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Enhanced tensile properties of magnesium composites reinforced with graphene nanoplatelets

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ABSTRACT

The aim of this studys is to fabricate magnesium reinforced metal matrix composites using graphene nanoplatelets (GNPs) via powder metallurgy processing in order to enhance room temperature mechanical properties. The microstructural evaluation and mechanical behaviors of composite powders and extruded bulk materials were examined by X-ray diffraction (XRD), differential scanning calorimetry (DSC), Raman spectroscopy, transmission electron microscopy (TEM), scanning electron microscopy (SEM) equipped with energy-dispersive spectrometer and mechanical tests. The uniform dispersion and large specific surface area per volume of GNPs embedded in magnesium matrix led to increament in microhardness, tensile strength and fracture strains of the composites. For example, when employing the pure magnesium reinforced with 0.30 wt% GNPs, the increase of Young's modulus, yield strength, and failure strain of extruded nanocomposite was +131%, +49.5% and +74.2% respectively, compared to those of extruded materials with no GNPs additive. Additionally, mechanical properties of synthesized composites were compared with previously reported Mg–CNTs composites. It was found that GNPs outperform CNTs due their high specific surface area.

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1. Introduction

Graphene, a single layer of graphite, have attracted particular interests owing to its high electrical, thermal and mechanical properties [1–3]. In the field of thermal interface materials (TIMs) graphene (thermally conductive nanomaterial) has been used as excellent filler. The strong graphene coupling to the metal matrix particles caused an increase in the thermal conductivity of resulting composite up to 2300% [3–5]. Graphene nanoplatelets (few layer graphene) have also been considered as an ideal reinforcement to improve the electrical and mechanical performance of different polymers [6]. However, the GNP/Metal nanocomposites have shown lower strength than expected. In 2011, an attempt was made to synthesize the Al–graphene nanocomposite through hot isostatic pressing and extrusion techniques [7]. The experimental results revealed that Al–graphene nanocomposite showed decreased strength and hardness. Recently, many researchers have made successful attempts to synthesize the aluminum–graphene nanocomposites for their mechanical applications. Pérez-Bustamante et al. [8] investigated the effect of ball milling time on micro hardness behavior of aluminum–graphene nanoplatelets nanocomposites. Jeon et al. [9] evaluated the thermal and tensile properties of aluminum 5052-H32-graphene nanocomposite through friction stir processing. The thermal conductivity of the aluminum 5052-H32-graphene nanocomposites was measured to increase by more than 15% in comparison with that of the aluminum matrix. The friction stir processing and graphene reinforcement both improve the ductility of the fabricated composites. The tensile strength of graphene nanoflake–aluminum nanocomposites was investigated by Yan [10]. The nanocomposites were prepared using ball milling followed by hot isostatic pressing. The tensile testing results showed that with increasing filling content of graphene nanoflakes, both tensile and

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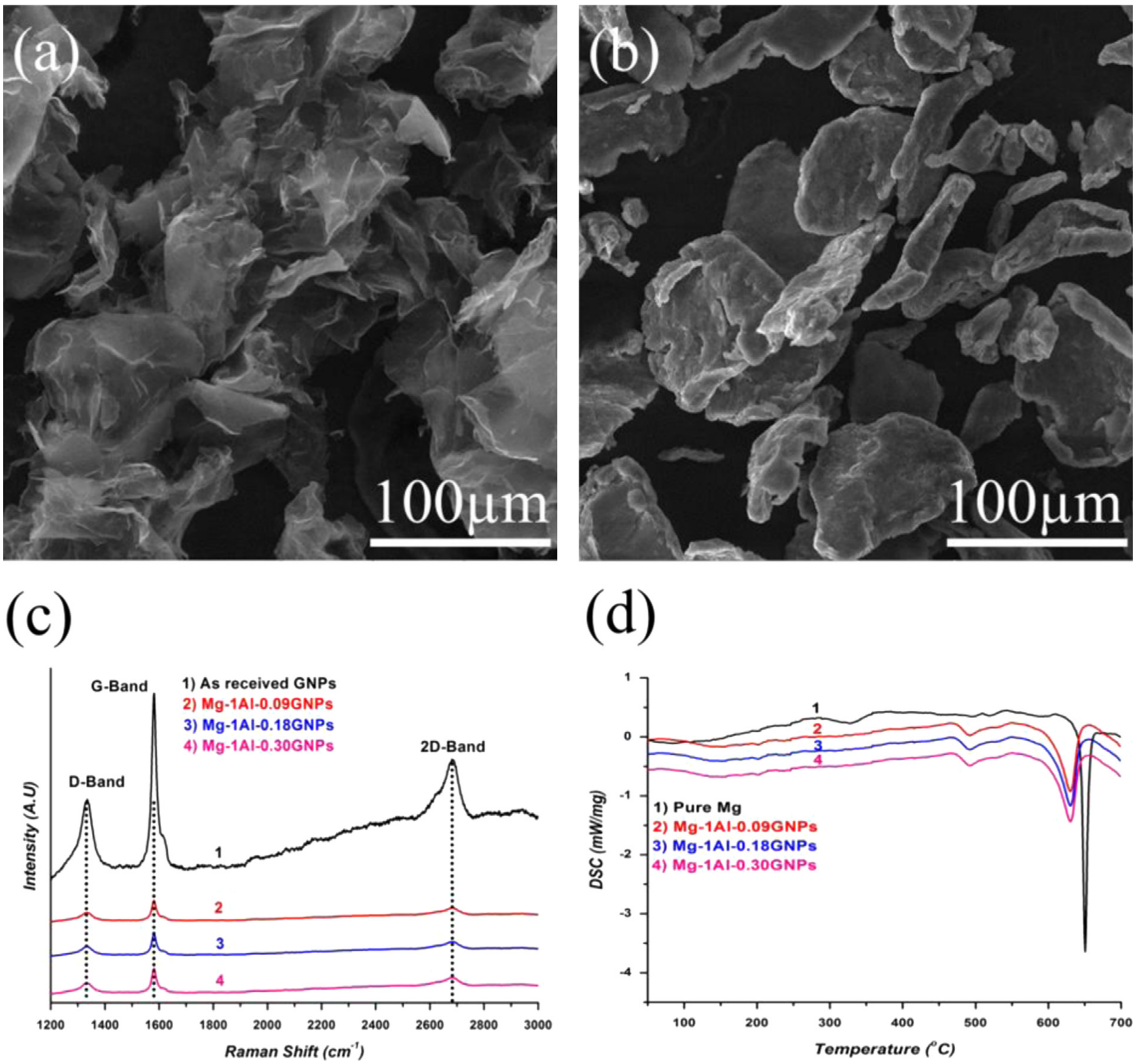

Fig. 1. SEM images of as received (a) GNPs, (b) Mg powders. Raman spectra (c) and Differential scanning calorimetry (d) of composite powders.

yield strengths were increased without losing the ductility performance. Similarly, in another study, flexural strength of aluminum 6061 alloy was enhanced with addition of graphene sheets [11].

Although variable studies have indicated that mechanical properties of structural metal (aluminum) can be enhanced by addition of graphene sheets, it is still a great challenge to synthesize magnesium based metal matrix composites reinforced by graphene nanoplatelets due to poor wettability between magnesium matrix and graphene nanoplatelets. Chen et al. [12] have prepared graphene–magnesium nanocomposite to evaluate the microhardness. Experimental results revealed impressive increase in hardness of the nanocomposite. In our previous study [13], we have attempted to evaluate the tensile strength of graphene nanoplate–magnesium nanocomposite, however the synthesized composite showed very poor ductily. This may be attributed to the poor wettability of magnesium with graphene nanoplatelets. In present work, an attempt is made to increase the wetabbility of graphene with magnesium matrix. Since graphene have good wetabbility with aluminum matrix, therefore small amount of aluminum particles can be added into magnesium matrix along with graphene nanoplatelets to enhance the wetabbility.

The basic objective of present work is to produce Mg matrix composites reinforced with GNPs by powder metallurgy method. Here, we propose simple strategy to increase the compatibility of carbonaceous material (GNPs) with magnesium matrix by integrating aluminum particles. The synthesized composites showed improved mechanical properties.

2. Experimental procedure

2.1. Raw materials

The reinforcements, graphene nanoplatelets(GNPs) were purchased from Nanjing Xian Feng Nano Material Technology Co., Ltd. Jiangsu, China. The average thickness and diameters of GNPs were 5–15 nm and 10–25 μm respectively. The matrix, Mg powder of 70 μm particle size was supplied by Shanghai Customs Golden Powder Material Co., Ltd. China.

2.2. Preparation of nanocomposites

The magnesium–GNPs composites were fabricated using liquid based mixing in ethanol. The Mg powder (with 98.99% purity) was mixed with varying weight fractions of GNPs (0.09%, 0.18% and

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