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Effect of milling on dispersion of graphene nanosheet reinforcement in different morphology copper powder matrix

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ABSTRACT

The effective dispersion of Graphene Nanosheet (GNS) as reinforcement was studied with various morphology of Copper (Cu) powder as matrix. High energy milling was used for modifying the morphology of the Cu powders. The Cu powder with Spherical and dentric shape was used in this study. Using high energy milling both the powders were milled for 8 h and 16 h respectively. The morphology of Cu powders was altered as flake shape upon milling. GNS (2 wt. %) was added as reinforcement uniformly with various morphology Cu powder used as matrix. The effect of size and shape of Cu as matrix on Cu/GNS composite properties was comprehensively studied. The Cu/GNS composite was prepared using powder metallurgy technique. Using the different shape and size of the Cu as matrix the interface of GNS has been studied. The hardness properties of Cu/GNS composite are evaluated. The effect of GNS interface in Cu particles has a significant influence on mechanical properties of composites. The hardness of Cu matrix composite has improved up to 20% compared to that of pure Cu. Thus morphology of Cu has the ability to improve the mechanical properties with GNS reinforcement.

1. Introduction

Composite is the combination of two or more materials which are having different phases and the properties superior to the base material. Metal Matrix Composite (MMC) applications are more in bimetallic metals in the field of mechanical, aerospace, automotive and electrical industries [1]. High strength, high electrical and thermal conductivity with ductility make MMC peculiar than bimetallic metals. Copper (Cu) reinforced with nano carbon materials earns more attention due to its enhanced mechanical properties without affecting its electrical and thermal properties. Carbon materials such as carbon nanotubes, graphene nanosheet, diamond, graphite are highly used as reinforcement with Cu.

Graphene nanosheet (GNS) has received considerable interest in research due to their extraordinary high elastic modulus (1 TPa) and fracture strength (125 GPa*)* [2] as well as with high flexibility [3]. Other than their exceptional mechanical properties, GNS have extremely high surface area [4], excellent chemical stability [5] as well as higher thermal [6] and electrical properties [7]. All these characteristics have made GNS outstanding reinforcement materials for developing advanced nanocomposites for cryogenic, nuclear, space applications [8]. Graphene dispersed phase has great potential applications in aerospace or electronic fields as advanced composite materials [9].

Considerable researches have performed on GNS reinforced polymer matrix composites with significant enhancement in mechanical properties compared to those of base metal [9–11]. However, few papers have been done in preparation and analysing mechanical properties of metal/GNS reinforced composites [12–16]. Due to drawbacks suchs as poor wetting behaviour, weak interfacial bonding to metal matrix materials, agglomeration among themselves with van-der-Waals force [17], inhomogeneous distribution of GNS in the matrices and degraded thermal stability at high processing temperature make GNS as complicated reinforcemet with metal [18].

Several production methods have been used for fabricating Cu/GNS composite such as powder metallurgy, accumulative roll bonding, ball milling, electro deposition. Among the above methods powder

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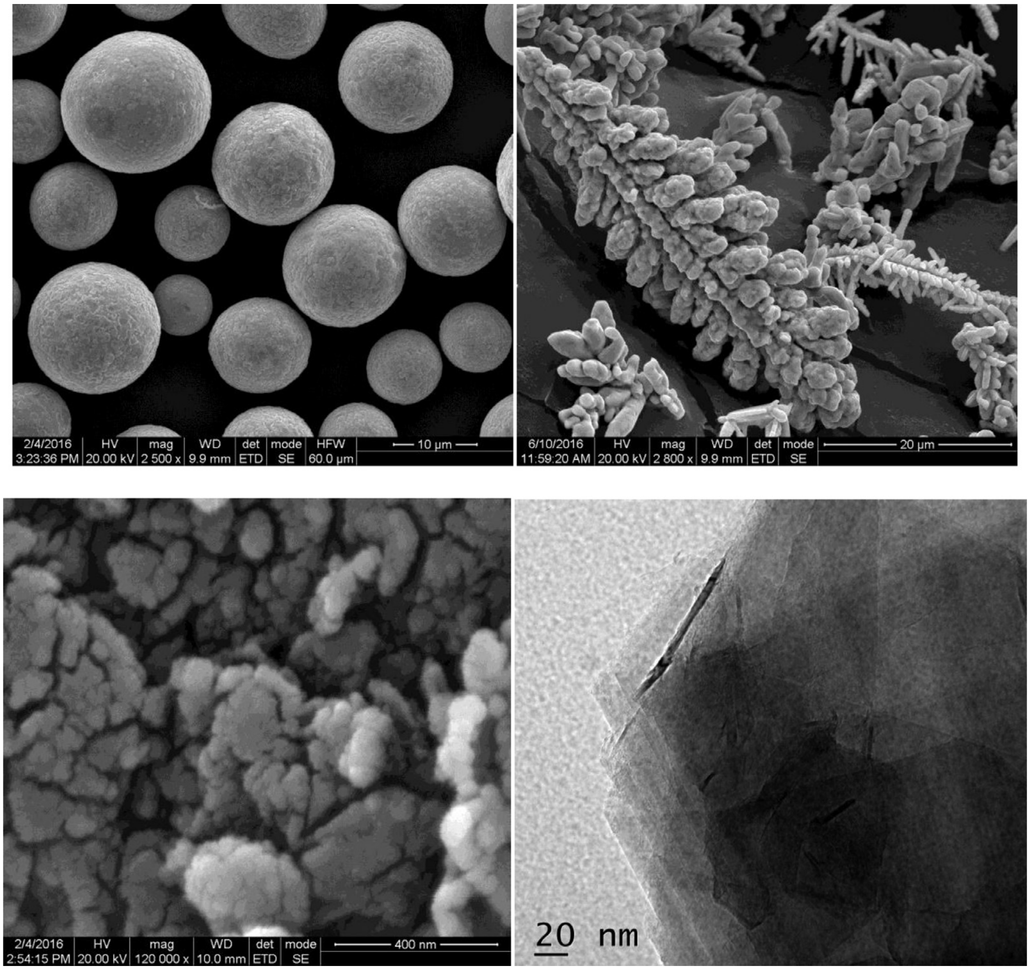

Fig. 1. (a) SEM image of pure spherical Cu powder (b) SEM image of pure dendritic Cu powder (c) SEM image of prepared GO (d) TEM image of prepared GO.

metallurgy assisted with ultra sonication technique shows high uniform dispersion of GNS and excellent mechanical properties [12]. High energy milling is an important method for producing composites materials with various morphology, improved mechanical properties etc. Also it is an inexpensive and fast method.

Previously, Ponraj et al. [35] successfully fabricated Cu/GNS composite using powder metallurgy technique with Polyvinyl Alcohol (PVA) treatment followed by sintering shows 10% enhancement of compressive strength compared to pure Cu matrix with 0.2 Wt.% of GNS [13]. Moreover, GNS reinforcements with other process have so far been reported poor efficiency [18] due to agglomeration among themselves with Van-der-Waals force, poor wetting behaviour or weak interfacial bonding to matrix materials.

Graphene has higher strength than other materials [19]. Hence, it can be a suitable candidate to be added as a filler material in MMC to improve the mechanical properties [20]. After high energy milling, morphology and mechanical properties are changed. The spherical and dendritic structures of Cu powder are converted into micro layer structure and hardness is improved. Both micro layer structure and hardness improvement are the results of the penetration of two dimensional GNS into Cu powder during milling [21].

In order to explore the full potential of GNS reinforced Cu, in this work; we authors take effort to enhance the bonding between Cu and GNS with surface modification technique. Since GNS is in nanolevel and modifying its surface is highly difficult. On other hand Cu particles are used in micron level. Using high energy milling the Cu powders surface modified. Also the literature confirms that nobody have studied the uniform distribution of GNS in the Cu matrix. This paper is going to deal with the uniformity in dispersion of GNS with various morphology Cu powders and its mechanical properties.

2. Experimental

2.1. Materials

Sodium nitrate, $NaNo_3$ (99.99%), Cu spherical powder supplied from Sigma-Aldrich, Graphite, Sulphuric acid (H_2So_4), Hydrogen Peroxide, Potassium Permanganate, Hydrochloric acid supplied from Rankem chemicals. All chemical reagents were analytical grade and distillation deionized water.

2.2. Preparation of Cu/GNS composite

High energy milling done on Cu powder for size reduction using planetary micro mill pulverisette 7 from fristch Gmbh with tungsten carbide balls in Tungsten carbide vial. The ball to powder ratio used is 10:1. In our previous work, the Cu/GNS composite fabricated using powder metallurgy technique exhibit 9% enhancement in mechanical properties than pure Cu. PVA is a highly hydrophilic material **[**22,23**]**. Cu powders treated with 3 wt % of PVA for creating a hydrophilic effect on the surface [23]. Graphene Oxide (GO) is prepared by modified Hummers method [24]. Aqueous GO is added to the enhanced hydrophilic Cu powder and then stirred with a mechanical stirrer. Prepared Cu/GO composite powders heated at 650 °C at a heating rate of 40 °C min^{-1} and kept in the flow of nitrogen for 2 h. Upon heating the GO reduces to GNS and PVA decays. Cu/GNS composites fabricated by using suitable die sets at high load (1 GPa) the specimen fabricated at 12 mm diameter and 12 mm long. The cold compacted sample sintered