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Microstructure of nickel foam/Mg double interpenetrating composites

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Abstract: The magnesium matrix double interpenetrating composites reinforced by nickel foam were fabricated by pressureless infiltration technology. Then the morphology of the nickel reinforcement and the microstructures of composites were characterized by SEM. The results show that not only is the nickel foam reinforcement reticular in three dimensions, but also the struts of foam keep the network structure, which ensures that the Ni foam/Mg composites are double interpenetrating. The interface bonding of composites between magnesium matrix and nickel foam reinforcement is good, without reaction around the interface, which is the indispensable condition that advanced composites should possess. Magnesium matrix distributes in the windows of nickel foam, the triangle center holes and microhole of nickel struts, and the composites have double interpenetrating structure, which makes the composites have unique properties.

Key words: pressureless infiltration; nickel foam; double interpenetrating composites; interface bonding; fractograph

1 Introduction

Magnesium, with a low density of 1.7 g/cm^3, is highly suitable for applications of weight reduction[1−3]. Other advantages include satisfactory room temperature properties, damping capacity, electrical and thermal conductivities[4]. There is a growing demand for magnesium and its alloys used as structural materials in aerospace, automobile and transport industries. However, their applications are limited due to the lower strength when being exposed to elevated temperatures[5]. It has been widely reported that metal matrix composites (MMCs) are perfect candidates for improving mechanical properties such as strength, stiffness and hardness. Such improvements have been observed earlier in MMCs based on aluminum, copper, zinc alloy matrix[4−6]. The traditional approaches to fabricate metal matrix composites are to combine the continuous matrix phase with one or more discrete reinforcement phases, which is widely used for the production of short fibre reinforced composites[6−8]. Recently, a novel fabricating technology, in which light weight metal matrix can be infiltrated into the porous and continuous preform at moderate infiltration temperatures and pressures, has been proposed[8−10]. These kinds of composites have the following special microstructure characteristic. Both the matrix and reinforcement phase are continuous, tridimensional, inter-twisting and interpenetrating. These metal matrix composites reinforced by three dimensional network structure are very interesting due to microstructure characteristic and special mechanical properties. For each phase is a continuous network penetrated by similar networks of other constituents, the interpenetrating composites exhibit rather high specific strength, stiffness and wear-resistance, excellent thermal and electrical conductivities, and they are to be attractive candidates for structural and functional materials[10−11].

Most studies have investigated ceramics as a viable

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reinforcement in magnesium alloy due to its high strength and high temperature refractory properties[11−16]. However, up to now, there is little literature reporting nickel reticulated structure reinforcement to improve the properties of magnesium alloys. The objective of this study was to fabricate interpenetrating composites reinforced by the nickel foam metal by pressureless infiltration technology. An emphasis is placed on the microstructure and fractograph of composites.

2 Experimental

A reticulated polyurethane sponge with interconnected pores was chosen to prepare the porous preform by the replica process, as shown in Fig.1. The cleaned sponge was pretreated by the use of coarsening, sensitization, activation and ungluing methods. The pretreated polymeric foam was chemdeposited and electrodeposited, and then, the oxidation and reduction process was carried in oxidizing and reduction atmosphere, respectively. Then, the reticulated nickel foam was obtained. The Ni foam is made up of cells and struts that consist of central triangular shaped opening holes surrounded by strut walls as shown in Fig.2. Furthermore, there are numerous continuous tiny cavities in the strut walls (Figs.2(c) and (d)), which makes the struts have a three-dimensional reticular structure similar to that of the foam. This special structure was deliberately designed in the experiment in order to increase interfacial bonding between the matrix and struts.

The commercial AZ61 magnesium alloy ingot, whose chemical composites are shown in Table 1, was chosen as matrix in this experiment. The infiltration mould containing nickel foam reinforcement and AZ61 matrix was put into the vacuum chamber, and then the gas in the chamber was evacuated to 6×10^{-2} Pa. After the infiltration mould was heated up to the appointed

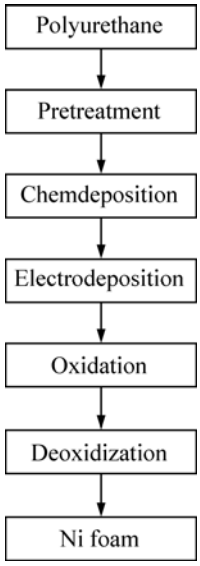

Fig.1 Preparation process of nickel foam reinforcement

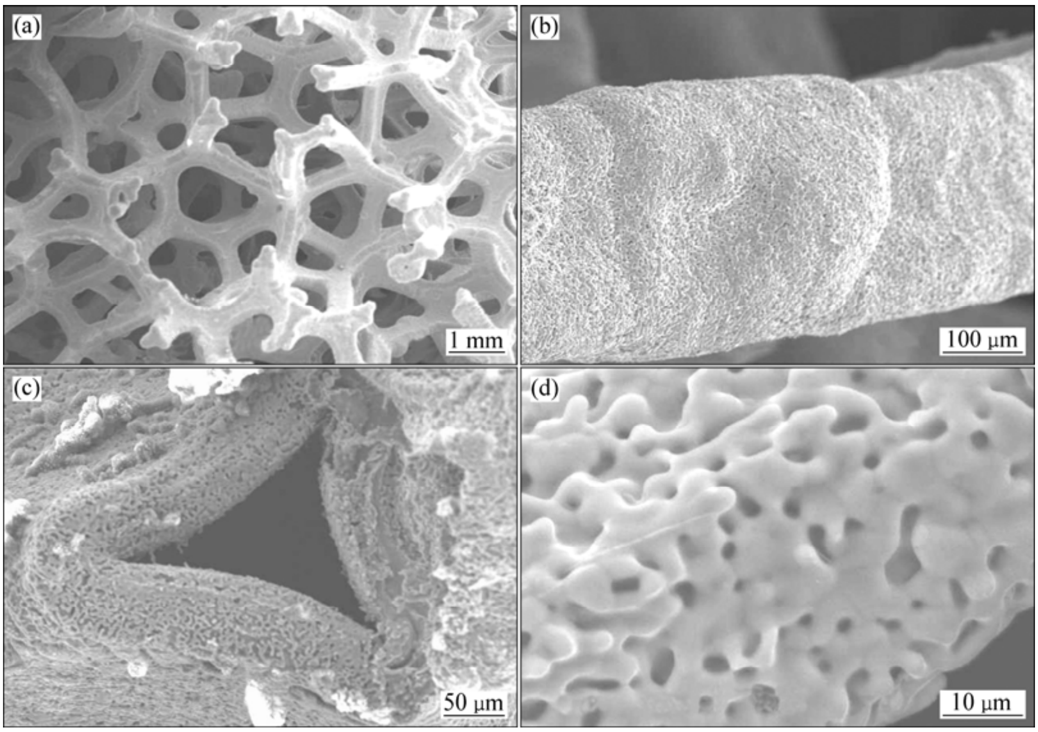

Fig.2 Morphologies of Ni foam reinforcement: (a) Foam, in low magnification; (b) Strut, in low magnification; (c) Cross section of strut; (d) Surface of strut

Table 1 Chemical compositions of AZ61 magnesium alloy (mass fraction, %)

Al	Mn	Zn	Si	others	Mg
5.8−7.2	>0.15	0.40−1.5	0.10	0.30	Bal.

temperature 670 ˚C at the rate of 15 ˚C/min, the nickel foam reinforcement has been infiltrated by the magnesium alloy melt for 50 min at the constant appointed temperature. Finally, the Ni foam/Mg interpenetrating composites were obtained, and the microstructure and fractograph of the interpenetrating composites were investigated by an S360 scanning electron microscope.

3 Results and discussion

3.1 Microstructure

It is found that the interpenetrating composites are composed of the white Ni foam strut and the gray magnesium alloy matrix, as shown in Fig.3. The Ni foam reinforcement keeps reticular structure well. And the casting flaw such as pores and bubbles cannot be found in composites, which ensures the soundness and the enhanced properties of the composites. Because of the reticular structure that is the relic of the porous electroplate, the walls have an interpenetrating structure after the infiltration of magnesium alloy matrix into the cavities. Such an interpenetrating structure, which is called local interpenetrating structure, will boost the interface bonding of the Ni foam struts to AZ61 matrix in the triangle holes and cavities since this microstructure increases the interface area. Furthermore, the interpenetrating structure of struts makes the local composites change into the double metal, which reduces the stress concentration and makes the composites more uniform. In addition, the Ni foam network is not destroyed by pressureless infiltration, which makes the overall composites have an interpenetrating structure. The structure, which is called the overall interpenetrating structure, restricts magnesium in the foam cells. The composites, possessing both the local interpenetrating structure and the overall interpenetrating structure, are called double interpenetrating structure composites. This unique structure makes composites have high strength and good ductility, which broadens the application of magnesium in aerospace. The interface between the magnesium and nickel matrix in composites is good for the matrix and reinforcement interlocks with each other, as shown in Fig.3(c), which is important to the mechanical interface bonding. No reactant or diffusing layer is found round the interface, which proves that the interface of the composites is mechanical bonding.

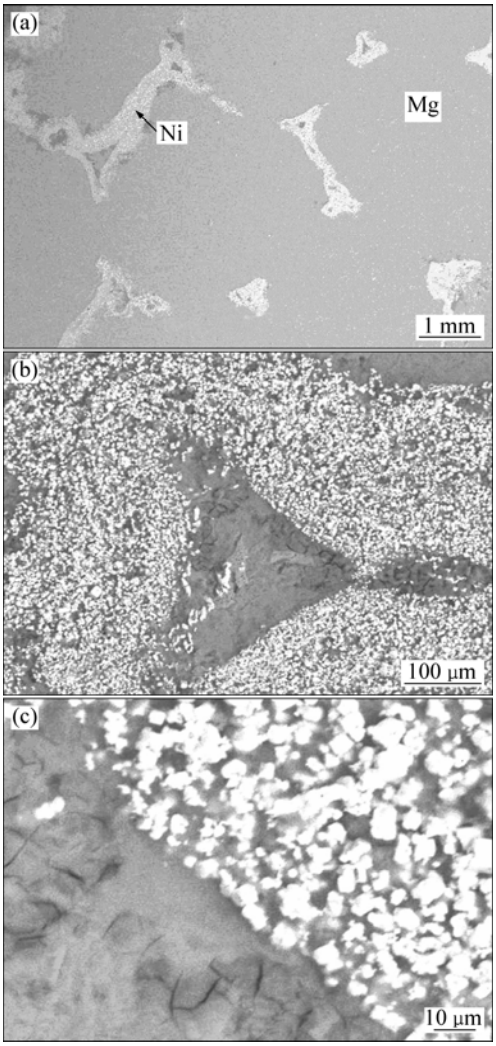

Fig.3 Morphologies of Ni foam/Mg interpenetrating composites: (a) Low magnification image; (b) Higher magnification image; (c) Interface

3.2 Fractograph

The fracture surface of the interpenetrating composites reinforced by the Ni foam is shown in Fig.4. Fig.4(a) shows the scanning electron microscope image of the entire flat and smooth fracture surface, which shows that the struts of Ni foam ruptures at the inner of them. The whole surface shows the characteristic of the brittle fracture for both the matrix and reinforcement are brittle materials. Fig.4(b) shows the microstructure of the fracture surface of a strut. The magnesium matrix is not tensile for the magnesium matrix is restricted severely by the reticular struts and the matrix has the similar plasticity to the reinforcement. When the composites ruptures, the interface bonding is still good, and no crack is found at the interface since the interface has the interlock structure, as shown in Fig.4(c). The interface bonding is increased for the interface friction is enhanced by the interface interlock mechanism. Furthermore, the surface of matrix in the foam cell and the struts almost have the same fracture plane, which shows that the ductility of the interpenetrating composites is

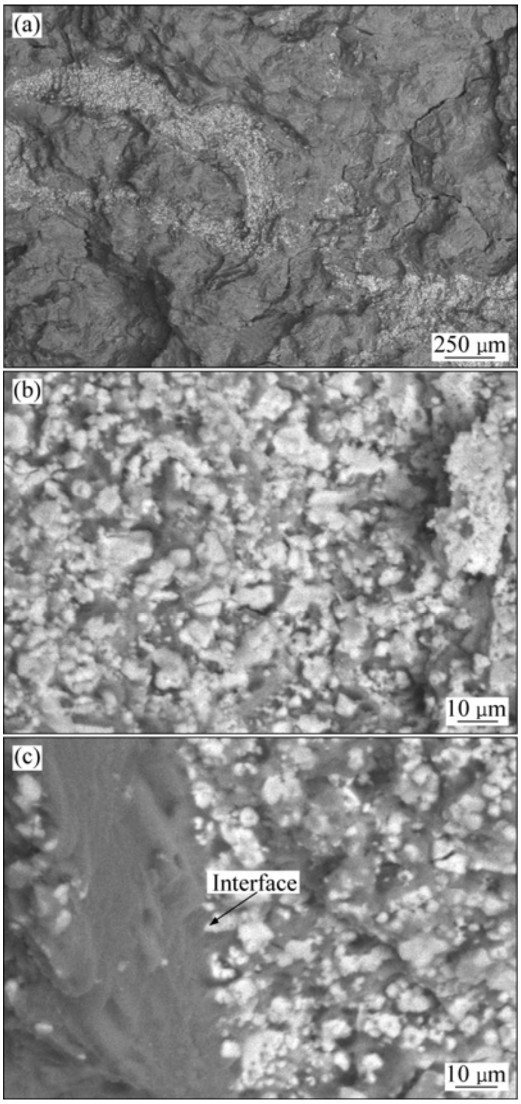

Fig.4 SEM images of fracture surface of interpenetrating composites: (a) Overview; (b) Strut at high magnification; (c) Interface between struts and matrix

predomenanted by the magnesium matrix.

4 Conclusions

1) The magnesium matrix double interpenetrating composites reinforced by nickel foam are fabricated by pressureless infiltration technology.

2) The interface bonding of composites between magnesium matrix and nickel foam reinforcement is good because the interpentrating composites have unique double interpenetrating structure.

3) The ductility of the interpenetrating composites is predomenanted by the magnesium matrix.

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