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Effect of Transition Metals on Aging Behavior of Al-Mg-Si Alloys

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The influence of addition of the-small amount of transition metals to Al-Mg-Si alloy had reported by many researchers. It was known that some transition metals improved the mechanical property of Al-Mg-Si alloy. For example, the addition of copper increased the peak hardness of Al-1.0mass%Mg_2Si alloy. In this work, several transition metals (P, Q and R) were selected and added to Al-1.0mass%Mg_2Si alloy. One element, two elements and three elements were added to Al-Mg-Si alloy and their aging behavior, tensile properties and microstructure were investigated. It was found that the Al-Mg-Si alloy including three elements showed the highest peak hardness at higher aging temperature. TEM analysis for samples aged at 573 K has also indicated that the number density of precipitates in the Al-Mg-Si alloy including three elements was higher than other alloys.

Keywords: *Al-Mg-Si, noble metal, age-hardening .*

1. Introduction

The Al-Mg-Si alloy is the age hardening aluminum alloy after heat treatment. The addition of the transition element has been reported as a method to raise the strength of these alloys. The effect of Ag- or Cu- addition on the properties of Al-Mg-Si alloys has been investigated before. It was reported that the maximum hardness in this alloys was increased, the aging time to the maximum hardness was decreased, and the elongation in tensile tests was increased both for Ag- and Cu- added Al-Mg-Si alloys. We also reported the effect of Ag or Cu- addition on the improvement of the microstructure, such as the change of the precipitate sequence or crystal structure, and the enhancement of the number density[1]. The precipitate observed in the Ag-added Al-1.0mass%Mg_2Si alloy was similar to the quaternary AlMgSiCu (Q') phase, which precipitated dominantly in the Cu-added alloy[2]. The effect of both Ag and Cu addition on the properties of Al-Mg-Si alloys, however, has not been investigated in detail. The aim of this work is to study the noble metal Cu, Ag, Au on the aging behavie of Al-1.0mass%Mg_2Si alloy.

2. Experimental

The alloy of Al-1.0mass%Mg_2Si (base alloy) and the base alloy with noble metal Cu, Ag, Au addition were obtained by the laboratory casting. The chemical compositions of the alloys are shown in Table 1. Amount of Au was less than that of Cu or Ag content.The specimens were solution heat treated at 848K for 3.6ks in an air furnace, quenched in chilled water, followed by an aging treatment at 423, 473, 523 and 573K for different periods. Vickers hardness was measured using AKASHI MVK-EII hardness tester (load: 0.98N, holding time: 15s). The specimens for TEM observations were prepared by electrolytic polishing. The microstructure was observed using TOPCON EM-002B operated at 120kV and JEOL-4010T operated at 400kV.

3. Results and discussions

Figure 1 shows the age hardening curves obtained for alloys aged at 423K. The hardness of the alloy with single-addition of noble metal was higher than the base alloy. Among three alloys with single-addition of noble metal, the maximum hardness is the highest for A alloy, the age-hardening rate of B alloy is the highest. On the other hand, the alloy with addition of Cu+Ag has the similar maximum hardness with A alloy, and the similar increase speed of the hardness in early aging period with B alloy,which is considered as the effect of Ag addition. The alloys with the addition of Cu+Ag+Au, F alloy and G alloy, have the similar maximum hardness with A alloy.
Ramarkable difference of hardness for alloys were appeared samples aged at 573K. Figure 2 shows the age hardening curves of alloys aged at 573K. The hardness of the alloy with addition of Cu+Ag increased at this temperature rather than the base alloy.The maximum hardness of all alloys appeard around 0.12~0.48ks. And the alloys of F and G have the highest maximum hardness, C alloy has the similar maximum hardness with A alloy, even though the amount of noble metal in C alloy is much smaller than in A alloy.
Figure 3 shows TEM bright-field images obtained for E and G alloys peak aged at 573K. The in cident beam direction is parallel to the [100]Al direction.There are only rod-shaped precipitates along to <100>Al direction. And the number density of precipitates in G alloy (Fig.3(b)) are more than that in E alloy (Fig.3(a)).
Figure 4 shows the HRTEM image of the G alloy aged at 573K for 0.12ks. This is the cross section of the rod-shape precipitates. The hexagonal network of the bright dots in this precipitate was observed with the spacing about 0.69nm, and the <1120> direction of the precipitate and <100>Al direction of the matrix makes an angle of 15 degrees which is similar to that of β’phase in the base alloy.

4. Conclusions

- The maximum hardness of A alloy was the highest, and the age-hardening rate of B alloy was increase of the hardness in early aging the fastest among all alloys.
- C alloy showed the similar maximum hardness at 573K to A alloy, even though the amount of noble metal in C alloy is much smaller than that in A alloy.
- The number density of precipitates in G alloy are more than that in E alloy at 573K.
- The hexagonal network of the bright dots in the β’–phase was observed and its spacing of bright dots was about 0.69nm.

5. References

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Table 1 Chemical composition

	Mg	Si	Cu	Ag	Au	Al
base alloy	0.630	0.370				bal.
A alloy	0.612	0.371	○			bal.
B alloy	0.597	0.361		○		bal.
C alloy	0.613	0.36			○	bal.
D alloy (Cu>Ag)	0.588	0.359	○	○		bal.
E alloy (Ag>Cu)	0.662	0.345	○	○		bal.
F alloy (D alloy+Au)	0.638	0.395	○	○	○	bal.
G alloy (E alloy+Au)	0.648	0.393	○	○	○	bal.

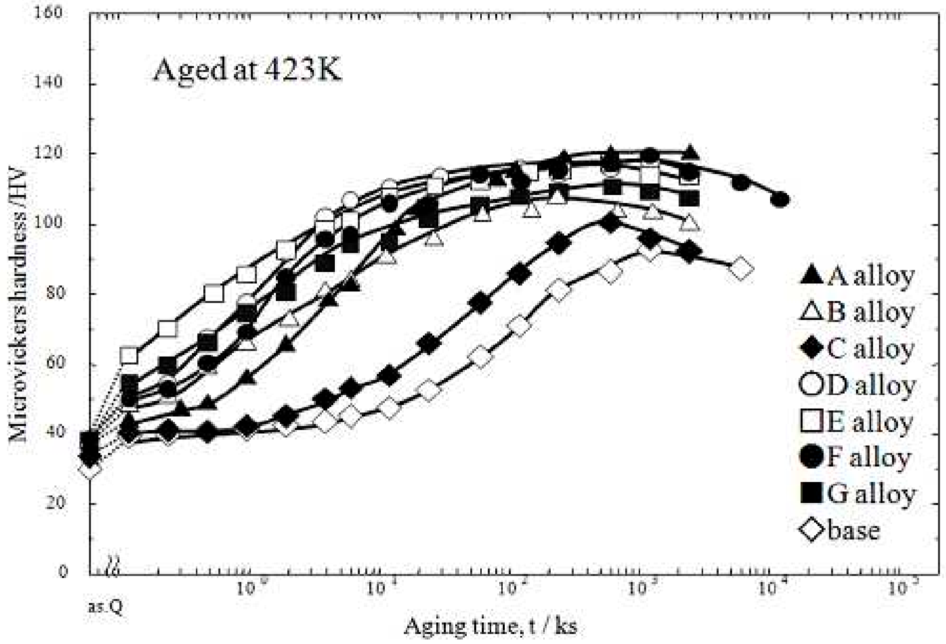

Fig. 1: Age-hardening curves of alloys aged at 423K

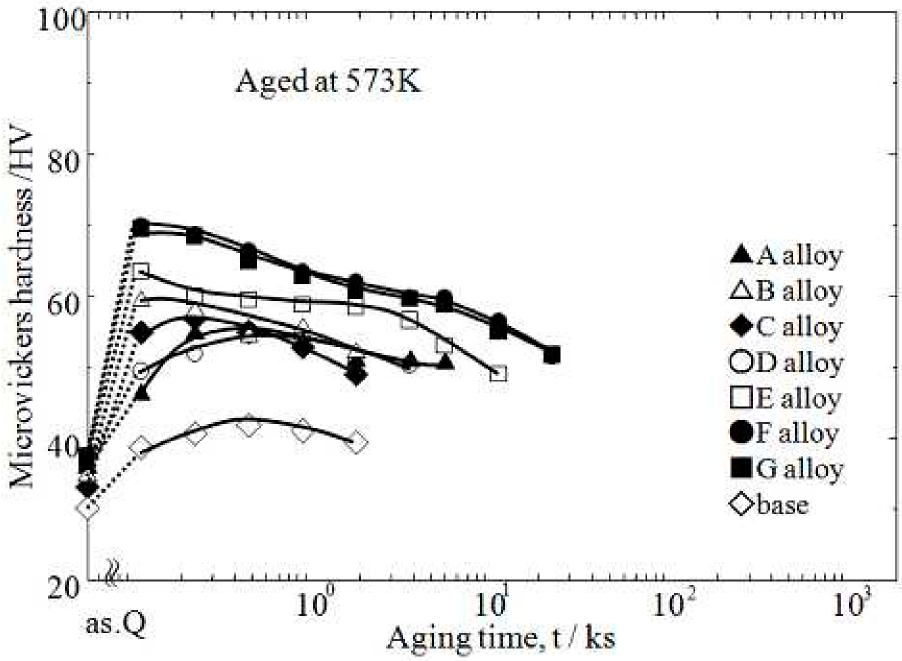

Fig. 2: Age-hardening curves of aged at 573K

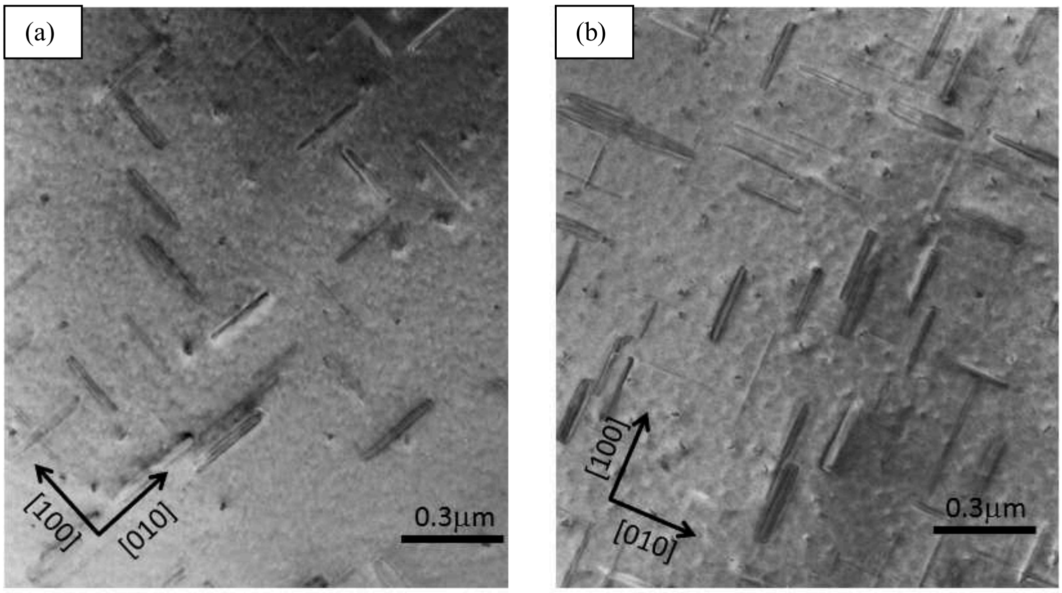

Fig. 3:TEM bright-field of (a) E alloy, (b) G alloy in aged at 573K

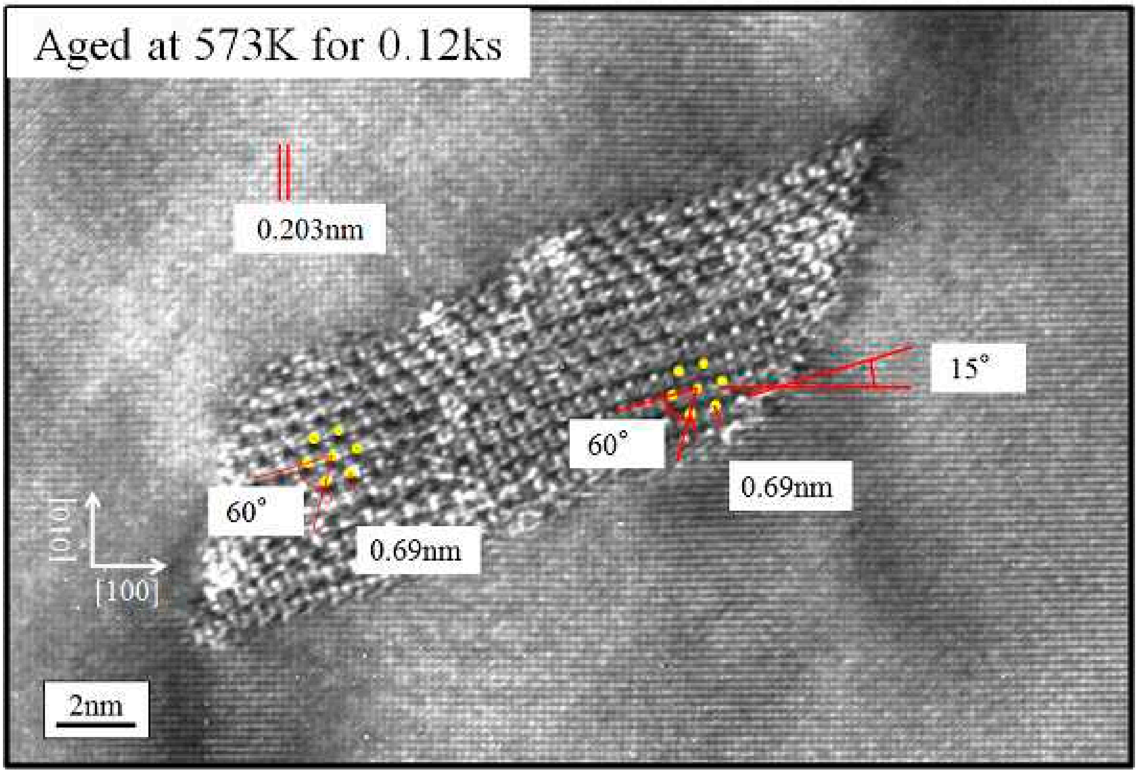

Fig. 4: The HRTEM image of the G alloy in aged at 573K for 0.12ks