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Mechanical properties of graphene oxide reinforced aluminium matrix composites

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ABSTRACT

In this paper, the properties of powder metallurgy produced samples of GO reinforced aluminium composites were examined. Discs of 20 mm diameter and 0.5 mm thickness were made from pure Al powder of 35 μm particle size and with GO reinforcement at different GO wt% (0.05, 0.1 and 0.2). The mixture of Al/GO powders prepared through liquid infiltration were cold compacted and then sintered. The GO reinforced Al matrix composites were characterised using the scanning electron microscope with energy dispersion spectroscopy (SEM/EDX) for investigation of the homogeneous dispersion of GO into the matrix. X-ray diffraction (XRD) analysis for crystallographic phase and micro-Raman spectroscopy was used to identify the phases inside the composite matrix after the sintering process. Micro hardness and the strength values from the produced Al/GO composites were recorded. It is evident from the results obtained that where uniform mixing is achieved, GO reinforced Al composites can be produced with similar hardness values as for those produced from rGO reinforced Al composites.

1. Introduction

The potential improvement in properties achievable from metal matrix composites make them desirable materials in automotive and aerospace industries [1,2]. These include the potential for increased strength, higher elastic modulus, higher service temperature, improved wear resistance, decreased part weight, high electrical and thermal conductivity, low coefficient of thermal expansion and high resistance to thermal fatigue and creep. MMCs were first applied in the production of space craft components, in which high mechanical properties are required for operation in the extreme working environments [3]. The low density of aluminium enables its usage within many MMCs applications, additionally, it is inexpensive in comparison to widely used low density metals such as Ti and Mg [4,5]. High corrosion resistance and better formability makes Al a material used for automobile applications over other alternatives, including ferrous metals. Powder metallurgy or casting are the techniques generally used to fabricate Al composites with the addition of reinforcement to enhance its properties [6–8]. Nano reinforcements such as CNT's and graphene as reinforcement for MMCs have attracted many researchers recently due to their exceptional mechanical [9], thermal [10,11], electrical [12] and tribological [13] properties.

CNT's are promising materials in the design of nano sensors that can be used for precise mechanical and physical properties at micro level that can be extended to nano level which is far from justified. Raffaele et al. [14] have modelled bending armchair CNT's based on gradient elasticity theory, the effect of size on young's modulus was investigated. Emerging applications such as nano-electromechanical systems (NEMS) needs design and optimization of beam like components [15]. Raffaele et al. [16] have identified the need for the design optimization while working with nano materials and have adopted the size effect of nanostructures in nano formulations. The practical engineering applications of CNT's are limited due to the availability of exact solutions for specific cross-sections, it is always challenging to find out the exact solutions for the visco-elastic non-local nano beams made of composite materials under torsion [17]. It can also be noted that the lack of availability of stress-driven systems in order to predict CNT's behaviour under loading limits CNT's applications as the small scale effects in the beams will be neglected [18,19]. CNT's have displayed strengths 10 to 100 times higher than steel, such unique properties in combination with better thermal and electrical properties can lead to the production of promising micro and nano-electro mechanical systems [20] and

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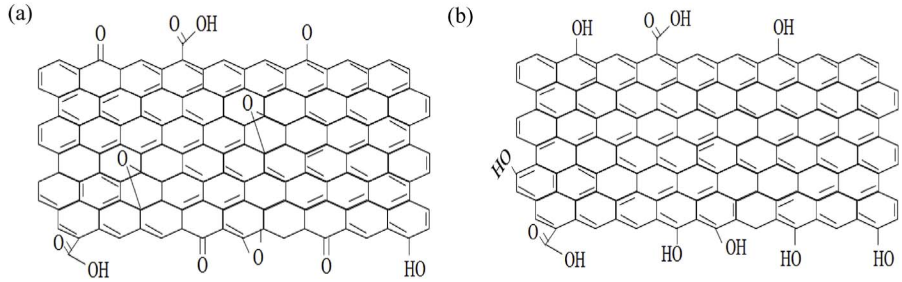

Fig. 1. Chemical formulae of graphene derivate.
(a) Graphene oxide and (b) Reduced graphene oxide.

medicine sector [21].

The recent research carried out on the aluminium matrix composites reinforced with carbon nano tubes [22–24] and graphene [25–29] have shown promising increase in mechanical properties which is evident that nano reinforcement for aluminium possess is high potential in future applications. Even though, CNT's enhances the properties of Al matrix composites significantly, the major aspects of uniform dispersion, wetting between the CNT and the base metal still needs more insight. Graphene, a structural element of CNTs is a promising reinforcement for metal matrix composites with a different form factor. Graphene as a reinforcement provides less weight and more strength and high conductivity to the composite material, which possess the potential to replace the conventional materials used in flywheels, cables and even possess a capability to evolve as a strong functional material in energy storage, structural and bio medical fields [12,30]. Its remarkable properties such as Young's modulus of 1 TPa, fracture strength of 125 GPa, thermal conductivity of 5000 W/m-k [30] could be used in various applications especially electrical, automobile and aerospace. Graphene oxide (GO) and reduced graphene oxide (rGO), shown in Fig. 1 (a) & (b) are the frequently used derivatives of graphene as a reinforcement. Dispersions of GO are very stable in aqueous environments. The use of rGO in the powder state is prone to form agglomeration and is more hydrophobic in nature. Even though graphene possesses excellent properties, a major drawback to the use of graphene in many applications is its cost.

From the literature, it is observed that only a small amount of investigation has been conducted to date for the production of GO and rGO reinforced metal matrix composites relative to other composites [31]. Fig. 2(a) shows the number of graphene related publications per year, from which it can be noted that there is a gradual increase in research publications since its discovery in the year 2004. It can be noted that 84.57% of articles out of total number of articles published were original research articles. Fig. 2 (b) shows the percentage breakdown of published papers in terms of filed explored, in which only 1.67% of the work contributed towards all the physical, chemical, metallurgical and engineering aspects of the composites produced from graphene and its derivatives. There is still a long way to go in area of MMCs to develop a feasible process to produce and distribute these reinforcements in matrix homogenously. The current experimental focus from researchers internationally is to develop graphene reinforced aluminium MMCs through powder metallurgical or severe plastic deformation routes.

Rashad et al. [26] have successfully fabricated aluminium matrix composite reinforced with graphene nano platelets (GNP) through semi powder metallurgical route. It was reported that, the high specific area and 2-D structure of graphene increased tensile strength of the composite to nearly 11.1% with the addition of 0.3 wt% GNP's to aluminium. Stephen et al. [27] fabricated graphene–aluminium nano composites through ball milling, hot isostatic pressing and extrusion. It was reported that the tensile strength of the Al matrix composite can be increase up to 12% by using multi walled CNT's as reinforcement. Boostani et al. [29] have reported that graphene sheets as reinforcement facilitates the strengthening of Al matrix composites exceptionally, by using thermally activated dislocation and pinning the SiC nano composites to the matrix. Hwang et al. [32] demonstrated the use of rGO as reinforcement in MMC's to enhance the mechanical properties through molecular level mixing process. It was reported that elastic modulus and yield strength can be increased to 30% and 80% respectively by reinforcing Cu matrix composite with 2.5 vol% rGO. Li et al. [33] achieved uniform distribution of rGO in Al matrix through electro static interactions between the rGO and Al flakes. It was reported that, elastic modulus and hardness increased to 18% and 17% respectively, by reinforcing Al with 0.3 wt% of rGO. Shin et al. [34] have successfully fabricated aluminium alloy 2024 composites

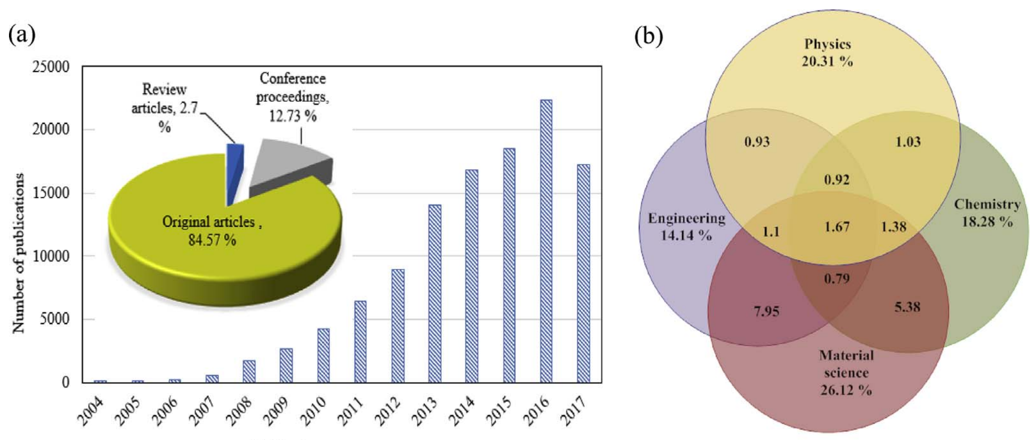

Fig. 2. Research articles on graphene.
(a) Number of publications corresponding to publishing year and (b) percentage breakdown of publications.

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