Preparation, Microstructure and Mechanical Properties of AlN / Mg-Al-RE Composites

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Abstract： In the process of high temperature service, the Al11RE3 phase in Mg-Al-RE alloy will soften and even decomposition into Al2RE phase, while the Mg17Al12 phase is easy to grow, coarsen, and dissolve when the service temperature is higher than 150 ℃ , which is not conducive to the service temperature and high temperature performance improvement of Mg-Al-RE alloy. The high temperature performance of Mg-Al-RE alloy can be improved by adding ceramic particles with high temperature stability. In this paper, the in-situ AlN/Mg master alloy were prepared by Mg-Al-Mg3N2 reaction system. The effects of nano-AlN particles on the microstructure and mechanical properties of Mg-Al-RE composites were studied.

Keywords: in-situ AlN particles, Mg-Al-RE composites, mechanical properties

1 Introduction

Magnesium (Mg) alloys are the most promising lightweight materials for engineering applications, mainly because of their low density. However, the potential engineering applications of Mg alloys are limited due to their relatively low absolute strength. Adding ceramic particles to Mg alloys to obtain Mg matrix composites is an effective way to further improve its high temperature mechanical properties. It is found that AlN particle has excellent physical properties such as high melting point (2200 °C), high elastic modulus (310 GPa), low thermal expansion coefficient (4.4×10^{-6}/°C), and low density (3.2 g/cm^3), which can be used as a reinforcing phase to improve the properties of Mg alloys. In this paper, the in-situ AlN/Mg master alloy was prepared and the effects of nano-AlN particles on the microstructure and mechanical properties of Mg-Al-RE composites were discussed and analyzed.

2 Experimental procedure

In this study, 40wt.% AlN/Mg master alloy was prepared by Mg-Al-Mg_3N_2 reaction system. The Mg-4Al-4La-0.3Mn alloy was used as the matrix alloy. The 0.5-3.0wt. % AlN/AE44 composites were prepared by cast method. The microstructure was observed by OM (Zeiss Axio Vert.A1), SEM (JEOL JSM-7800F), and TEM. A tensile testing machine (CMT6305-300KN) was used to test the mechanical properties of composites at room temperature at a strain rate of 1×10^{-3} s^{-1}.

3 Result and discussion

Microstructure of in-situ AlN master alloy

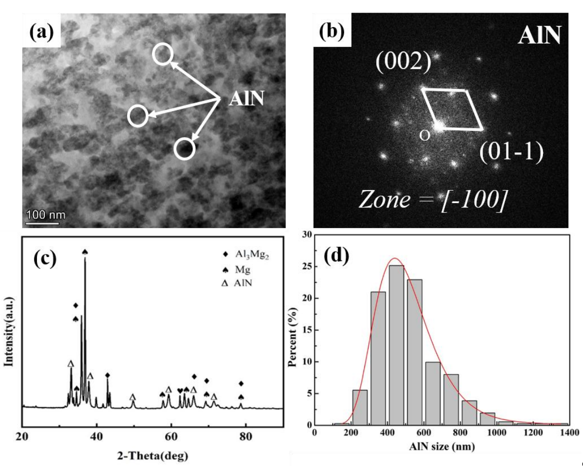

Figure 1. In-situ AlN/Mg master alloy:(a) TEM image, (b) SAED image, (c) XRD results; (d) size statistics diagram of AlN particles.

Fig. 1(a) shows the TEM image of in-situ AlN/Mg master alloy. It is found that AlN particles are uniformly distributed in the Mg matrix, with good dispersion and no obvious agglomeration. Fig. 1(b) is the selected area electron diffraction pattern (SAED) pattern of AlN particles. Combined with the XRD results (Fig. 1(c)), the in-situ AlN/Mg master alloy is mainly composed of AlN, Al_3Mg_2, and α-Mg phases. As shown in Fig. 1(d), the size of AlN particles generated by in-situ reaction varies from 100 to 1200 nm, and the size is mainly distributed in the range of 400-600 nm.

Microstructure of AlN/AE44 composites

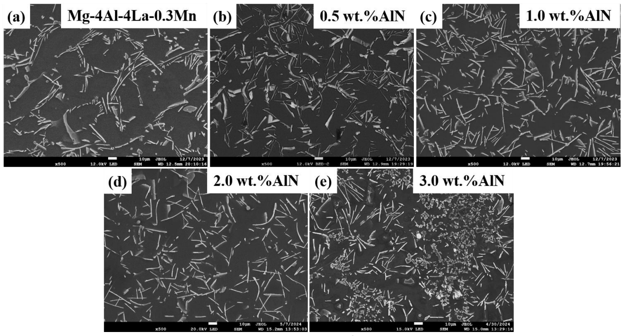

Figure 2. Microstructure images of AlN/AE44 composites with different AlN content

The in-situ nano-AlN particles were added into the AE44 alloy to obtain AlN/AE44 composites. Fig. 2 shows the microstructure of cast AE44 alloy and AlN/AE44 composites. As shown in Fig. 2(a), the microstructure of AE44 alloy is mainly composed of dendritic grains. The morphology of the second phase is mainly needle-like and rod-like, and there are also a small number of bulk shaped phases. As indicated by Figs. 2(b-e), compared with the matrix alloy, the addition of nano-AlN particles significantly improves the distribution of needle-like $Al_{11}La_3$ phase and bulk Al_2La phase. The size of the second phases was firstly reduced and then increased with increasing AlN content. The 2.0 wt.% AlN/AE44 composite shows the most uniform distribution of the second phases.

Mechanical properties of AlN/AE44 composites

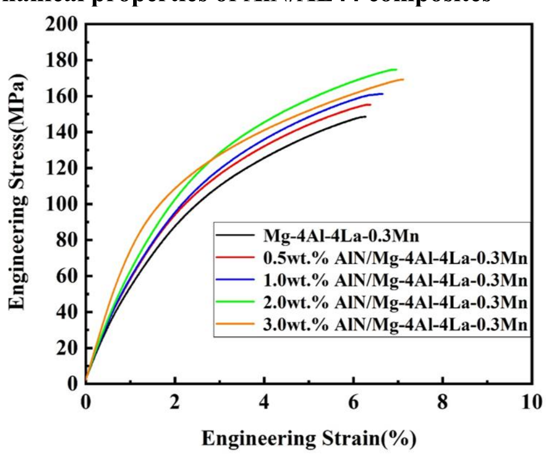

Figure 3. Room temperature tensile engineering stress-strain curves of AlN/AE44 composites.

Fig.3 shows the tensile engineering stress-strain curves of AlN/AE44 composites, and the corresponding mechanical properties are shown in Table 1. The addition of nano-AlN particles simutanously increased the yield strength, tensile strength, and ductility of AE44 matrix alloy. The 2.0 wt. % AlN/AE44 composite shows the best comprehensive mehcanical properties with the yield strength, tensile strength, and ductility of 96 Mpa, 175 MPa, and 7.0%, respectively.

Table 1. Tensile properties of AlN/AE44 composites.

Composites	$\sigma_{0.2}$/MPa	σ_{UTS}/MPa	ε/%
AE44	70	148	6.3
0.5 wt.% AlN	82	155	6.4
1.0 wt.% AlN	90	161	6.7
2.0 wt.% AlN	96	175	7.0
3.0 wt.% AlN	99	169	7.1

4 Conclusion

The addition of AlN particles significantly reduces the sizes of the second phases, and improves the distribution of the second phases. The nano-AlN/AE44 composites show improved comprehensive mechanical properties compared to matrix alloy. The increased mechanical properties of the composites are attributed to the strengthening effects of nano-AlN particles and finer sized AlRE phases.

5 Acknowledgments

This work is financially supported by the National Key Research and Development Program of China (Grant No. 2021YFB3701000), the National Natural Science Foundation of China (Grant Nos. 52201106 and U21A2048), and the Natural Science Foundation of Chongqing China (Grant No. CSTB2022NSCQ-MSX1289).

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