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Effect of Sintering Temperature on Graphene Oxide Reinforced Copper Matrix Composite Fabricated Through Powder Metallurgy Technique

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ABSTRACT: Composite materials revolutionize engineering, seamlessly blending diverse components for enhanced strength and versatility. These advanced structures, combining fibers and matrices, redefine traditional material boundaries. Their lightweight yet robust nature propels innovation across industries, from aerospace to automotive. Embracing composites heralds a new era of design possibilities and heightened performance. The work has been carried out by the bulk Cu/GO sintered composite's microstructure, grain development, and texture are examined to the sintering temperatures. The copper/graphene oxide (Cu/GO) composite is made using the powder metallurgy approach, which uses fine Cu particles as the matrix. The consequences of sintering for one hour at a different temperature > 600 Celsius are to be examined. According to the study, GO limits inhibit grain growth during sintering. Additionally, because of the varying rates of grain formation, sintered composites have irregular texture. The composite reaches its maximum hardness when sintered at different temperatures. The mechanical characteristics of the composite are observed as the sintering temperature increases and Cu/GO sintered has influenced the density, porosity, and hardness.

KEYWORDS: Copper (cu), Graphene oxide (GO), Powder Metallurgy, Sintering, Microstructure, Hardness.

I. INTRODUCTION

Copper (Cu) has long been used in a variety of industries due to its conductivity and wear resistance, but its mechanical properties limit its potential applications. Composite materials, particularly those containing graphene oxide (GO), which enhances Cu's mechanical properties while preserving conductivity, offer a solution. Problems such as agglomeration and uniform distribution hinder the effective integration of GO into Cu matrices. This work aims to optimize the sintering process to maximize the mechanical properties of Cu-GO composites. Graphene oxide (GO) is an ideal reinforcement material for Cu matrices due to its remarkable mechanical and electrical characteristics. Its incorporation into Cu matrices has led to advancements in metal, ceramic, and polymer matrix composites.

Conventional methods often fail to produce homogenous dispersion and strong interfacial bonding between Cu and GO. Approaches that are novel, such as flake powder metallurgy, have the potential to address these problems. Researchers have improved the mechanical properties and dispersion of Cu-GO composites by modifying traditional powder metallurgy techniques. In addition, a variety of techniques, including in-situ synthesis and cold spray forming, can be used to create reliable and robust Cu-GO composites. This work combines flake powder metallurgy and conventional powder metallurgy to prepare Cu-GO composites with varying GO content and sintering conditions. In addition to providing industry and research communities with valuable information for developing high-performance materials with a wide range of applications, this study advances the fundamental theories guiding the production of Cu-GO composites. By carefully analysing the mechanical properties of these composites, including hardness, wear resistance, and compression strength, this study aims to identify the optimal sintering conditions that will enhance the performance of Cu-GO composites. By opening the door to the development of innovative materials with uses across multiple industries, the study's findings may further the field of composite materials research. due to aluminium hybrid composites enhanced mechanical qualities, suitability for traditional processing methods, and potential for cost savings during manufacture. Choosing the appropriate mix of reinforcing materials is largely responsible for the performance of these materials.

A. Copper Composites

Copper composites have excellent electrical and thermal conductivity along with good mechanical properties. In the modern era, the need for conducting materials in the industry is high. Many researchers and scientists showed their interest in developing conducting materials. The copper- based materials satisfy the conducting needs but their mechanical properties restrict many potential applications. In many applications, copper-based materials are applied as conducting materials besides that in some places it needs to withstand high pressure to avoid failure. Especially, in the energy sector, there is high conductivity copper needed with high mechanical strength to improve the machine life.

B. Graphene Oxide

The remarkable characteristics of graphene oxide (GO), a two-dimensional carbon material derived from graphite. For advanced applications, it is widely used in graphene oxide reinforced polymer, metal, and ceramic matrix composites (GRPMC, GRMMC, and GRCMC). New techniques, such as powder methodology, have improved mechanical properties and dispersion in metal matrix composites, especially in copper (Cu) and aluminium (Al) matrices, despite difficulties with interfacial bonding.

II. EXPERIMENTAL DETAILS

Commercially available copper (Cu) powder of 80-150µm size was used as matrix material and graphene oxide (GO) powder of ~10µm was selected as reinforcement material to fabricate Cu-GO composite using powder metallurgy technique. The properties of copper and graphene oxide powders/particles used in the study was listed in Table 1.

Table -1: Properties of Cu-GO composite.

Sr.no	*Description*	*Copper (Cu)*	*Graphene oxide (GO)*
1	Size	80-150	~10µm
2	Purity	>99.5%	>99%
3	Density	8.94 g/cm³	0.98 g/cm³
4	Crystal type	FCC	Hexagonal
5	Melting point	1080°C	3600°C
6	Supplier	H. Chandan mal & Co., Chennai	Ultra nanotech Ltd., Bangalore

Mechanical alloying of metallic Cu particles with 5wt% GO was carried out for one hour at 200 rpm. Subsequently, the blend was compacted at approximately 960 N/mm2 using a 100-ton universal testing machine via cold compaction. Grain structure, bonding, strength, and thermal resistance were all improved by microwave sintering. The procedure was to place the specimens in an alumina crucible containing SiC particles and heat them for four hours to 650 °C. By reducing thermal stress and porosity, this technique enhances the qualities of composite materials. The final samples' density, microstructure, and hardness were measured on samples with diameters of 10, 15, and 20 mm.

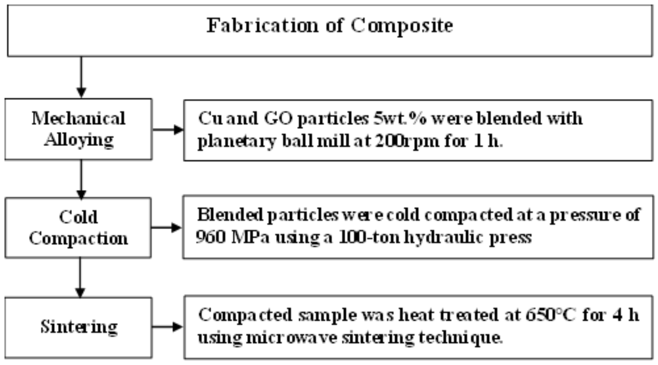

Chart -1: Flow char of composite fabrication

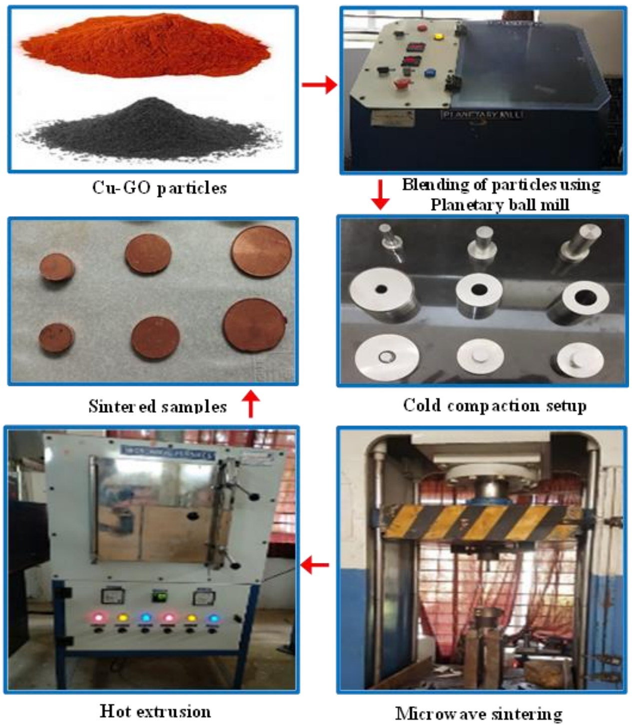

Fig -1: The detailed step-by-step fabrication of composite specimen

III.RESULTS AND DISCUSSIONS

Table -2: Density and porosity measurements of Cu-GO composites.

Sr.no	*Material*	*Theoretical density (g/cm³)*	*Exp. Sintering density (g/cm³)*	*Porosity (%)*
1	Cu-GO-10mm	8.5420	7.9528	6.8973
2	Cu-GO-15mm	8.5420	8.1352	4.7620
3	Cu-GO-20mm	8.5420	8.4297	1.3147

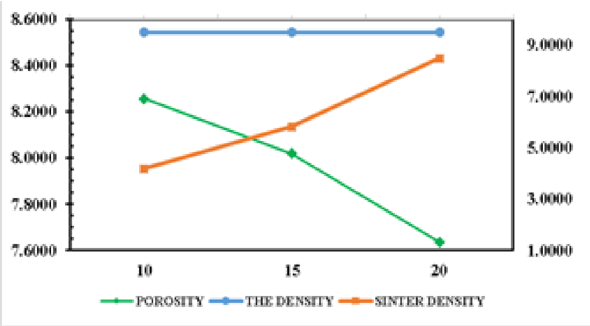

Fig -2: Theoretical density, Experimental density, and porosity of sintered samples

The experimental sinter density and porosity of sintered samples are shown in figure 2 and Table 2. The obtained results revealed that there was a marginal reduction in mass density of composite due to the addition of GO in the Cu matrix. However experimental mass density of copper and composite samples was relatively close to theoretical mass density for 20mm size sintered sample which indicate that this technique was effective for producing near dense composite materials. The observation on experimental mass density values showed an increasing trend, which was due to good bonding of cu and GO particles. in the sintering process. The fabrication process may also be a reason for the porosity, high value 6.89% for Cu-GO-10mm. The mass density of the composites increases with increase in pellet size and maximum density was observed for 20mm size pellet. This may be due to good bonding and compaction of particles, less friction between die wall and particles and reduced pore size. Despite increase in density, the porosity of the composites also decreases steadily from 6.89% for Cu-GO-10mm to 1.31 % for Cu-GO-20mm sample. This would be due to the fact boundary between the soft copper matrix with the irregular structure of fly ash particulates was not appreciable.

A. *Hardness Test*

Vickers hardness value of copper –graphene oxide composite sample was found to increase with increase in pellet size and maximum hardness, about 24% higher than that of pure copper was observed Vickers hardness values of synthesized Cu-GO composites are shown in figure 3 and Table 3. It was observed from the microhardness values, there is a significant increase in Vickers hardness of Cu-GO composite compared to that of pure copper. About24% increase in Vickers hardness was noticed for Cu-GO-20mm compared sample. Addition of GO, good compaction, good bonding, less friction between die wall and particles and reduced pore size between particles increases the Vickers hardness composite significantly.

Table -3: Vickers hardness results of fabricated Cu-GO composites.

Sr.no	*Material*	*Microhardness, Hv*
1	Pure copper [2-9]	85
2	Cu-GO-10mm	88.70 (↑ 4%)
3	Cu-GO-15mm	96.39 (↑ 13%)
4	Cu-GO-20mm	105.34 (↑ 24%)

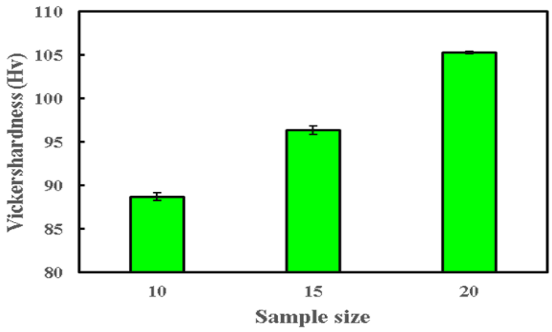

Fig -3: Vickers hardness of sintered samples

B. *Microstructure Analysis*

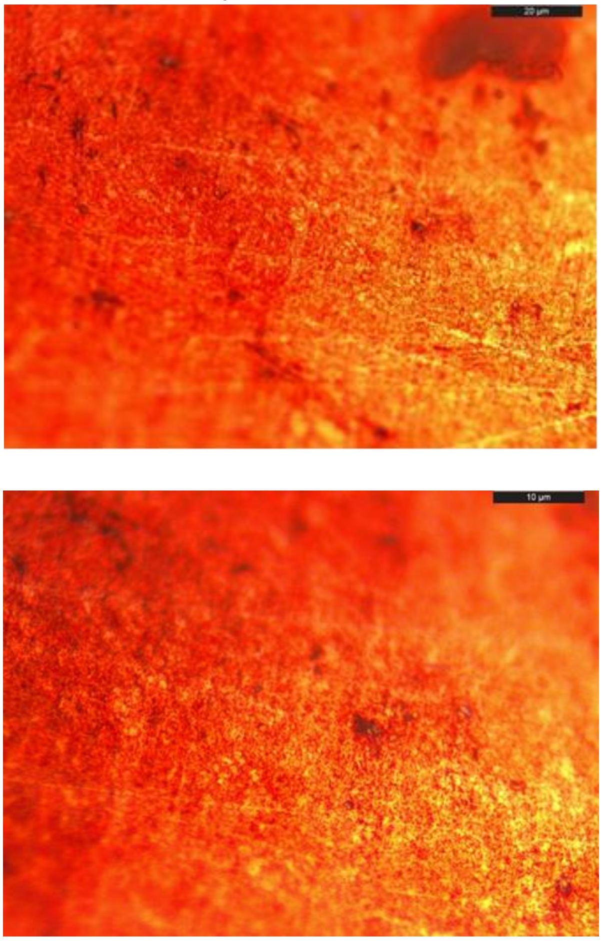

Fig -4: Optical micro graphs of fabricated samples (a) Cu-GO-10mm 50X, 100X

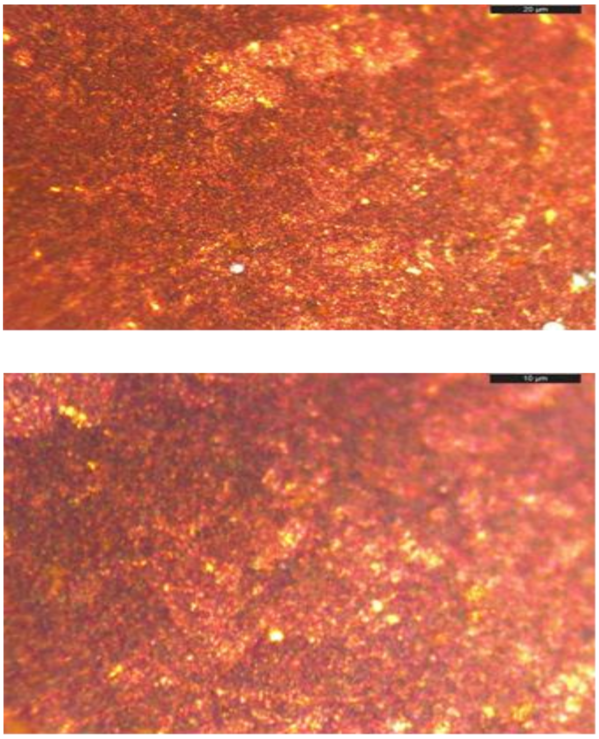

Fig -4: Optical micro graphs of fabricated samples (b) Cu-GO-15mm 50X, 100X

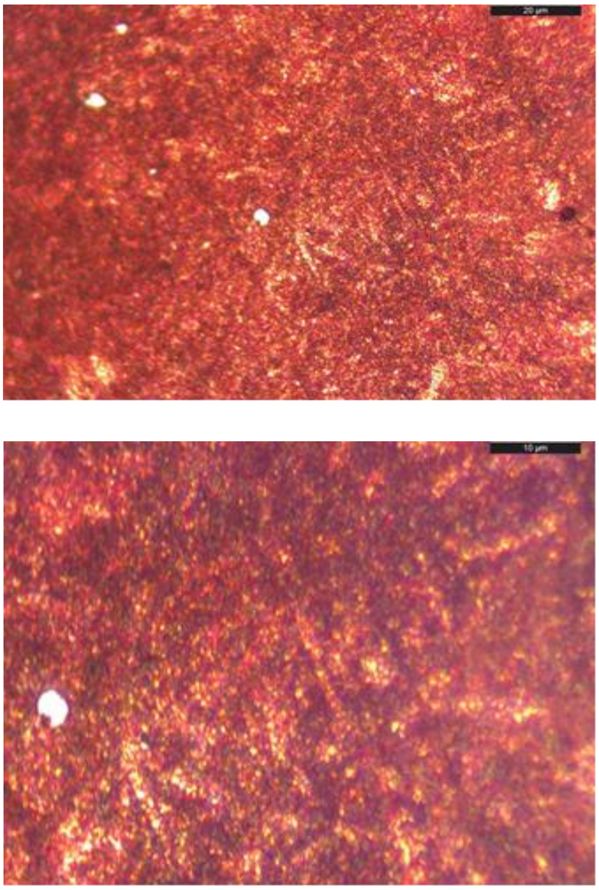

Fig -4: Optical micro graphs of fabricated samples (c) Cu-GO-20mm 50X, 100X

Optical micrographs showed that, the presence of Go and uniform distribution of GO particles in the copper matrix. The optical micrographs of Cu -GO composites were shown in figure 4(a) to (c). It was observed from the micrographs that the GO particulate reinforcement was distributed uniformly throughout the Cu matrix. No significant agglomeration was noticed in the micrographs. Increase in porosity with increase in decrease in pellet size was revealed in the micrographs. Compared with micrograph of Cu-GO-10mm in the case of Cu-GO-20mm, wide grain boundary was noticed. Decrease in density and hardness was due to irregular structure of GO and poor bonding between GO and Cu, and therefore wider grain boundary was obtained. Still, the grain size of Cu decreased significantly.

CONCLUSIONS

In this work, copper (cu) with 5 wt.% graphene oxide (GO) were successfully fabricated using powder metallurgy technique. The physical, microstructural, and mechanical properties of fabricated composite were investigated in detail. The conclusions derived from the study are as follows.

1. The presence of GO particles slightly decreases the mass density of pure copper, increases the Vickers hardness of the fabricated composite to 24% than pure copper. Maximum experimental sinter density was observed for 20 mm size composite sample and maximum Vickers hardness was noticed for again 20mm size composite sample which was due to good bonding between copper matrix and graphene oxide reinforcement.
2. Experimental sintering density was increased with increase in composite sample size which was due to good compaction between Cu and GO powder, less friction between compaction dies wall and Cu-GO particles and more surface area so that low pressure is enough to get good compaction samples.
3. Porosity of fabricated composite samples decreases significantly, and low porosity was noticed for 20mm size composite sample of about 1.31%, which was due to fact that the pore gap between the particles get reduced because of good bonding and good compaction.
4. Optical micrograph clearly reveals the microstructure of fabricated copper and graphene oxide composite samples, presence of graphene oxide content, refined grain size and grain boundary.

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