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Research on YAl_2 intermetallics particles reinforced Mg–14Li–3Al matrix composites

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ABSTRACT

A novel Mg–14Li–3Al (LA143) matrix composite reinforced with YAl_2 intermetallics particles was developed by stir-casting. The microstructure and interface characteristics of the YAl_{2p}/LA143 composite were investigated. The results show that, YAl_2 particles distribute uniformly in the composite, and a good interfacial bonding is obtained with no reaction products at particle/matrix interfaces. YAl_{2p}/LA143 composite exhibits excellent mechanical properties. The tensile strength and yield strength are significantly improved by the addition of YAl_2 particles, while a good ductility property is kept. During tensile deformation, YAl_2 particles may prevent the propagation of crack in microscale. The YAl_2 particles can be compatible with the deformation of the matrix due to their deformation, exhibiting a "soft" restriction to the matrix. Therefore, the strength and toughness of the YAl_{2p}/LA143 composite can be improved by the above effects.

1. Introduction

Mg–Li based alloys, known as the lightest metallic structural materials, have been widely studied both theoretically and experimentally [1–3]. Due to their attractive features of high values of specific strength and specific modulus, excellent anti-shock and electromagnetic shielding properties, Mg–Li based alloys have great potential for use not only in aerospace and military but also in automobiles and electrical appliances [4,5]. However, Mg–Li based alloys have intrinsic problems such as aging stability, low tensile strength and poor corrosion resistance [6,7]. These problems would limit their widespread applications. To improve the strength of Mg–Li based alloys, various elements have been added [7,8]. But, these alloys show strength degradation due to ageing and poor corrosion resistance. The composite strengthening is one of the feasible ways to improve the strength and to prevent the degradation of mechanical properties of Mg–Li based alloys [9]. SiC, Al_2O_3 fibers and Mg_2Si particles [10–12] have been used to reinforce Mg–Li based alloys recently. The results [12] show that the ceramic reinforcements can substantially improve the mechanical properties of Mg–Li based alloys. However, the chemical incompatibility between ceramic reinforcements and Mg–Li alloy matrix remains a critical problem to be solved, which is harmful to the ductility of the composites. Thus, some intermetallic compounds that own relatively high specific strength as well as high specific stiffness and have good chemical compatibility with metals or alloys, have been selected and utilized as the promising reinforcements of metal matrix composites [13–15]. Compared with Mg–Li based alloys, YAl_2 intermetallic compound has high melting temperature (1748 K), high Young's modulus (158 GPa), high hardness (HV = 645) and relatively low coefficient of thermal expansion (CTE = 10×10^{-6} K^{-1}). So it can be supposed that YAl_2 particle reinforcement Mg–Li based composites possess favorable properties.

In this paper, YAl_2 particles were chosen as reinforcement to prepare Mg–14Li–3Al matrix composite, and the microstructure, interface characteristics, mechanical properties and fracture behavior were investigated systematically.

2. Materials and methods

In this study, Mg–14Li–3Al (LA143) alloy was used as matrix alloy, and YAl_2 intermetallics particles (obtained from General Research Institute for Nonferrous Metals) with an average size smaller than 37.5 μm were chosen as reinforcement. Mg–14Li–3Al (LA143) alloy and the 20 vol% YAl_{2p}/LA143 composite were prepared by stir-casting at 650 °C in a resistance furnace under an argon atmosphere. The superheated slurry was stirred at 720 r/min for 30 min.

The microstructures and structures of the composite were characterized by XJP-3C optical microscope (OM), JSM-5800 scanning electron microscope (SEM) and D/MAX-2000 X-ray diffractometer (XRD). Interface characteristics of YAl_{2p}/LA143 composite were carried out using Hitachi H-800 transmission electron microscopy (TEM) and JEM-2100F high-resolution electron microscopy (HREM), operating at 200 kV.

The room-temperature and high-temperature mechanical properties were examined by MTS-880 material testing machine at a strain rate of 0.5 mm/min rate. The subsize flat specimens (12.5 mm in gauge length, 4 mm in width, and 3 mm in

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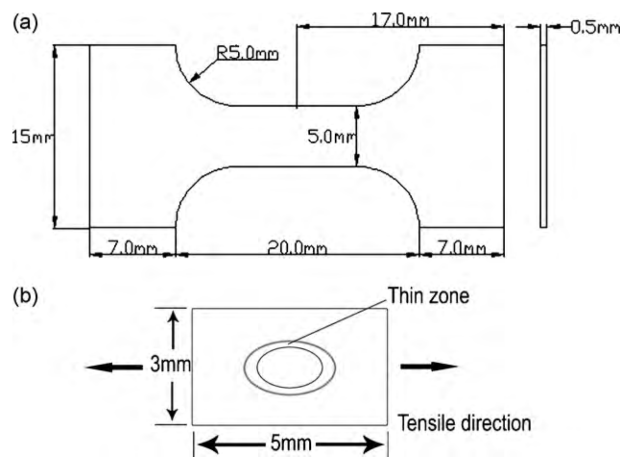

Fig. 1. Configurations of the tensile specimens for SEM/TEM in situ observation. (a) SEM, (b) TEM.

Table 1
The parameters of materials for simulation.

Materials	Elastic modulus (GPa)	Tensile strength (MPa)	Poisson's ratio
Matrix	34.5	120	0.31
Reinforcement	100/300/500	800	0.25

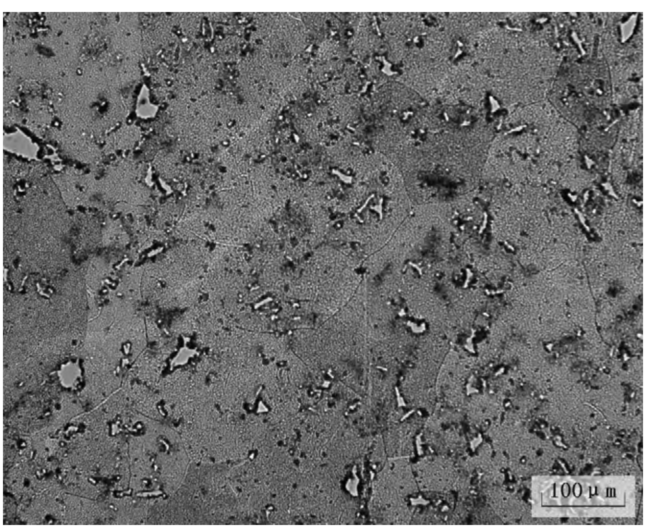

Fig. 2. OM microstructure of the as-cast YAl_{2p}/LA143 composite.

thickness) were machined from the central region of the ingots. An MTS 632.12C-20 extensometer with 25 mm gauge length (+12.5 mm/−2.5 mm range) was used to measure yield strength, tensile strength and elongation.

In situ tensile test of the composite was used to observe fracture and deformation processes by JSM-5800 scanning electron microscope (SEM) and Hitachi H-800 transmission electron microscope (TEM), respectively. The configurations of in situ tensile specimens are shown in Fig. 1. A notch of 0.25 mm in width and 80 μm in root radius was cut perpendicular to the loading direction in the middle of specimen for SEM in situ observation using electrical discharge machining (EDM).

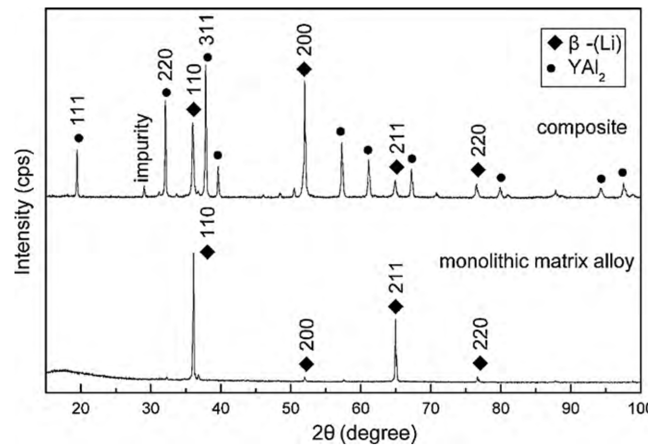

Fig. 3. X-ray diffraction patterns of monolithic matrix alloy and composite.

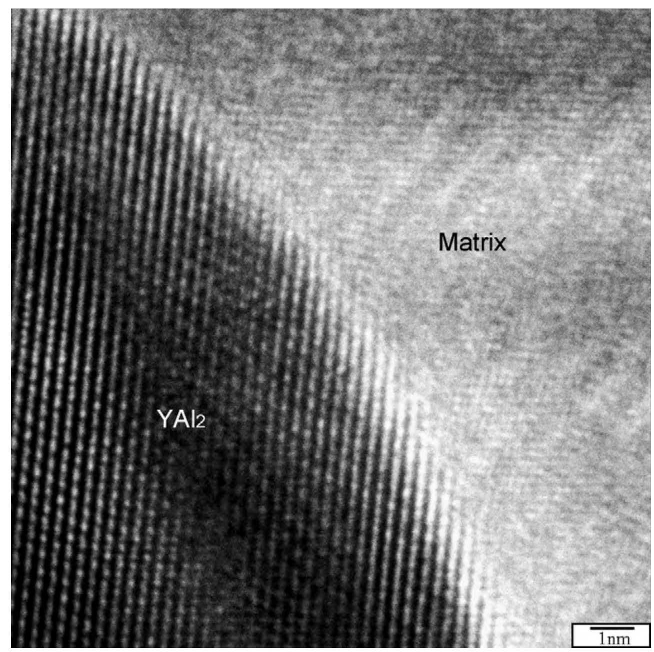

Fig. 4. HREM micrograph of the interface between YAl_2 particle and matrix.

The tensile deformation behavior and features of the composite were simulated by finite element method. The parameters of material for simulation are shown in Table 1.

3. Results and discussion

3.1. Microstructure and interface characteristics

The microstructure of as-cast YAl_{2p}/LA143 composite is shown in Fig. 2. The YAl_2 particles distribute homogenously in the grains and grain boundaries of the matrix, while no obvious particles agglomeration phenomenon is observed. X-ray diffraction patterns (Fig. 3) indicate that the composite consists of β-(Li) phase and YAl_2

Table 2
Tensile properties of the monolithic matrix alloy and composite.

Materials	Temperature	σ_b (MPa)	$\sigma_{0.2}$ (MPa)	ε (%)	E (GPa)	ρ (g/cm^3)
Mg–14Li–3Al (LA143)	20 °C	115	94	26	34.5	1.36
20 vol%YAl_{2p}/LA143	20 °C	225	161	9	73.2	1.52
Mg–14Li–3Al (LA143)	180 °C	37	20	34	–	1.36
20 vol%YAl_{2p}/LA143	180 °C	78	57	18	–	1.52