Materials Science & Engineering A 733 (2018) 414–418

Contents lists available at ScienceDirect

Materials Science & Engineering A

journal homepage: www.elsevier.com/locate/msea

Graphene nanoplatelets reinforced Mg matrix composite with enhanced mechanical properties by structure construction

Linglong Meng, Xiaoshi Hu, Xiaojun Wang*, Chunlei Zhang, Hailong Shi, Yeyang Xiang, Nanjia Liu, Kun Wu

School of Materials Science and Engineering, Harbin Institute of Technology, Harbin, 150001, People's Republic of China

ARTICLE INFO

Keywords:
Magnesium
Graphene nanoplatelets
Layered structure
Fracture
Mechanical properties

ABSTRACT

Balanced strength and toughness are essential elements for application of metal matrix composites and can be realized through structure construction. In this work, graphene nanoplatelets (GNPs) reinforced magnesium laminated composites were fabricated. The composites with 0.25 vol% and 0.75 vol% GNPs exhibit tensile strength of 160 MPa and 179 MPa, respectively (136 MPa for pure Mg). Homogeneously dispersed GNPs promotes the load transfer capacity and constrains the transformation of Mg foils to monolithic materials. The induced laminated structure prohibits the dislocation motion and strengthens the composites. The prolonged crack pathway by laminated structure also maintains the elongation to an appreciable level.

1. Introduction

Magnesium (Mg) has the superiority of low density and high specific strength and stiffness. Thus, Mg is attractive for lightweight structural systems and has the potential to improve energy efficiency and system performance in aerospace, automobile and mobile electronics applications [1,2]. However, the low strength and inherent negative ductility caused by the HCP structure restrict its application [3]. The main solution to enhance the strength was addition of ceramic particles, but always accompanied with the further deterioration of ductility, which is also an important indicator for the application of materials [2]. Selection of ideal reinforcements is still a challenging issue. Nanoscaled carbonaceous reinforcements, such as carbon nanotubes and graphene, have been demonstrated effective in prohibit the serious deterioration of the ductility when homogeneously dispersed in the composites [4–9]. However, their inherent clustering tendency restricts the fulfillment of their strengthening efficiency and the clusters always served as cracking sources. Of the two reinforcements, graphene has inherent two-dimensional (2D) geometry and possesses an extraordinarily high elastic modulus of 1 TPa and yield strength (YS) of 130 GPa, which has been considered as promising candidate in enhancing composite materials. However, the difficulty of fabrication has been the bottleneck of its application. Graphene nanoplatelets (GNPs) are less expensive and easier to obtain, and still preserve many of the attractive properties of graphene, thus arousing the interest of researchers to adopt GNPs as reinforcement in Mg based composites. The tensile yield strength of ZK60 alloy was increased by 62% with 0.05 wt% GNPs addition and reached 256 MPa by Du et al., which exhibits ultra-high strengthening efficiency [10]. Ball milling was always adopted to homogeneously disperse GNPs with metal particles, and high-performance GNPs/Ti, GNPs/Cu and GNPs/Al composites were successfully fabricated by spark plasma sintering (SPS) or pressure infiltration method [11–15]. Mg will not react with GNPs and damage the structure and mechanical properties. By mixing GNPs with Mg chips, stir casting and disintegrated melt deposition (DMD) are also feasible in manufacturing GNPs/Mg based composites [16,17]. Homogeneous dispersion of GNPs was always pursued in metal matrix composite (MMCs) to fulfill their strengthening efficiency, but the inevitable clusters still depress the strengthening efficiency. 2D dispersion of GNPs in MMCs benefits the fulfillment of their in-plane strength. In addition, 2D dispersion of the reinforcements always induced the laminated structure in MMCs, which has been demonstrated an efficient way to keep both the strength and toughness in our previous work [5]. As the promising structural metal with light weight, exploiting laminated GNPs/ Mg matrix composites and uncovering their mechanism of action is of great significance.

Here in this work, Mg matrix composites reinforced by GNPs with laminated structure were constructed to pursue the further mechanical enhancement. GNPs were sprayed on Mg foils to construct the structural units, and followed by hot pressing and rolling, laminated GNPs/ Mg composites were successfully fabricated. The mechanical properties and microstructures of the composites were investigated to understand the effects of structural design.

* Corresponding author.
E-mail address: xjwang@hit.edu.cn (X. Wang).

https://doi.org/10.1016/j.msea.2018.07.056

Available online 17 July 2018
0921-5093/ © 2018 Elsevier B.V. All rights reserved.

2. Experimental procedures

In this paper, a facile strategy to synthesize GNPs reinforced Mg composite was reported. After acid treatment and sonication, GNPs were homogeneously dispersed in alcohol, then GNPs were sprayed onto Mg foils without clusters. Hot pressing and rolling were then adopted to fabricate the laminated composites. The structural design guaranteed the uniform dispersion and load transfer capacity of GNPs. What's more, the laminated structure induced by the introduction of GNPs functioned to change the crack pathway, which leads to energy dissipation in the tensile process. The results demonstrate the significance of structure design and pave a way for the fabrication of laminated Mg composite.

GNPs were produced by thermal reduction of graphite oxide from Knano Co. Ltd. (P.R. China), and the thickness of GNPs is less than 10 nm, which contain about 30 layers of graphene. GNPs were first added to the mixture of H_2SO_4 and HNO_3 with a volume ratio of 3:1. After ultrasonic treated for 60 min, the slurry was stirred for 5 h at 70 °C and then filtered and washed by distilled water until the PH reached 7, and then dried at 105 °C. GNPs dispersion with a concentration of 0.1 mg/ml alcohol were prepared for spray dispersion. Mg foils were washed by HNO_3 in advance. The pressure used for the spray was 0.33 MPa. By adjusting the spray time, the content of GNPs in the composite can be controlled to 0.25 vol% and 0.75 vol%. The fabricated composite units were stacked layer by layer and sintered at 620 °C for 6 h with the pressure of 50 MPa. For the hot rolling process, the total reduction was 80% with 10% reduction per pass. For comparison, pure Mg was also fabricated by the same process.

The dispersion of GNPs on Mg foils and the microstructure of Mg and composites were carried out by scanning electron microscopy (SEM, SUPRA 55 SAPPHIRE). Raman spectra were utilized to analyze the structural characteristics of GNPs by a Raman Station (B&WTEK, BWS435–532SY) with a 532 nm wavelength laser corresponding to 2.34 eV. Dog-bone shaped specimens with gauge length of 18 mm and width of 10 mm were used for the tensile test by an Instron 5583 machine under a crosshead speed of 0.5 mm/min, and three samples were tested for each material. Transmission Electron Microscope (TEM, Talos F200x) was adopted to characterize the GNPs distribution and the interface between GNPs and Mg matrix.

3. Results and discussion

Fig. 1a shows the morphology of raw Mg foil. Mg foil with 0.75 vol % GNPs is shown in Fig. 1b with homogeneous GNPs dispersion. Inside Fig. 1b exhibits the high magnification SEM picture, and blank area can be checked, which will facilitate the combination of the adjacent Mg foils. Raman spectra was always adopted to characterize the quality of carbon nanotubes and graphene, and the intensity of the I_{2D}/I_G is ~ 4 for single layer graphene and decreases along with the increase in layer number [18]. The I_{2D}/I_G value of the acid-treated GNPs is 0.78, illustrating the presence of multiple graphene in the raw reinforcement. Fig. 1d exhibits the composite with 0.75 vol% GNPs, and robust laminated structure can be checked. GNPs located at the interface place and prohibited the total transformation of stacked Mg foils to bulk material.

Tensile test was conducted to evaluate the mechanical properties of Mg and the composite, and the results were shown in Fig. 2a. The incorporation of only 0.25 vol% and 0.75 vol% GNPs improved the ultimate tensile strength from 136 MPa to 160 MPa and 179 MPa. The elongation to failure of the two composites are still maintained at 4.9% and 2.7% with 5.5% for pure Mg. Comparing with the reported reinforcements/Mg composites [19–25], the composites report here exhibit outstanding strengthening efficiency with relatively low content of GNPs, as shown in Fig. 2b. $(\sigma_c\text{-}\sigma_m)/V_f\,\sigma_m$ was always adopted to calculate the strengthening efficiency [5,26], where σ_c and σ_m are the tensile strengths of the composite and the matrix, respectively, and V_f is the volume fraction of the reinforcements. The method reported here helps facilitate the homogeneous dispersion of GNPs and their strengthening effect when compared with the composites contain similar content reinforcement. The reported results illustrate the significance of laminated design in Mg composite with enhanced strength and without excessive deterioration of ductility.

The extraordinary strengthening efficiency and appreciable ductility are attributed to the laminated structure design. The fabricating process promotes the uniform dispersion of GNPs in Mg matrix. Robust bonding

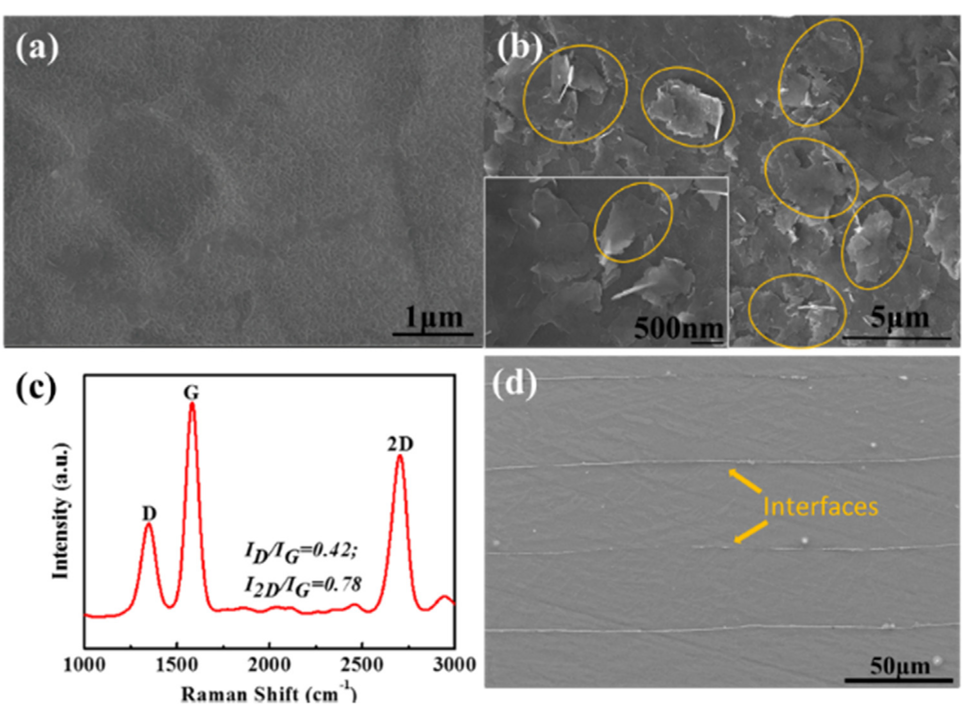

Fig. 1. (a) Surface morphology of Mg foil. (b) 0.75 vol% GNPs on Mg foil, and the yellow circles indicate the GNPs. (c) Raman spectra of the acid-treated GNPs. (d) 0.75 vol% sintered GNPs/Mg composite with robust interface, as illustrated by the yellow arrows.

Download English Version:

https://daneshyari.com/en/article/7971684

Download Persian Version:

https://daneshyari.com/article/7971684

Daneshyari.com