Effect of Gd on Interfacial Microstructure and Mechanical Properties of Mg/Al Bimetallic Composites by Compound Casting

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Abstract: To strengthen the bonding properties of Mg/Al bimetallic composites, rare earth Gd was added to the Mg/Al bimetallic composites manufactured by a novel compound casting, and the interfacial microstructure, mechanical properties and strengthening mechanism of the Mg/Al bimetallic composites with Gd addition were studied. Without Gd addition, there was a thin oxide film consisting of an alumina phase in the Mg/Al bimetallic interface, which hindered the diffusion of Mg2Si phase. After adding the Gd, the oxide film in the interface was broken and dissolved, significantly increasing the diffusion distance of the Mg2Si phase. The Al2Gd and Al8Mn4Gd precipitated in the interface. The primary Al12Mg17 phase and eutectic structure in the interface were greatly refined due to the heterogeneous nucleation and the inhibition of growth caused by the Mg2Si phase and Gd-rich precipitates. The interface was strengthened under the comprehensive effect of the fine grain strengthening and precipitation strengthening of the Mg2Si and Gd-rich precipitates.

Keywords: Gd; Mg/Al bimetallic composites; Compound casting; Interfacial microstructure; Mechanical properties; Strengthening mechanism

1 Introduction

Rare earth elements have strong metallicity, so they can easily combine with other metal elements to form RE precipitates. These precipitates have the functions of precipitation strengthening and can serve as the heterogeneous nucleation substrate to refine the microstructure of the metals. Besides, the rare earth elements can react with oxygen, sulfur, and other impurities in the molten metal to purify the melt and improve the properties of the materials. So, the rare earth elements are often used to modify various metal materials.

Heavy rare earth elements, such as Gd, have a high melting point and are often used to strengthen the mechanical properties and high-temperature resistance of the magnesium alloys. The application and research of the Gd mainly focus on its effect on the microstructure and properties of the single alloy. The investigation of the impact of the Gd on the bimetallic interface has not been reported yet. [1, 2].

2 Experimental procedure

The A356 aluminum alloy (Al-6.81Si-0.44Mg-0.21Fe-0.02Ti wt.%) was selected as the solid insert. AZ91D-xGd (x=0, 0.6) were prepared as the melt to cast around the solid insert. Foam patterns were prepared using expanded polystyrene (EPS) material with a density of 0.012g/cm^3. The schematic illustration of the lost foam compound casting experimental equipment in this work is illustrated in Fig. 1.

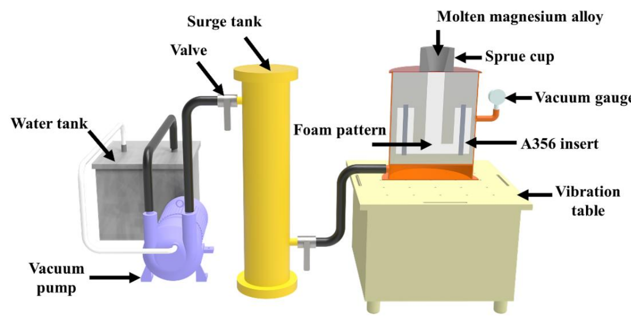

Fig. 1. The schematic diagram of the experiment.

The AZ91D magnesium alloy (Mg-9.08Al-0.62Zn-0.23Mn wt.%) was melted in a resistance furnace under CO_2 and SF_6 mixture gas protection. When the AZ91D melt reached the temperature of 740°C, the Mg-30Gd master alloy was added to the melt. After the Mg-30Gd master alloy was completely melted, the melt was thoroughly stirred. The molten metal was poured when it reached the pouring temperature of 720 °C, and the vacuum value in the sand flask was adjusted to 0.03 MPa. The microstructure and the mechanical properties of the Al/Mg interfaces were investigated.

3 Result and discussion

3.1 Microstructure of the Mg/Al bimetallic composites

Fig. 2 (a) shows the interfacial morphology of the Mg/Al bimetal composite without Gd addition. There are many black precipitate phases in the intermetallic compounds (IMCs) region. Plenty of coarse dendrites that grow perpendicular to the interface can be observed in the Eutectic region. In the E-IMCs region, a thin black boundary is found. Fig. 2(b-d) shows the distributions of O, Si, and Al elements in the Mg/Al bimetallic interface.

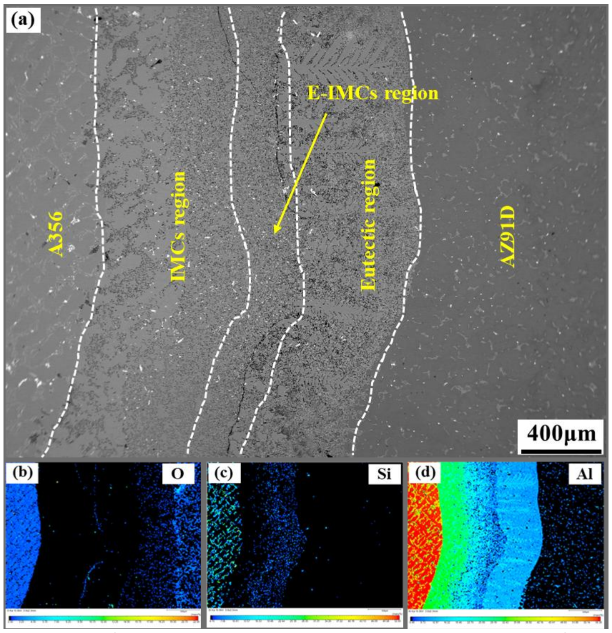

Fig. 2 Interfacial morphology and elements distributions of the Mg/Al bimetallic composite without Gd addition:(a) microstructure of the Mg/Al bimetallic composite; (b) the distribution of the O element; (b) the distribution of the Si element; (d) the distribution of the Al element.

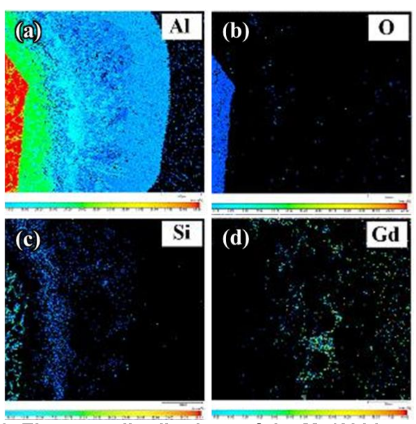

Fig. 3. Elements distributions of the Mg/Al bimetallic composites with Gd.

Fig. 2(b) indicates a region of oxygen enrichment in the middle of the interface. It can be found out that the morphology of that region is similar to the black boundary in the transition zone. The Si element in the interface is mainly concentrated in the range of the IMCs. In addition, a transparent edge is detected in the interface region with the Si element, and the position of this edge is highly coincident with the oxygen element enrichment film in Fig. 2(b). Fig. 2(d) displays that the distribution of the Al element in the IMCs is not uniform. As shown in Fig. 3, the diffusion distance of the Si element significantly increases. The apparent oxygen element enrichment film disappears.

3.2 Mechanical properties

Fig. 4 indicates the shear test results for the Mg/Al bimetallic composites without and with Gd addition. With Gd addition, the shear strength of the Mg/Al bimetallic composites reaches 46 MPa, which is 39% higher than that of without Gd.

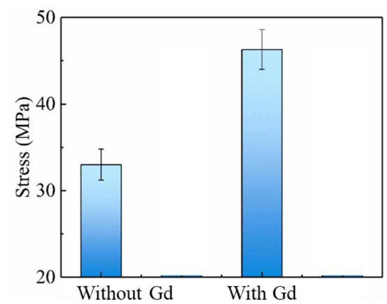

Fig. 4. Shear test results of the Mg/Al bimetallic composites without and with Gd.

Conclusion

1.Under the condition of no Gd, there was a thin oxide film in the Mg/Al bimetallic interface. The alumina phase was confirmed in the oxide film. With Gd, the oxide film was removed, and the primary $Al_{12}Mg_{17}$ in the E-IMCs region and the eutectic groups in the Eutectic region were refined.

2.The average shear strength of the Mg/Al bimetallic composites with Gd reached 46 MPa, which was 39% higher than that of the group without Gd addition

Acknowledgments

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References

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