Journal of Mines, Metals and Fuels, *71(12D): 77-82; 2023. DOI: 10.18311/jmmf/2023/47994*

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: *www.informaticsjournals.com/index.php/jmmf*

Direct Observation of Addition of Graphene to Copper Nanocomposite

B.C. Praveen Kumar[1]*, R. Shobha[2], Harish Hanumanthappa[3], R.M. Varun[4] and G.M. Yash[4]

[1]Department of Mechanical Engineering, Visvesvaraya Technical University, Belagavi - 590018, Karnataka, India; praveenkumar.bc@atria.edu

[2]Department of Industrial Engineering and Management, Ramaiah Institute of Technology, Bangalore – 560054, Karnataka, India

[3]Department of Mechanical Engineering, R.V. Institute of Technology and Management, Bengaluru – 560041, Karnataka, India

[4]Nanomaterials Research Centre, Department of Mechanical Engineering, Atria Institute of Technology, Hebbal, Bangalore – 560024, Karnataka, India

Abstract

Carbon atoms are tightly bonded in Graphene to form hexagonal crystal structures. This work synthesised graphene copper nanocomposites using the powder metallurgy technique. Graphene powder was coated with nickel using an electroless coating followed by ball milling. Further Nickle coated graphene with copper powder was hydraulic pressed and the samples were sintered in a furnace. The sintered samples were tested for wear properties by using a pin-on-disk wear testing machine at different loading conditions. The results indicate that the addition of Graphene by 0.25 wt % with Copper exhibits high wear resistance. This represents that nickel-coated Graphene plays a major role in converting low-resistance copper into high wear-resistant material. The newly fabricated nickel-coated Graphene with Copper nanocomposites shows a 71% increase in wear resistance when compared to pure Copper. Also, the wear coefficient and wear rate decreased for newly fabricated graphene copper nanocomposites when compared to pure copper.

Keywords: *Ball Milling, Electroless-Copper Coating, Scanning Electron Microscopy (SEM)*

1.0 Introduction

The most commonly used composite materials are metal matrix composites which are used for manufacturing parts for the automobile industries. Metal matrix composites have very good mechanical properties when compared to base metals. Also, metal matrix composites can be easily fabricated by advanced manufacturing techniques like powder metallurgy and casting. To achieve good mechanical properties in composite materials powder metallurgy technique has more advantages when compared to casting techniques.

Recently Graphene has been a subject of intensive research worldwide. It has shown a lot of exceptional properties such as Quantum Hall Effect (QHE), very high Young's modulus (1TPa), high fracture strength (125GPa), excellent thermal conductivity (5300$Wm^{-1}K^{-1}$) and good optical transparency (97%)[1]. A great deal of work has been done in the area of synthesis and characterization of Graphene reinforced with metal matrix composites.

Copper (Cu) is the most common material used in integrated circuits, electrical switches, and electronic

*Author for correspondence

enclosures due to its outstanding qualities such as high electrical conductivity, and fatigue resistance. Despite this, its mechanical properties are limited. Researchers studied copper-based nanocomposites reinforced with various particles to evaluate their properties for functional applications compared to pure (unreinforced) matrix material[2].

2.0 Materials and Method

2.1 Material Selection

Copper is chosen as a base material and Graphene is chosen as a filler material. Table 1 shows the properties of Copper and Graphene.

Table 1. Properties of Copper and Graphene

Properties	Copper	Graphene
Density	7g/cm^3	0.1g/cm^3
Young's Modulus	117Gpa	2.2-2.4Tpa
Thermal Conductivity	394W/mK	3000 W/mK
Melting Point	1083^{0}C	3600^{0}C

2.2 Fabrication of Nanocomposites

The powder metallurgy technique was used to prepare the graphene copper nanocomposite samples. Initially, before the hydraulic press, Graphene powder is coated with nickel by electroless coating. Later this coated graphene powder is mixed with Copper in a ball mill. Then the mixed Copper and nickel-coated Graphene powder were made into small billets by using hydraulic press. Further, the billets are sintered in a muffle furnace at a temperature of 8000C for 4 hours[3].

2.3 Experimental Procedure

In this study, 0.25 wt.% of nickel-coated Graphene is reinforced with pure Copper powder. The mixture is thoroughly blended in a ball mill for about 2 hours. After the ball milling process, the blended powder is compacted in a hydraulic press. After the compaction process, the compacted powder is sintered in a muffle furnace at about 8000C and it is cooled at room temperature. The sintered

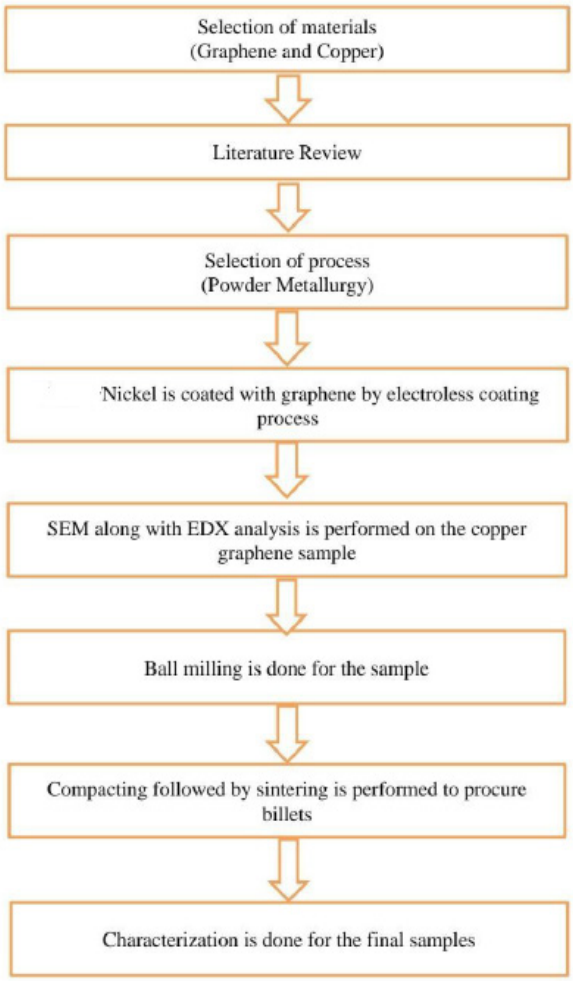


Figure 1. Methodology.



Figure 2. Pure copper.



Figure 3. Nickel coated Graphene.



Figure 4. Ni-coated billet sample (30mm x 6mm).

nanocomposites were characterised before and after the wear test. The 0.25 wt.% of nickel-coated graphene with pure copper specimen was tested by using Pin on disk wear testing machine for different loading conditions such as 10kN, 20kN and 30kN[4].

3.0 Results and Discussion

The results show that the addition of nickel-coated

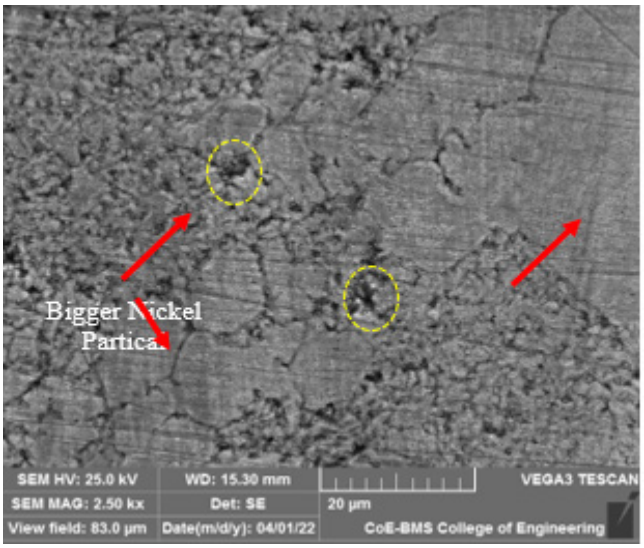


Figure 5. SEM image of a specimen of Nickle coated of Graphene with Copper before wear.

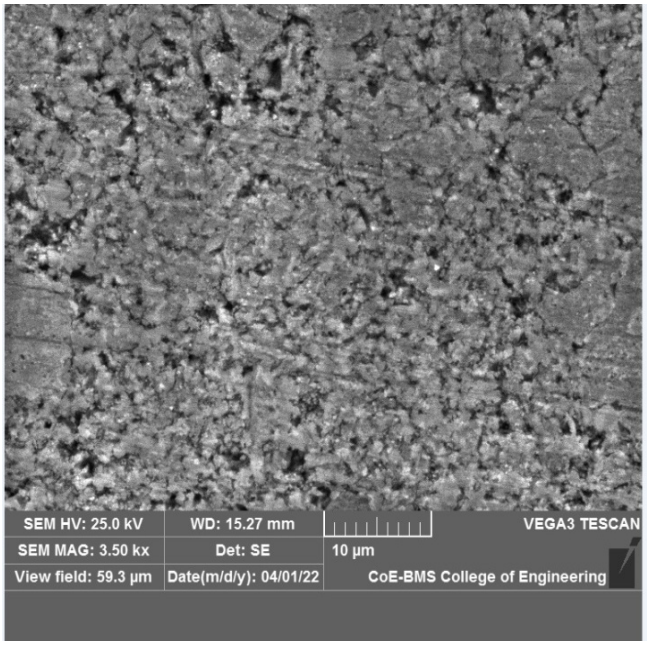


Figure 6. SEM image of Specimen Graphene with Copper before wear

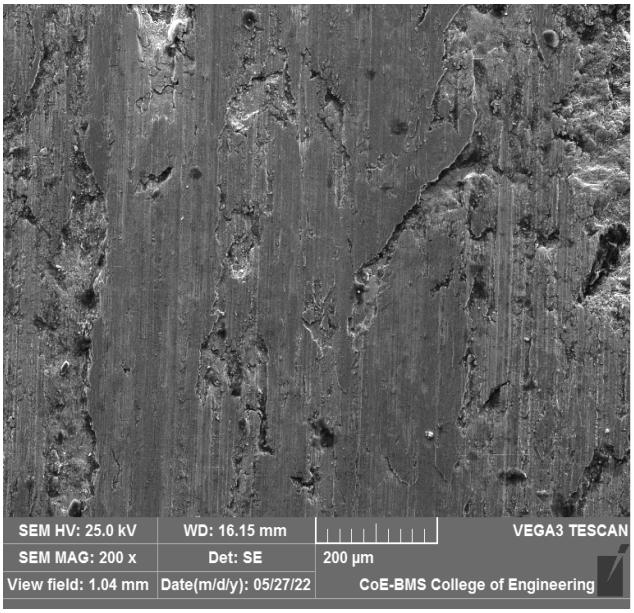


Figure 7. SEM image of a specimen of Nickle nickel-coated Graphene with Copper after wear.

Graphene with Copper can increase the Copper properties and convert Copper into wear-resistant material. The Tribology properties such as the wear resistance of each component are determined by a wear test by a pin-on-disk wear testing machine and the same results were compared with pure copper nanocomposites.

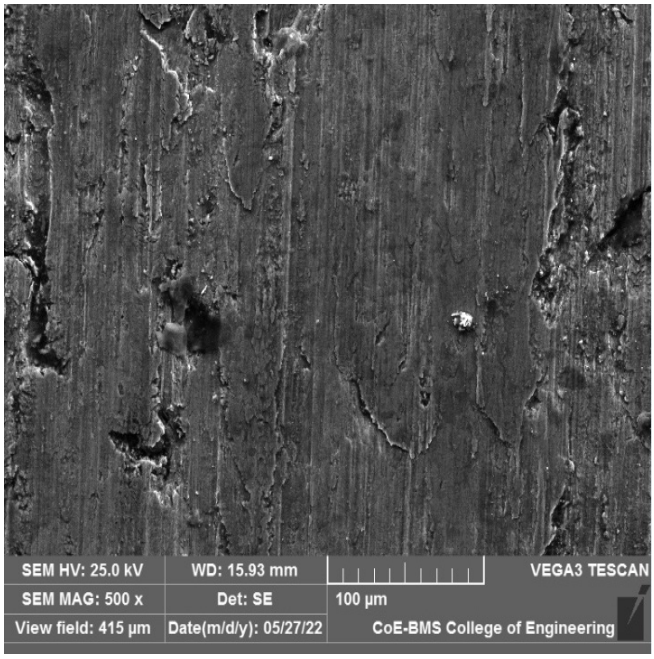


Figure 8. SEM image of a specimen of Coated Graphene with Copper after wear

3.1 Wear Test

The wear test is performed using the pin-on-disk testing machine with different load conditions. The load was varied from 10kN to 30kN with an interval of 10kN. Initially, pure Copper was subjected to different loading conditions (10kN to 30kN). The wear test was also performed on a specimen of Nickle nickel-coated graphene with Copper at different loading conditions.

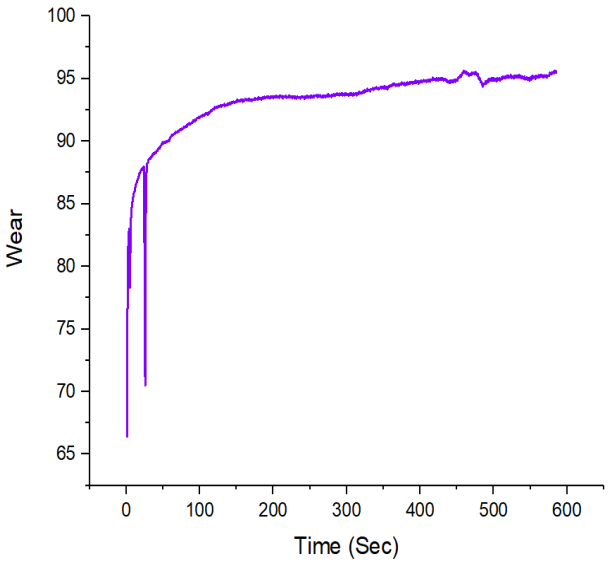


Figure 9. Wear Analysis for Pure Copper at 10 kN Coated.

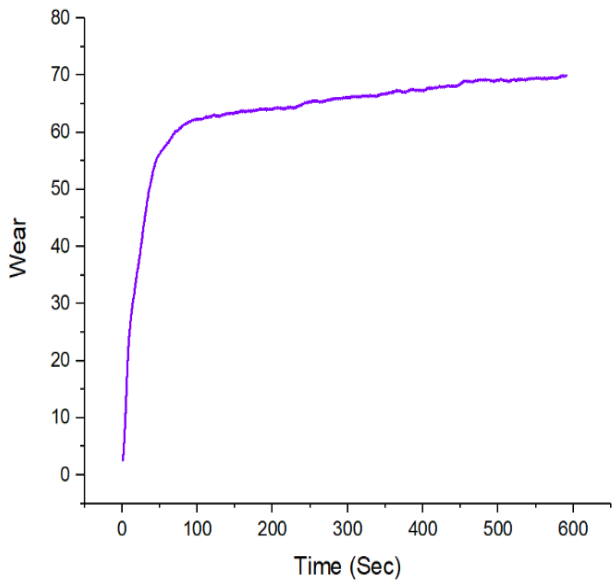


Figure 10. Wear Analysis for Nickle Graphene with Copper at 10 kN.

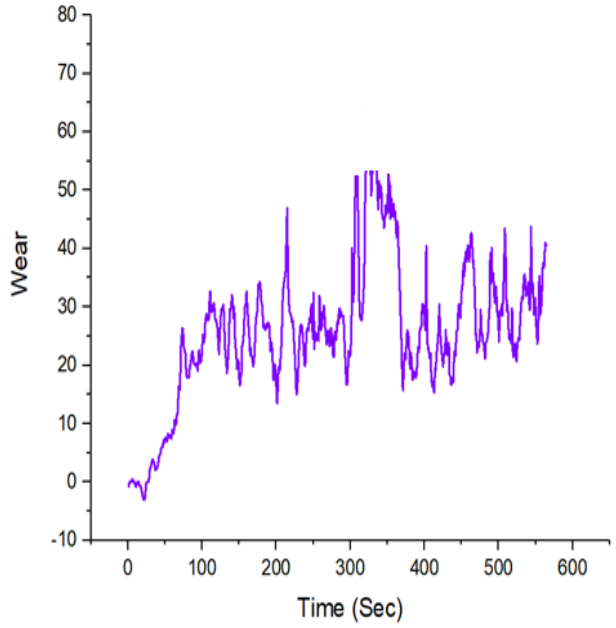


Figure 11. Wear Analysis for Pure Copper at 20 kN Coated.

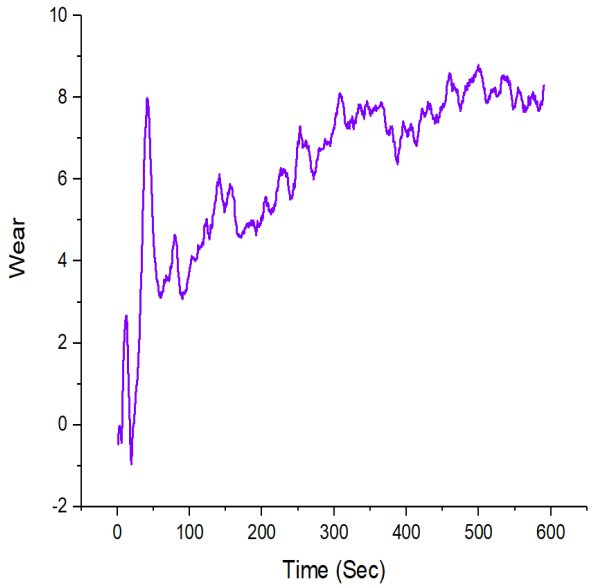


Figure 12. Wear Analysis for Nickle Graphene with Copper at 20 kN.

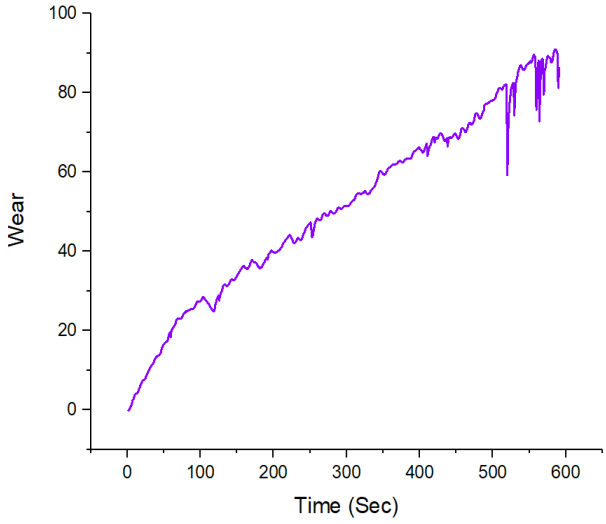


Figure 13. Wear analysis for pure copper at 30 kN.

The results show pure Copper as the maximum wear coefficient when loaded at 10kN compared to 20kN and 30kN as shown in Figures 3.5, 3.7 and 3.9. These results represent with increase in load for pure copper showing higher wear resistance and a lower friction coefficient of about 95%.

The results show the specimen of nickel-coated Graphene with Copper as the maximum wear coefficient when loaded at 10kN compared to 20kN and 30kN as shown in Figures 10, 12 and 14. These results represent with increase in load for pure copper matrix shows higher wear resistance and lower friction coefficient of about 67%.

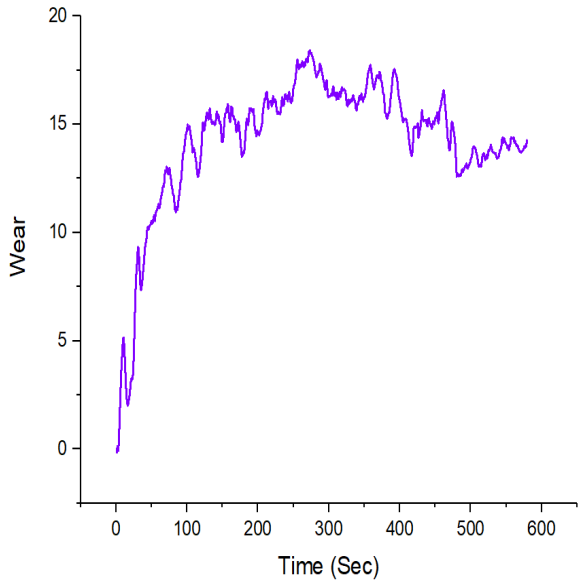


Figure 14. Wear analysis for Nickle coated Graphene with Copper at 30 kN.

When comparing pure Copper (Figure 3.5) with nickel-coated Graphene-copper nanocomposite (Figure 3.6), shows higher wear resistance and a lower friction coefficient of about 71%.

The results represent that the wear properties of nickel-coated graphene copper nanocomposite were improved when compared with pure copper. Therefore, fabricated metal matrix composites can be used to replace pure copper in the industry.

4.0 Conclusion

In the present work powder metallurgy technique was adopted to fabricate graphene copper nanocomposites. The Nickel-coated Graphene-Copper nanocomposites were characterised by using SEM. The analysis shows that nano-graphene particles are uniformly distributed in copper (Figure 3.1). The wear rate of coated graphene-copper nanocomposites was improved compared to pure copper.

The wear friction coefficient of nickel-coated graphene-copper nanocomposites was reduced compared to pure copper.

The results show that the powder metallurgy technique is the most suitable technique for the fabrication of high-wear resistance nanocomposites.

5.0 References

1. Wang HY, Huang, Wu, Hou L, Yang, Jin Zou. Synthesis, growth mechanism and thermal stability of copper nanoparticles encapsulated by multi-layer graphene. Carbon. 2012; 50(6):2119-2125. https://doi.org/10.1016/j.carbon.2011.12.063
2. Zhang, Z. Strengthening effect of graphene derivatives in copper matrix composites. J Alloys Compds. 2016; 654(1):226-233. https://doi.org/10.1016/j.jallcom.2015.09.013
5. Varol T, Canakci A. Microstructure electrical conductivity and hardness of multilayer Graphene/Copper nanocomposites synthesized by flake powder. Int J Miner Metall Mater. 2015; 21(4):704-712. https://doi.org/10.1007/s12540-015-5058-6
6. Tang, Yang, Wang, Li M. Enhancement of the mechanical properties of graphene-copper composites with graphene nickel hybrids. Mater Sci Eng. 2014; 599(1):247-254. https://doi.org/10.1016/j.msea.2014.01.061
7. Singh P, Nayak KK, Bhattacharjee J, Besra. The production of a corrosion-resistant graphene-reinforced composite coating on copper by electrophoretic deposition. Carbon. 2013; 61(1):47-56. https://doi.org/10.1016/j.carbon.2013.04.063
8. Ren, Meng, Shehzad, Xu, Qu, Yu, Luo J K. Mechanical properties of nickel-graphene composites synthesized by electrochemical deposition. Nanotechnology. 2015; 26(6):1-8. https://doi.org/10.1088/0957-4484/26/6/065706 PMid:25605375.
9. Hwang, Yoon, Jin, Lee, Kim, Hong, Jeon. Enhanced mechanical properties of Graphene/Copper nanocomposites using a molecular-level mixing process. Adv Mater. 2013; 25(46):6724-6729. https://doi.org/10.1002/adma.201302495 PMid:23983045