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ARTICLE

Microstructure, Mechanical Properties and Electromagnetic Shielding Effectiveness of Mg-Y-Zr-Nd Alloy

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Abstract: The as-cast Mg-Y-Zr-*x*Nd alloys with different Nd contents were prepared, and the effects of Nd content on microstructure, mechanical properties and electromagnetic interference (EMI) shielding properties were investigated. The results show that the grain sizes are refined from 70.1 μm to 45.2 μm, discontinuous bone-shaped β phases are formed mostly in the triple junction of grain boundaries when the content of Nd increases to 2.63 wt%. The mechanical properties and EMI shielding capacity are both enhanced significantly by adding Nd element. The alloy with 2.63 wt% Nd has a good combination of mechanical properties and EMI properties. T6 heat treatment is able to further improve the EMI shielding effectiveness. The above-mentioned experiment results are attributed to the microstructural variation caused by adding different contents of Nd.

Key words: Mg-Y-Zr-Nd alloy; microstructure; mechanical properties; EMI shielding property

With the rapid development of science and technology, the wireless devices such as the GSM and UMTS towers, radar systems, mobile phones, computers, GPS systems and other electronics-based products are used widely[1-3]. The electromagnetic (EM) radiation emitted by these devices can cause health problems such as nervousness, insomnia, languidness, and headaches. The accurate, reliable and safe outputs are also suffering from unwanted electromagnetic interference (EMI) from other communication systems[4,5]. So effective EMI shielding materials are required to diminish the damage of electromagnetic radiation.

Metals are by far the most common materials for EMI shielding due to their higher electrical conductivity which is the major contribution for the reflection of the electromagnetic radiation[5]. The current shielding metals which achieve an excellent shielding effectiveness (SE) such as silver, nickel, copper, gold and their coating are suffering from their high density and high cost. Ni-Fe alloy and permalloy are attractive because they have both good electrical conductivity and magnetic permeability, thus providing reflection and absorption losses at the same time. But they are only used to low-frequency magnetic shielding, and restricted by their heavy weight. The existing polymer composite shielding materials are light, but cannot be used as structural materials. Therefore light-weight shielding materials are reguired urgently, especially in the portable electronics and aerospace industries[6-8].

It is well known that magnesium is the lightest structural metallic material with attractive electromagnetic shielding properties at ambient temperature, which are considered to be the very potential EMI shielding materials[9]. The WE (Mg-Y-Nd) series have become relatively successful magnesium alloys with superior mechanical properties at high temperature and good corrosion resistance, and already been applied in the aerospace area[10-14]. In the present study, the effects of Nd content on the microstructure, the mechanical properties and EMI shielding properties of as-cast Mg-Y-Zr-Nd alloys were investigated. In addition, the alloy with good combination of mechanical and shielding properties was heat treated in order to attain better shielding effectiveness.

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1 Experiment

Four alloy ingots were prepared from high purity Mg (99.98%), Mg-30Y (wt%) , Mg-30Nd (wt%) and Mg-27.85Zr (wt%) master alloy by melting in an electrical resistance furnace in a mild steel crucible at 750 °C. Flux was used during this process to prevent the oxidative combustion of metal liquid surface. The additions of Nd into the four alloys were 0 wt%, 1 wt%, 3 wt% and 4 wt%, respectively. The actual chemical compositions of these alloys were determined by an inductively coupled plasma analyzer (ICP), as listed in Table 1. Two types of heat treatments were performed to the cast ingots, namely solid solution at 525 °C for 8 h (T4), and T4 plus artificial ageing at 150 °C for 24 h and then cooling in air (T6).

Specimens for microstructure observations were prepared by mechanical grinding, polishing, and subsequent etching. The specimens were etched with a mixture of 0.8 g picric acid, 10 mL ethanol, 2 mL acetic acid and 2 mL water. Microstructure was examined by an optical microscope (OM) and scanning electron microscope (SEM, TESCAN VEGA II LMU). Phase analysis was carried out with a Rigaku D/MAX-2500PC X-ray diffractometer (XRD). The average grain size and volume fraction of precipitates were counted by Image-pro-plus. Tensile samples were cut into rectangular shapes with 10 mm width, 2 mm thickness and 30 mm gauge length. Tensile testing was carried out on a CMT5105 machine at a crosshead speed of 3 mm/min at room temperature. Fracture surface was investigated in a scanning electron microscope (SEM). EMI SE (attenuation upon transmission) was measured by DR-S01 shielding effectiveness tester with its input and output connected to NA7300A network analyzer. The range of scan frequency was from 30 MHz to 1.5 GHz. The samples were in a disc form with 115 mm in diameter and 2 mm in thickness. Electrical conductivity of disc specimens in different conditions was measured with a conductivity meter (SigmascopeSMP10) at 20 °C.

2 Results and Discussion

2.1 Microstructural characterization

The optical micrographs of as-cast alloys are shown in Fig.1. It is revealed that the grain size of the alloy decreases with increasing of Nd content. The average grain sizes were measured to be 70.1, 60.5, 45.2 and 42.9 μm for the alloys with 0 wt%, 1.01 wt%, 2.63 wt% and 3.30 wt% Nd, respectively. The content of Nd element as low as 2.63 wt% leads to a large maximum reduction of the grain size, which does not distinctively change when Nd content is higher than 2.63 wt%. The grain refinement might be attributed to that the enrichment of Y and Nd elements in the solid-liquid interface results in a greater degree of the constitutional supercooling and prevents the grains from growing up in the process of solidification[15,16]. Furthermore, when the content of Nd increases from 1.01 wt% to 2.63 wt% and 3.30 wt%, the eutectic or intermetallic phases in the vicinity of grain boundaries become more and bigger.

Table 1 Chemical composition of Mg-Y-Nd-Zr alloys (wt%)

Alloy	Y	Nd	Zr	Mg
YKN0	4.95	0	0.53	Bal.
YKN1	5.08	1.01	0.74	Bal.
YKN3	4.84	2.63	0.70	Bal.
YKN4	4.56	3.30	0.61	Bal.

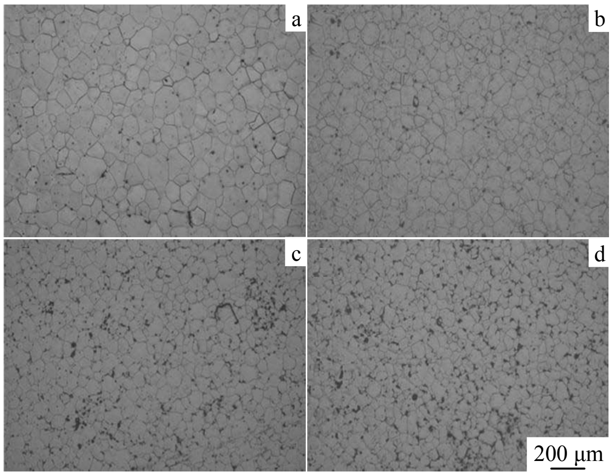

Fig.1 Optical micrographs of as-cast alloy with different Nd contents: (a) YKN0 , (b) YKN1, (c) YKN3, and (d) YKN4

The back-scattering SEM images in Fig.2 reveal that the alloys with 0 and 1.01 wt% Nd are mainly composed of α-Mg and a few cuboid-shaped phases at the grain boundaries. When Nd content increases to 2.63 wt% and 3.30 wt%, discontinuous bone-shaped phases are formed mostly in the triple junction of grain boundaries. According to the EDS results presented in Table 2, the cubic phases are mainly composed of Mg and Y, and the bone-shaped phases along grain boundaries are composed of Mg, Y and Nd.

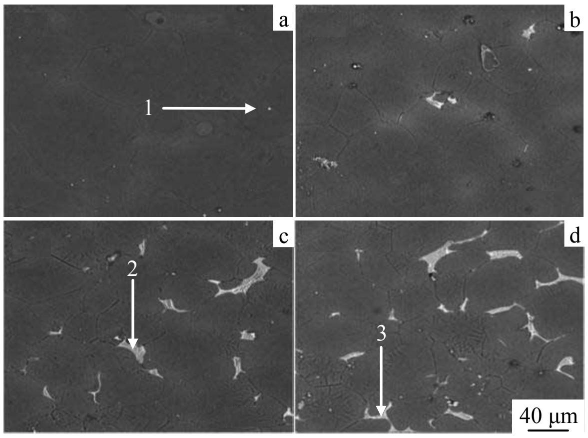

Fig.2 SEM images of as-cast alloys with different Nd contents: (a) YKN0, (b) YKN1, (c) YKN3, and (d) YKN4