Novel Nanocomposite Alloys With Enhanced Mechanical Performance and Customised Thermal Expansion Factor for Electro-Packaging Use

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**Abstract:** This study used a wet-mixed approach and traditional powder metalworking to create copper nanocomposites enhanced by graphite nanoplatelets (GNPs). To determine the optimal dispersal method, wet mixing and the use of ball mills were used. Following the mixture, a qualitative investigation of the material's composition revealed that the wet mixture is a suitable method for dispersing the GNPs. After that, research continued on how the graphite content in materials affected their structure, density, toughness, elasticity modulus, and thermal contraction rate. It has been demonstrated that as graphite percentage increases, graphite aggregates become more visible and negatively impact their final qualities. The inclusion of graphite caused the Cu-GNP alloys to be lighter than the unreinforced copper and to have a higher toughness and Young's modulus of elasticity. The main process of reinforcement in this study is the finetuning of grains, which was found by looking at the microstructure of pure metal and its mixtures during sintering.  In addition to their mechanical qualities, hybrids' rate of thermal expansion can be significantly lowered. This property, when combined with appropriate structural qualities, may make combinations a viable option for use in electronic container systems.

**Keywords:** Nanocomposite; Tailored coefficients; Mechanical strength; Copper; Graphene.

# Introduction

In recent years, substances known as metallic matric nanocomposites (MMNCs) have become commonplace in a variety of sectors, including the aerospace, automotive, and electronics packaging sectors. For example, take the area of gadgets in the box: as technological development and electronics device efficiency rise in tandem, devices emit greater amounts of heat, making temperature issues in choosing materials and layout increasingly important. In fact, sophisticated electronics packaging supplies have a major impact on the functionality and usability of packed electronics assemblies [1]. The main purposes that need to be taken into account are heat transfer and dissolution, mechanical assistance, thermal insulation, and ecological safeguarding. Computer cooling systems, or heat sinks, for short, were created to address this problem. Ceramics having a rate of thermal extension (CTE) around 3 × 10−6 K−1 and 8 × 10−6 K−1 and a thermal conductivity of in excess of 170 W/mk have been suggested as appropriate for implementation in this instance.

A number of factors ought to be taken into consideration when choosing an appropriate substance for use in electronics packaging in order to balance function, efficiency, manufacturing, dependability, and price. Because of its great thermal conductivity as well as its expenses, aluminium has become one of the most intriguing metals for use in electronics packaging systems. Its poor yield strength and elevated expansion rate at ambient temperatures, however, have restricted its use [2]. Therefore, it is essential to enhance these properties via the creation of nanocomposite or thermal treatment, with the goal of overcoming these shortcomings and increasing the use of metals and their alloys. Nevertheless, novel compounds that have superior mechanical characteristics, a low coefficient of expansion due to heat, and a high degree of electrical and thermal conductivity must be created so as to expand the use of metal alloys [3]. Therefore, it is crucial to create the substance so that the strengthening substance is dispersed uniformly and that the reinforcement element and matrices form a good interface connection. In broad terms, solid and insoluble nanoparticles may be added to metal matrices to create metal matrice hybrids [4]. Depending on the intended use, these insoluble and solid particles may be oxides employed, borides, nitric oxide carbide, or carbon-based compounds. Research claims that traditional casting methods are inappropriate for creating this sort of material because of the low wetting between hot copper and reinforcement granules. In order to create the copper-based materials, alternative ways of production were devised, like powder metalworking methods. Aluminium and its alloys are primarily used in thermal management and electrical wrapping, in addition to for architectural and mechanical purposes. It ought to be remembered that contaminants can have a significant impact on the electrical functions of metal alloys. Certain impurities can precipitate during the process of heat treatment, which would reduce the conductivity of the material. For example, Caron et al. have observed how 0.065% iron added throughout the process of production may reduce silver's conductivity to electricity to just 96% (IACS) [5].

Furthermore, it has been noticed that copper's electrical ability may be reduced to 82%, 75%, or 49% in the IACS, accordingly, by the addition of 0.2% zinc and 1.3% Al, which is or 0.05 percent P. However, graphene nanoplatelets may draw a lot of interest when used as reinforcement materials because of their special qualities, which include very good thermal conductivity and low coefficients of expansion due to heat in the cross-plane axis. The main objectives of this work are to create novel Cu/GNP alloys with enhanced durability, suitable for electricity and heat transfer, and customised CTE, in addition to examining the impact of nanoplatelets of graphene on structural aspects of metal composites as well.

# Experimental works

## Materials and method

The 99.95 percent of pure copper (Cu) powdered form, measuring 160–250 µm in size. The material was provided by GKN Industries India; it possesses an uneven shape with an interior that is porous (soft texture). The identical firm provides graphene nanoplatelets, or GNPs, with an outer size of 750 m2/g, dimensions of 30 µm in length, 150 nm in thickness, and 100% purity. To use the unique physical, thermal, and electrical properties of graphite nanoplatelets, there should be a uniform distribution of GNPs inside a metal substrate. Thus, in this study, physical grinding and a unique moist mix approach suggested by Bradshaw were used to distribute GNPs throughout the metallic substrate; both methods are detailed in the next paragraphs [16-21].

Using a Pulverised 5 global ball mill, which consists of mechanical milling procedures, nanocomposite powders were prepared. Five millimetre hammered metal pellets served as the grinding medium, and the beginning powders were incorporated in a jar made of harder steel. It was decided to set the ball-to-powder ratio (BPR) at 15:1. An argon environment was used to avoid corrosion throughout the milling step, and alcohol was used as a method controlling ingredient (PCA) to avoid excessively hot metal shaving welding. In order to maintain the appropriate temperature throughout the milling procedure, the nervousness of a cylindrical grinding device at 200 rpm for 90 minutes occurred manually; reference specimens made from pure copper were additionally manually turned in the same conditions. A 30-minute stop step-by-step was added following each 30-minute anxiety period. Using ultrasonic stimulation, nanoplatelets made from copper atoms were initially disseminated independently in alcohol. To get the desired final percentage of carbon nanoplatelets (GNPs), a suspension of water was introduced by drops onto a copper powdered solution following 45 minutes of ultrasound. Laminated particles containing 3.0 vol% and 8 vol% graphite have been generated by varying the GNP concentration [22-29]. The liquid was ultrasonically processed for 60 minutes to achieve a seamless dispersion. The resulting mix was then passed through filters, and the ultimate composite powder was created by drying it for six hours at 90 °C.

# Result and discussions

The proportional density and Vickers toughness of these metal nanocomposites, as shown in Figure 3, are indicators of graphite concentration. It is evident that, especially in the Copper-8 vol% GNPs samples, the overall density of metal and its combined components dropped as an indicator of GNP concentration. Therefore, it is reasonable to draw the conclusion that the ultimate density of these compounds is negatively impacted by the GNP component. The bulk density of the combinations decreased in excess of what was expected, and this difference is most likely caused by more permeability within the material. As previously demonstrated, GNPs have a tendency to combine with more material, which causes steric barriers to emerge during compound condensation and limits the movement of matrix components to the aggregates [6, 30-33]. However, because of the GNPs' ability to smooth grain structure inside the framework, the Vickers toughness of the mixtures grew as the SnP concentration rose. The degree of mismatch stresses induced into the substrate, whether it's a result of reinforcing with distinct features or because of microstructural shifts, is indicated by the ratio of heat expansion readings. During heating, the remaining strains at the borders are caused by the physical characteristics, morphologies, or volume of each phase's grain. Barring metal expanding or the borders breaking down, the remaining strains at the edges may be communicated. In this study, the mechanical characteristics and CTE of the metal composites have been enhanced by reinforcing with two distinct percentages of graphite. Anisotropic features happen because GNPs tend to be oriented across from the compressing guidance, which has been shown before. It was expected that the CTE in the composites would behave in an uneven way because the graphite CTEs were very different when they were oriented in the same plane or out of the plane [7]. In this study, all CTE tests of the Cu/GNP composites were conducted in an orientation perpendicular to the compression pressure [8, 34-39].



**Figure 1.** XRD images of hybrid composites

Figure 1 illustrates how increasing the GNP concentration reduced the rate of heat expansion of metal composites [9]. This phenomenon may be connected to the stronger drag force that GNPs apply to the movement of the grain line. Furthermore, because of their extremely reduced CTE, GNPs applied additional compression stress to the boundaries of grains throughout the growth of metal [10]. The force exerted throughout the expanding process may restrict this characteristic of metal grains, leading to a reduction in the composite's CTE. Furthermore, there was a strong correlation between the observed CTEs in our study and those published in the scientific literature [11]. Numerous models have been developed for determining the CTE of composites, depending on the research currently accessible on the subject of composite product CTE. As previously mentioned, the synthetic materials were created using the uniaxially compacted method, and throughout the process of compaction, the GNPs exhibit a preferential orientation with regard to the compression axis [12].

As a result, the type of orientation of choice could have an impact on the characteristics of composites along many knives; consequently, modelling ought to allow for it [13]. Figure 2 shows the computed CTEs for different percentages of volume of graphite with positive CTE, jointly alongside the observed dementia for pure copper, copper-4.0 vol% GNPs, and copper-8.0 vol% GNPs that were. An alternative definition for the volume percent of graphite having positive CTE is the volume percentage of the GNPs oriented parallel to the compression [40-45]. The impact of GNPs with a damaging CTE could be substantial if 60% of the GNPs were aligned parallel to the compression power [14], as shown in Figure 3. The impact varies with the amount of GNPs in Al oriented in that direction. It indicates that less than 20 percent of the total proportion of GNPs were oriented orthogonal to the compression power, based on comparison with the observed CTE values of the copper-4.0 vol% as well as the copper-8.0 vol% GNPs that are However, it is theoretically possible to speculate that the Cca within the composite might be less if the copper and GNPs in Al had a close relationship. In contrast, it was discovered that the copper-8.0 vol% GNPs had a poorer GNP effectiveness as a result of CTE decrease than the copper-4.0 vol% GNPs, which Poor interface connection, permeability, and nanoparticle agglomeration at increased graphene contents might be the cause of the poor effectiveness [15, 46-50].



**Figure 2.** Relative density of the composites based on various volume fraction of graphene



**Figure 3.** Hardness values of the composites based on various volume fraction of graphene

# Conclusion

Cu/GNP Tiny materials were effectively created by a traditional grinding method and wet-mixed. Both wet mixture approaches have a lot of promise for usage as disperse methods, but the ball milling method isn't the right way to distribute the particles of GNPs inside the iron matrices, as confirmed by the GNPs' Raman spectroscopy and microstructural studies. Grit refining resulted from the unpredictability of tiny particles of graphene inside a matrix caused by wet combining, with most of the graphene found near the iron border of the grain. The graphite nanoplatelets aligned predominantly parallel to the compression axis throughout the mixed powder's compacting, suggesting the finished product may exhibit anisotropic features. Aside from diamonds being located at the edges of the grains, when the graphene concentration is increased to 7 vol%, the amount of aggregates rises significantly, and the nanoplatelets are likely to accumulate in clusters. Because of the refinement of grain operation, the materials' hardness, according to Vickers, and modulus of elasticity rose when the graphite concentration was raised. The coefficient of thermal growth of metal alloys varied at multiple temperatures between 200 °C and 700 °C, indicating that an increase in nanoparticle concentration resulted in a reduction in the rate of heat contraction of metal alloys.

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