

EFFECTS OF SOLUTE Mg CONCENTRATION ON MECHANICAL PROPERTIES AND DISLOCATION CHARACTERISTICS OF Al-Mg ALLOY

*Yuki Koshino^{1,2}, Yasuhiro Aruga², Takuya Maeda¹, and Kenji Kaneko¹

¹*Kyushu University
Fukuoka, Fukuoka, Japan*

(*Corresponding author: koshino.yuki@kobelco.com)

²*Materials Research Laboratory, Kobe Steel, Ltd.
Kobe, Hyogo, Japan*

ABSTRACT

In general, there is a strong correlation between dislocation characteristics and mechanical properties of aluminum alloys. In this study, dislocation characteristics of tensile deformed Al-Mg alloys were examined by transmission electron microscopy. An Increase in the solute concentration, ranging between 0.3 and 1.1%, Mg leads to increase in strength and decrease in uniform elongation. The accumulation of dislocations during the tensile deformation is observed in lower strain as the concentration of solute Mg in the alloy is higher. It is believed that the solute Mg in Al-Mg alloy promotes the accumulation of dislocation during the tensile deformation resulting in the decrease in elongation.

KEYWORDS

Al-Mg alloy, Dislocation characteristics, Tensile deformation, Transmission electron microscope

INTRODUCTION

The influences of the amount of Mg concentration on the tensile properties of Al-Mg alloys has been investigated by many researchers. It has been understood that the tensile ductility of Al-Mg alloy is higher for the Al-Mg alloys with higher Mg concentration beyond 2 mass% (Mukai, Higashi, Hirano & Tanimura, 1993). Uchida and Yoshida (1995) reported the formation of microbands during the tensile deformation due to the localization of dislocations, and the amount of microbands were reduced when the Mg concentration of the Al-Mg alloy was increased from 3 to 9 mass%. Their study suggested that the dynamic recovery of dislocation was retarded due to the increase of the Mg concentration during the tensile deformation, which resulted the increase in ductility. On the other hand, in the case of Al-Mg alloys with the Mg concentration less than 3 mass%, the reason why the ductility of Al-Mg alloys decreases with increasing Mg concentration has not been sufficiently investigated. In general, the Mg concentration used for automotive usage is less than 1 mass%, in the case of Al-Mg-Si alloys (Aoki, 2013). Therefore, to clarify the roles of Mg in the low concentration range on ductility of aluminum alloys and to elucidate its mechanism contribute to alloy design of Al-Mg-Si alloys having good formability.

In this study, the tensile properties and dislocation characteristics during the tensile deformation of Al-Mg alloys with low Mg concentration (1.5 mass% or less) were compared.

EXPERIMENTAL PROCEDURE

Cold-rolled sheets of Al-Mg alloys with the chemical compositions, shown in Table 1, are examined. Tensile specimens (JIS Z2241 Type 13B) were solution treated at 723 K for 1.8 ks and quenched into water. Mechanical properties of the alloys were investigated by the tensile test at room temperature by AG-50kNIS (SHIMADZU, Japan) at an initial strain rate of 0.1/min. Deformed samples, with 2, 5, 10 and 15% of elongations, were thinned by electropolishing for TEM observation by JEM-ARM200F (JEOL, Japan) operated at 200 kV. The average grain sizes of the alloys observed with the optical microscope are 48–52 μm , which indicates that there is no significant difference in the grain sizes of the alloys.

Table 1. Chemical composition of alloys (mass%).

Alloys	Mg	Al
3M	0.30	Bal.
6M	0.54	Bal.
10M	1.10	Bal.
16M	1.50	Bal.

RESULTS AND DISCUSSION

Figure 1 shows the effects of Mg content on both (a) strength and (b) uniform elongation during the tensile tests. In the concentration range of Mg from 0.3 to 1.1%, the higher solute concentrations of Mg lead to the higher strength and lower uniform elongation. Figure 2 shows n-value variation during the tensile deformation for different Mg concentrations, 3M, 6M and 10M alloys. It was found that the alloys with higher Mg concentration resulted in the higher maximum n-value, as 0.35 for 3M, 0.37 for 6M and 0.39 for 10M. It was also found that the alloys with higher Mg concentration show larger reduction of n-value from maximum n-value to the n-value at the true strain of 15%, 0.10 for 3M, 0.12 for 6M and 0.16 for 10M at the late stage of deformation. These results suggested that the work hardening at the initial stage and dynamic recovery at the late stage progresses faster with the higher concentration of Mg in the alloy.

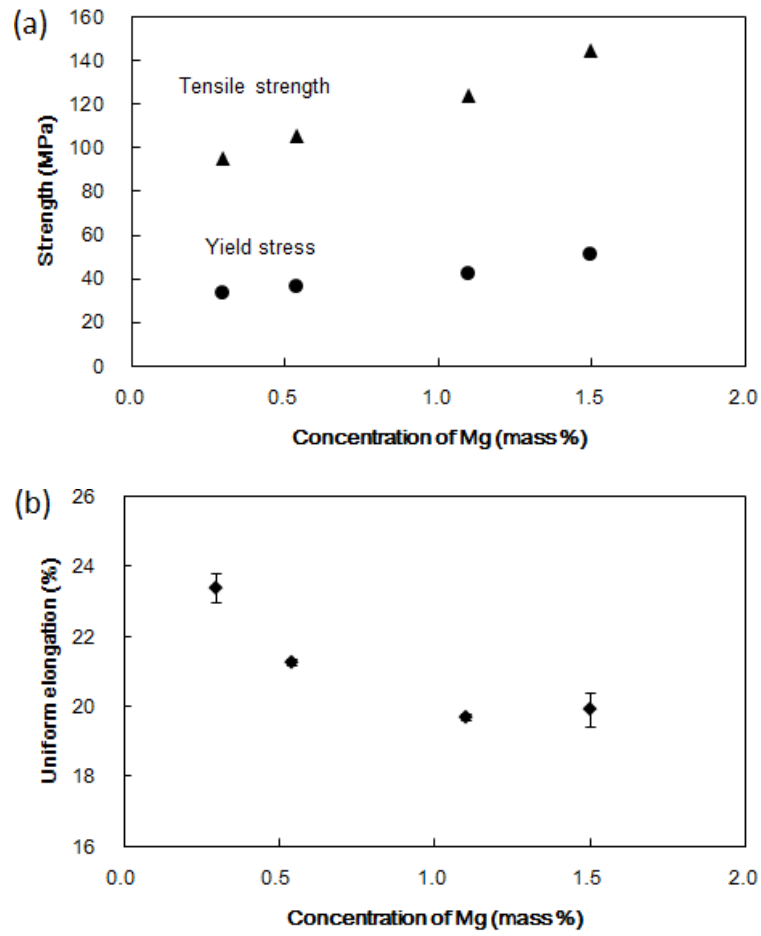


Figure 1. Effects of Mg content on (a) strength and (b) uniform elongation in tensile tests.

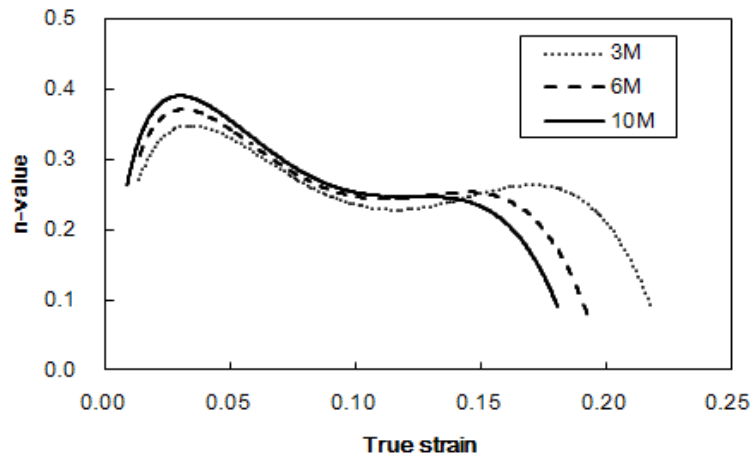


Figure 2. n-value variation during the tensile deformation in the Al-Mg alloys.

TEM bright field images of the tensile deformed 6M and 10M alloys are shown in Figure 3. Accumulation of dislocations, indicated by white arrows in Figure 3, is observed in the 15% deformed 6M alloy and 10% deformed 10M alloy. This indicates that higher Mg in solute accelerates the accumulation of

dislocations during the deformation. It is believed that the dislocations are more likely to be fixed by the Mg atoms in solute resulting in cross slip and intersection of dislocations, as the Mg concentration in the alloy becomes higher. As a result, in the concentration range of Mg 1.1% or less, work hardening rapidly undergoes from the initial stage and the dynamic recovery starts at the early stage during the tensile deformation in the alloy with a high Mg concentration, resulting in the high strength and low uniform elongation.

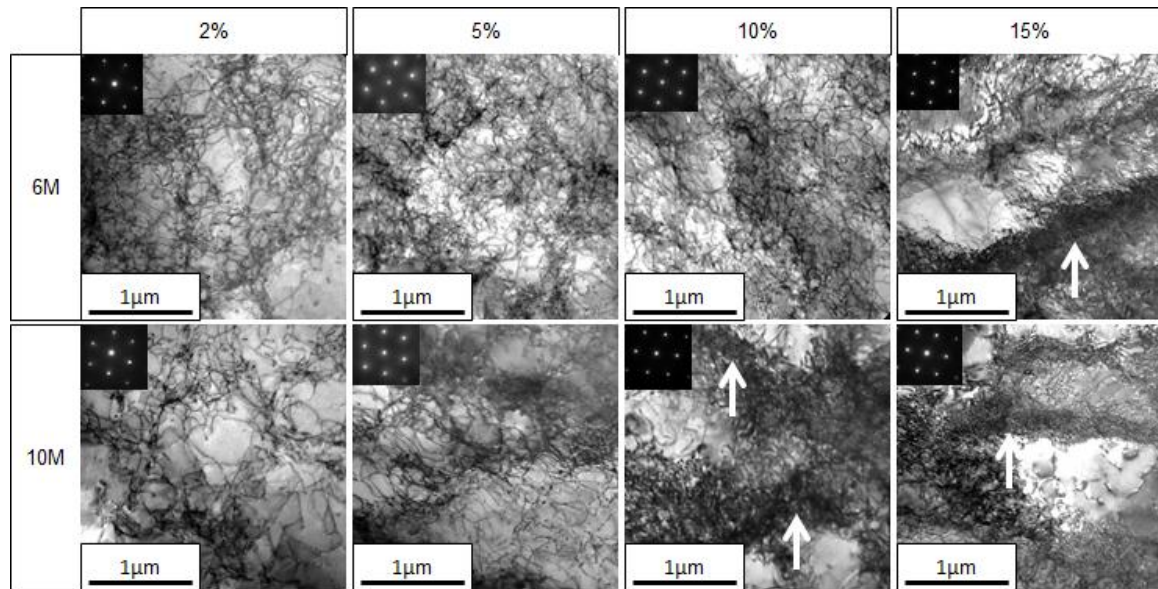


Figure 3. TEM bright field images of the 2, 5, 10 and 15% strained Al-Mg alloys.

CONCLUSIONS

The strength of Al-Mg alloy was increased with the increase of Mg content, while the uniform elongation was decreased, at alloys with Mg concentration less than 1.1 mass%. It is suggested that the increase of Mg concentration accelerates the progress of work hardening and dynamic recovery during tensile deformation caused by pinning of dislocations by Mg atoms in solute.

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