and fine microstructure of precipitates than those in the base alloy.

Keywords: *Al-Zn-Mg alloy, silver, copper, age-hardening, mechanical properties, precipitation, TEM*

1. Introduction

Al-Zn-Mg alloy has been known as one of the aluminum alloys with the good age-hardening ability and the high strength and used for the part of the fields which required high strenghth, such as aerospace and mass transportation. The precipitation sequence for the Al-Zn-Mg alloys is generally described as follows [1]:

Supersaturated solid solution →GPzones →metastable η'→stable η ($MgZn_2$).

The η' phase is the most important phase for the age-hardening in this alloy [2] and the addition of Cu and Ag increses hardness of this alloy. The aim of this work is the fundamental research to know the effect of Cu or Ag, Zr addition to Al- 2.6 mass% Zn – 2.0 mass% Mg – 0.3 mass% Si alloy on the age hardening behavior. 6 types of alloys were prepared and hardness measurement, tensile test and TEM observation were performed for those alloys.

2. Experimental

The alloys were obtained by nornal casting and the chemcal composition of alloys are shown in Table 1. Sheets with 1 mm thickness were made by hot extrusion and cold-rolling. The specimens were solution heat treated at 748K for 3.6ks in an air furnace, quenched in chilled water. 2 step aging treatment was performed for samples. The pre-aging was at 373K for 57.6 ks and the final aging was at 423K in oil bath. The micro-vickers hardness was measured with Akashi MVK-E II (load: 0.98 N, holding time 15 s). The dimension of tensile test specimens were 0.8 mm×5.8 mm and gauge length of 17.5mm. Peak-aged specimens were fractured at room temperature using by Instron type tensile machine. Fractured surface of specimens were observed by SEM (Hitachi S-3500). Thin specimens for TEM observation were prepated by electrolitic polishing method and microstructures were observed by Topcon EM-002B opration at 120kV.

3. Result and discussions

Figure 1 shows age-hardening curves all alloys with two-step aging. It can be seen that hardness of Cu or Ag addition alloys are higher than that of base alloy after the pre-aging. The hardness increases by paralleling with each other with increase of aging time after 0.48ks, and reaches the peak at 2.4 ks for all alloys. There were no remarkable difference of hardness between alloys with and without Zr.

Figure 2 shows nominal stress – nominal strain curves obtainerd for all of peak-aged alloys. It can been seen that the addition of Cu or Ag increases the tensile strength of the alloy though decreases the elongation slightly comparing with that of the base alloy (Fig. 2(a)). In Fig. 2(b), Zr-addition improves strength slightly. The tensile strength and the elongation, however similar to each other for the base alloy with or without Zr. Fig. 3 shows SEM images of fracture surfaces obtained for the peak-aged base and Ag addition alloys. The fracture surface of base alloy shows a typical transgranualr fracture with large dimples (Fig. 2(c)), while Ag-additionalloy also shows a typical ductile intergranualr fracture which has small dimples (Fig. 2(d)) on fractured grain surface. This is in good agreement with the result of elongation in tensile test.

Figure 4 shows TEM bright field images obtained for peak-aged base and Ag-addition alloys. The incident beam direction was parallel to the $[111]_{Al}$ direction. Fine spherical precipitates were observed in both samples, and the η' -phase existed in the matrix of both alloys based on the analysis of their electron diffraction patterns. The addition of Cu or Zr was also increased the number density of precipitates. This means that Ag or Cu addition is effective in the nucleation of precipitates.

Table 1. Chemical composition of alloys (mass %)

alloys	Zn	Mg	Si	Cu	Ag	Zr	Ti
Base	2.60	2.01	0.29	-	-	-	0.01
Cu addition	2.75	2.17	0.29	0.22	-	-	0.01
Ag addition	2.72	2.45	0.32	-	0.20	-	0.01
Zr addition	2.73	1.95	0.29	-	-	0.06	0.01
Cu+Zr addition	2.70	2.17	0.30	0.10	-	0.06	0.01
Ag+Zr addition	2.76	2.23	0.30	-	0.21	0.05	0.01

4. Summary

The effect of Cu or Ag addition on age-hardening behavior in Al-Zn-Mg-Si alloys was investigated by hardness measurement, tensile test and TEM observation. Results of the present study was summarized as follows:

1. Cu or Ag addition to Al-Zn-Mg-Si alloys with two-step aging increases the maximum hardness, 0.2% proof stress and tensile strength comparing with those of base alloy, although elongation was decreased. Zr-addition did not show remarkable difference for hardness and tensile strength.
2. The fracture surface of base and Ag-addition alloys showed typical transgranualr and intergranular fracture, which is in good agreement with their result of elongation in tensile test.
3. According to TEM observation, fine spherical η'-phase existed in the matrix of peak-aged alloys. The number density of the precipitates incresed with the addition of Ag or Cu .

References

[1] L.F.Mondolfo, N.Agjostein and D.W. Levinson: Trans. AIME. **206** (1956) 1378.
[2] J.K.Park and A. J. Ardel: Met. Trans. **14A** (1983) 1957.

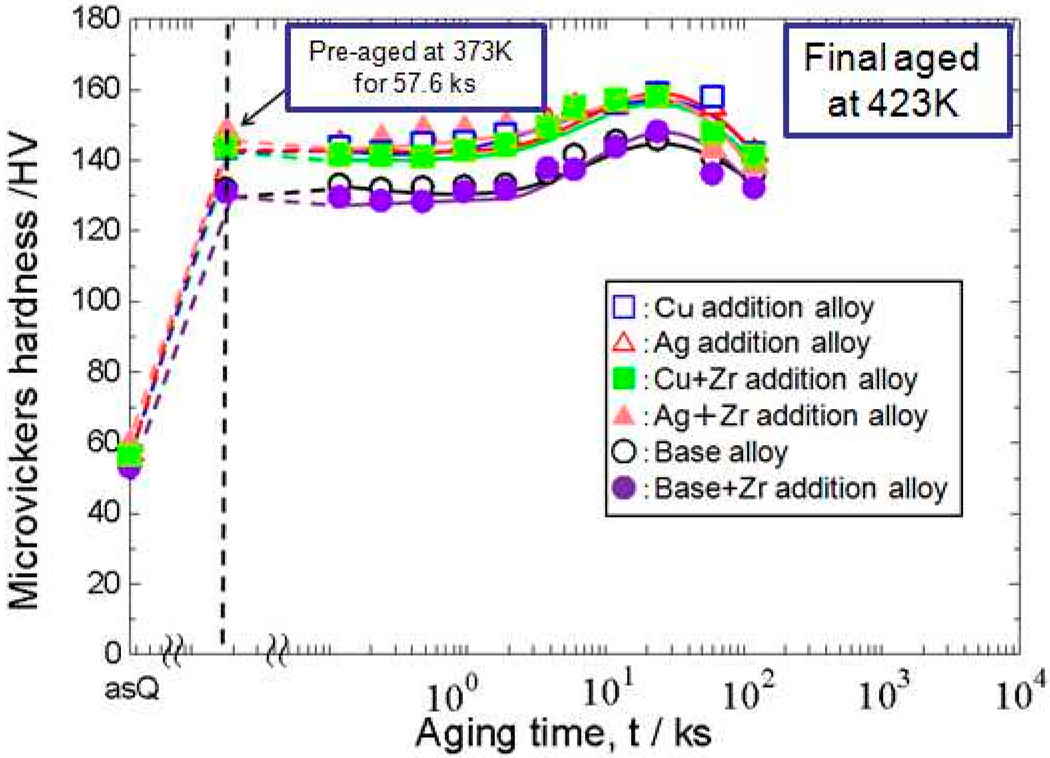

Fig. 1: Age-hardening curves of all alloys final aged at 423K.

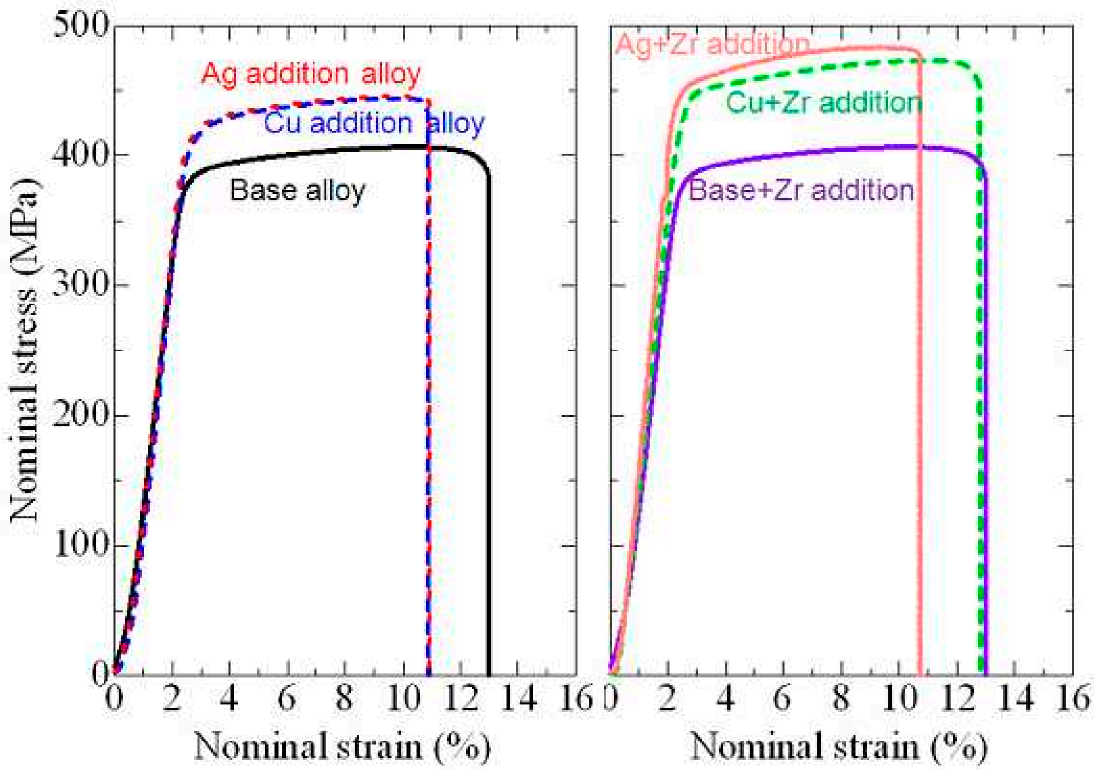

Fig. 2: Stress-strain curves of all of peak-aged alloys.

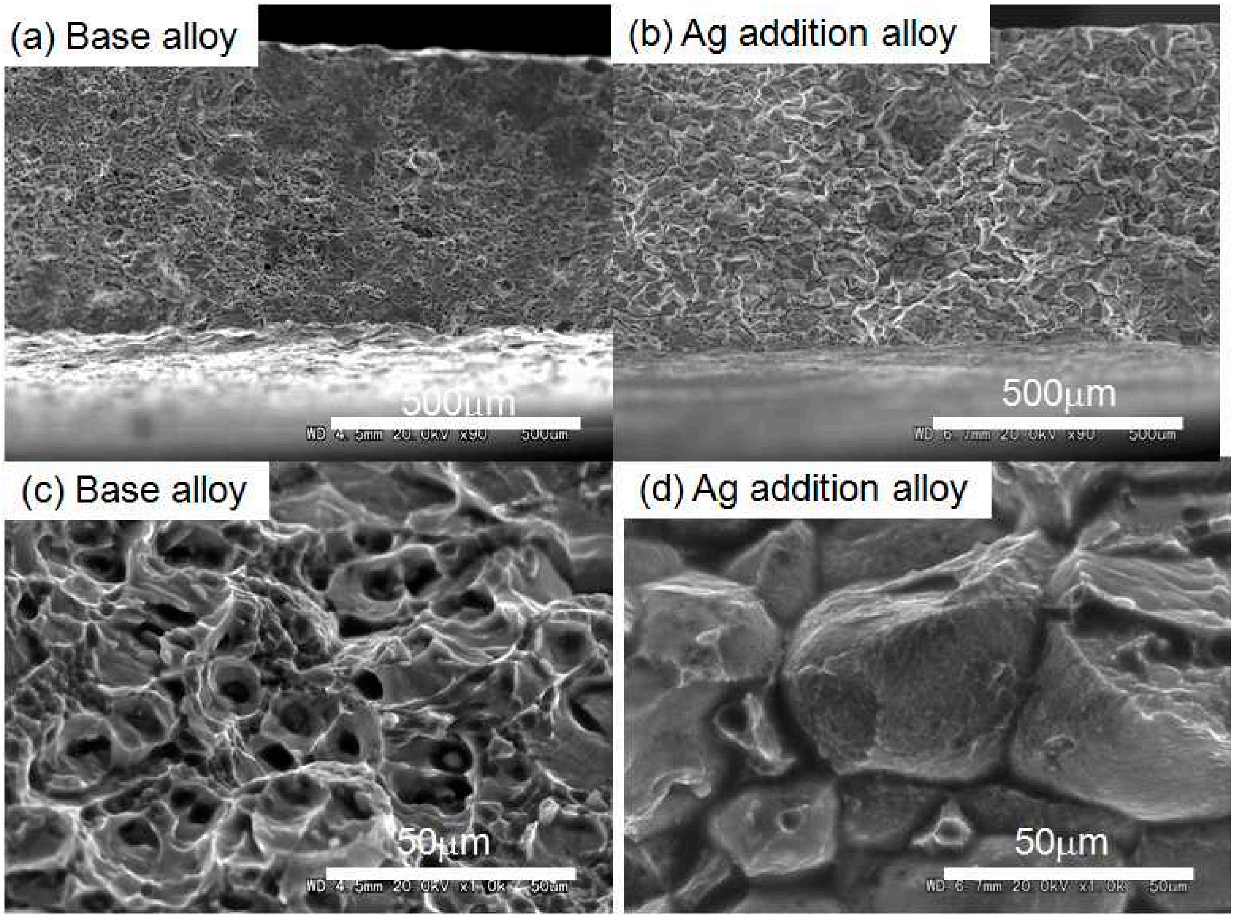

Fig. 3: SEM fractography obtained for peak-aged samples.
(a),(c) base and (b),(d) Ag-addition alloys.

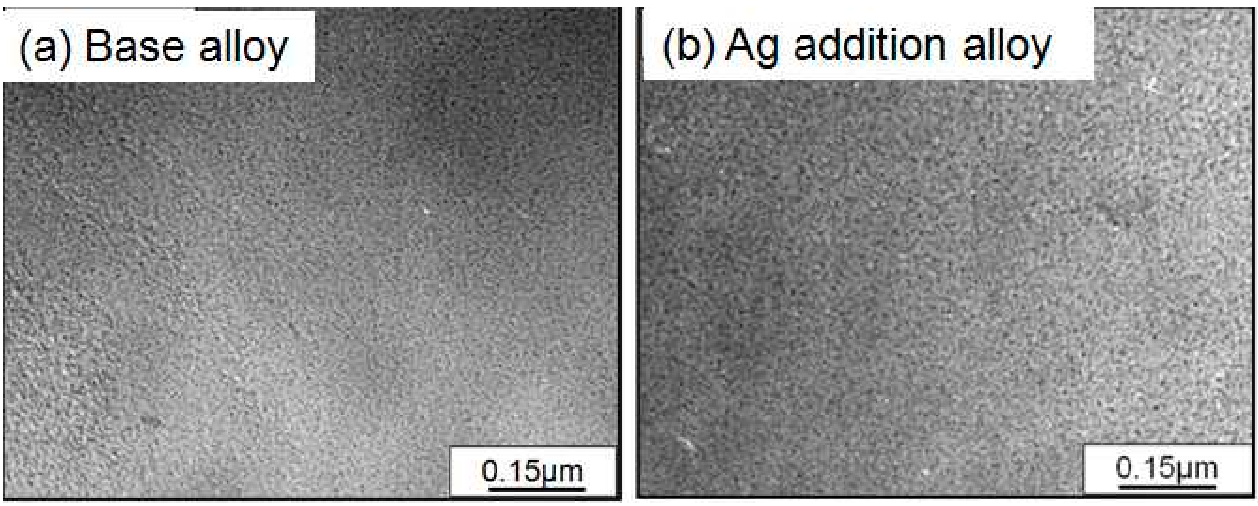

Fig. 4: TEM bright-field images obtained for peak-aged samples.
(a) base and (b) Ag-addition alloys.