Effect of Graphene Nanoplatelets (GNPs) on Properties of Pure Copper

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Graphene nanoplatelets (GNPs)/copper composites has been prepared by conventional powder metallurgy. Although GNPs/Al composites are widely studied, homogeneous dispersion of GNPs is still a big challenge for the researchers, which limits its use in practical applications. Our novel nano-processing route is free of ball milling which can damage the structure of GNPs during mixing. Therefore, our method can be an alternative of ball milling and it has a great potential for the synthesis of Cu based matrix nano-composite which is considered good for engineering applications. Nevertheless, the interface of GNPs/Cu plays a critical role in electrical resistivity in such a way that by increasing the GNPs/Cu interface the electrical resistivity increased.Nonetheless the hardness of the composite was increase by the introduction of GNPs.

In the last years, graphene-based composites has been intensly studied both regarding graphene-polymer [1-3] composites and graphene-ceramic [4-6] nanocomposites. It was shown that the presence of graphene leads to improved electronic conductivity, catalytic, and energy storage in composites. These graphene-based composites have wide applications in various fields, such as solar energy conversion, super capacitors, lithium secondary batteries and fuel cells [7-9]. However, compared with graphene-polymer and graphene-ceramic nanocomposites, graphene-reinforced metal matrix composites have not been intensively investigated. Interface problems that cause relative low density and poor dispersion of graphene has always been the main obstacle to the development of graphene-metal based composites[10].

On the other hand, reinforced copper has been extensively studied in recent years with the goal to attain better properties than pure copper or copper alloys reinforced by precipitation and solid solution hardening. Obtaining copper-based composites with a fine dispersion of GNPs seems to be a challenging in powder metallurgy for this type of a material[11]. In the present study, 4 and 8 vol.% graphene nano platelets/copper composite mixture were prepared by a novel dispersion method. The composites were then produced by a very simple conventional powder metallurgy route.

References

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The dispersion of GNPs and Cu powders were performed separately. At firs, the GNPs were ultra sonicated in ethanol for 45 min, and at the same time, Cu powders were dispersed by

mechanical agitation in ethanol. After ultra-sonication, the GNPs were added to the Cu powder slurry in ethanol, to obtain the final content of 4 and 8 vol.%. After 60 minutes mixing, the mixture was filtered and dried at 70 °C for 6 hours. Afterwards, the dried composite powder was compacted in a stainless steel die of 25 mm diameter at ambient temperature under the pressure of 600 MPa. The sintering of green samples was performed at 950 °C for 1 hour in argon flow. Beside the composites, pure Cu disks were produced as reference samples with the same conditions of composites. Electrical resistivity is evaluated through an electrical resistivity measurement system. Elemental dispersion was evaluated by microscopy and X-ray energy dispersion spectrometry(EDS). Vickers hardness of MMNCs was determined using 5 kg load. Young's modulus of MMNCs was evaluated by the measurement of the speed of ultrasound in the composite.
In Figure (1a) the powders of copper after the dispersion of 4%vol. GNPs are shown. It is evident that the surface of the powders are uniformely covered with GNPs. On Figure(1b), instead the microstructure of the sintered specimen is shown. The distribution of GNPs is very homogeneous and no large aggregate are seen.

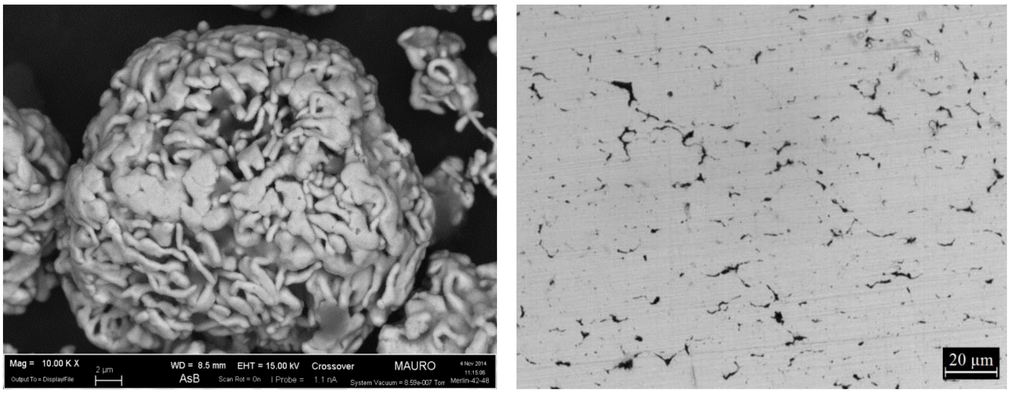

Fig. 1. GNPs distribution on the surface of a Cu powder grain(a) Polished section of a Cu-4vol. %GNPs composite, after sintering at 950 °C for 1 hour(b)

In Table (1) the data for hardness and electrical resistivity are shown for 4 and 8 vol.% GNPs in a pure cooper matrix. It is evident how the presence of GNPs reduce only slightly the electrical conductivity of the pure copper, but the hardness increases significantly. This is due to the reduction of grain size as a consequence of the homogeneous dispersion of GNPs. The GNPs are slightly detrimental to the electrical properties because of the reduction of copper grain size and the high number of GNPs/Cu interfaces.

Table1. Harness and electrical resistivity of GNPs/Copper composites

	Pure Cu	**Cu-4 vol.%GNPs**	**Cu-8 vol.%GNPs**
Electrical resistivity (μΩ.cm)	2.27	2.43	2.52
Hardness (HV5)	40	49	70.2

GNPs/Cu nanocomposites have been produced by conventional powder metallurgy. Taking a particular care to the dispersion method. The dispersion of GNPs in the Cu matrix is very homogeneous, bringing to an increase of mechanical properties, even if the electrical conductivity is reduced by the introduction of GNPs due to probably to the poor interface between pure copper and GNPs.