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EFFECTS OF SODIUM AND ZIRCONIUM ON INTERGRANULAR EMBRITTLEMENT OF Al-5 %Mg ALLOYS

*S. Kumeuchi[1], K. Horikawa[2], K. Tanigaki[2], and H. Kobayashi[2]

[1]*Graduate student, Osaka University, Toyonaka, Osaka, Japan*
*(*sairi.kumeuchi@impact.me.es.osaka-u.ac.jp)*

[2]*Osaka University, Toyonaka, Osaka, Japan*

In this study, the effects of sodium or zirconium on ductility and intergranular fracture of Al-5 %Mg alloys were investigated. Strain-stress curves were obtained by tensile test, where the strain rate was 8.3×10^{-4} s^{-1} at room temperature or 573 K. Reduction of area was used to evaluate the ductility. Al-5 %Mg alloys contained 0.1 % zirconium showed higher ductility. In the previous studies showing the effects of 2 ppm sodium, lower ductility with intergranular fracture was observed at 573 K. However, the present results showed that 165 ppm of sodium did not cause intergranular fracture at 573 K. In this paper, it was found that more than 20 ppm of sodium caused the decrease of ductility at room temperature.

INTRODUCTION

It is known that Al-Mg alloys show good workability and weldability. Meanwhile, coarse grained Al-5 mass%Mg alloys ("mass%" is hereafter "%") show lower ductility (embrittlement) at temperatures around 573 K (Horikawa et al., 1998). It is believed that the embrittlement is caused by grain boundary (GB) segregation by impurity sodium and GB sliding. Recently, Al-5 %Mg alloys containing 200 mass-ppm (hereafter "ppm") of sodium showed low ductility even at room temperature resulting from intergranular fracture (Horikawa et al., 2017). First-principle calculation also predicted that sodium caused GB embrittlement while that zirconium strengthened GBs of aluminum (Higashi et al., 2010). In this study, effects of high amount of sodium more than 20 ppm, and 0.1 % of zirconium on intergranular embrittlement of Al-5%Mg alloys were investigated fractured at room temperature and 573 K.

Experimental

Using aluminum of 99.999 % purity, magnesium of 99.9% purity, sodium of 99% purity and Al-4.93 %Zr alloys, Al-5 %Mg based alloys were melted and cast, using a graphite crucible. All processes were done under argon atmosphere. The chemical composition is shown in Table 1. The ingots were homogenized at 703 K for 18 h in argon. After that, round tensile test specimens having a dimension of ϕ 4 mm$\times$10 mm were made by machining. Tensile tests were carried out at a strain rate of 8.3×10^{-4} s^{-1}, at temperatures raging from room temperature to 573 K. Fracture surfaces were observed by SEM/EDS.

Table 1. Chemical composition (mass %)

Alloy	Mg	Na	Zr	Al
0.1Na	5.1	<0.0001	-	Bal.
23Na	4.9	0.0023	-	Bal.
200Na	4.95	0.0165	-	Bal.
0.1Zr	4.3	<0.0001	0.09	Bal.
0.1Zr20Na	5.1	0.00205	0.11	Bal.
0.1Zr100Na	5.0	0.011	0.10	Bal.

RESULTS

Figure 1 shows the effect of sodium on ductility of Al-5 %Mg alloys without (a) and with zirconium (b). Both alloys containing high amount of sodium showed lower ductility at room temperature and 573 K. In both alloys, the detrimental effect of sodium on ductility was high when tested at room temperature rather than tested at 573 K. The Al-5 %Mg alloys containing 0.1 %Zr showed better ductility. The fracture surfaces partly showed intergranular fracture in the 0.1Zr100Na alloy (Figure 2). Meanwhile, in the 200Na alloy without zirconium, intergranular fracture was only observed at room temperature.

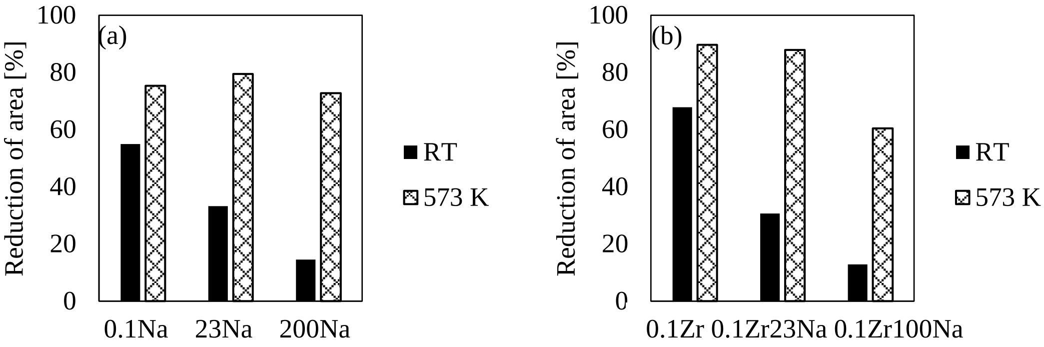

Figure 1. Reduction of area (a) Al-5%Mg-Na alloys, (b) Al-5%Mg-0.1%Zr-Na alloys

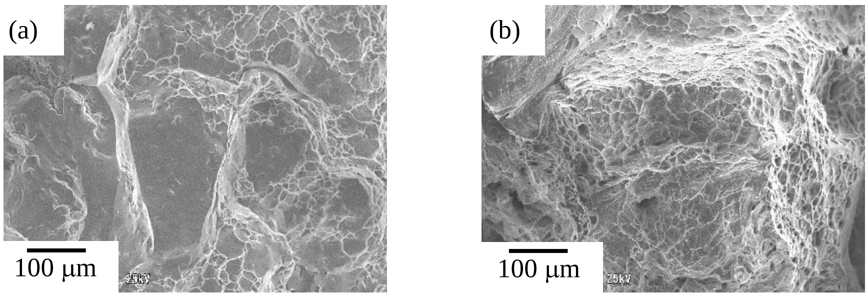

Figure 2. Fracture surfaces of 0.1Zr100Na alloys of (a) RT, (b) 573 K

CONCLUSIONS

The ductility of Al-5 %Mg alloys decreased with increasing sodium content (20–165 ppm) at room temperature. Fracture surfaces of the alloys containing more than 100 ppm sodium showed intergranular fracture at room temperature. However, the alloys showed high ductility when tested at 573 K regardless of the amount of sodium. It is obvious that the addition of 0.1% zirconium improved the ductility. Intergranular fracture was partly observed in the 0.1Zr100Na alloys at 573 K.

REFERENCES

Higashi, K. (2010). New innovations in alchemy dreamed by the first principle-the first volume. *The Japan Institute of Light Metals*, 60(8), 411–418.

Horikawa, K., Kuramoto,S., & Kanno, M. (1998). Sources of a trace amount of sodium, and its effect on hot ductility of an Al-5 mass%Mg alloy. *The Japan Institute of Light Metals*, 48(8), 371–374.

Horikawa, K., Kitahata, S., & Kobayashi, H. (2017). *Program of the 132nd Conference of Japan Institute of Light Metals*, 91–92.

KEYWORDS

Al-5%Mg alloy, Intergranular fracture, Sodium, Zirconium, Embrittlement