

# CHARACTERIZATION OF Cu-SiC-Gr HYBRID METAL MATRIX COMPOSITE

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**Abstract—** In Copper-Silicon Carbide-Graphite metal matrix composites, copper possesses excellent thermal and electrical conductivities, Silicon carbide possesses high strength and hardness, and Graphite has solid lubricating and low thermal expansion coefficient. Copper matrix containing Silicon Carbide and Graphite are widely used as brushes, and bearing materials in many applications due to the excellent thermal and electrical conductivities, and the favorable self-lubricating performance. The addition of solid lubricant particles into a metal matrix improves not only the anti-friction properties, but also wear and friction properties.

In this context, Copper-Silicon Carbide-Graphite MMCs are fabricated by mixing wt. % of 5, 7.5 and 10 Silicon Carbide and Graphite powder into copper powder followed by powder metallurgy. The composite powder mixture was cold compacted by Hydraulic press and then sintered in tubular furnace using argon gas. The MMCs are characterized by scanning electron microscopy (SEM)

**Keywords—**component; formatting; style; styling; insert (key words)

## I. INTRODUCTION

The concept of composites is not a human invention. Composite materials are extending the horizons of designers in all branches of engineering. Composites are heterogeneous in nature, created by the assembly of two or more components i.e. with a matrix and reinforcement materials, enable us to make better use of their virtues while minimizing to some extent the effects of their deficiencies. This process of optimization can release a designer from the constraints associated with the selection and manufacture of conventional materials. Composites are one of the most advanced and adaptable engineering materials known to mankind. Progress in the field of materials science and technology has given birth to these fascinating and wonderful materials. The matrix may be metallic, ceramic or polymeric in origin. The type gives the composites their shape, surface appearance, environmental tolerance and overall durability while the fibrous reinforcement carries most of the structural loads thus giving macroscopic stiffness and strength. A composite material can provide superior and unique mechanical and physical properties because it combines the most desirable properties of its constituents while suppressing their least desirable properties.

Understanding the relationships among the processing structure and properties of metal or ceramic interfaces is becoming increasingly important as performance requirements

demand the use of metal-ceramic composites in applications ranging from electronic devices to high temperature aircraft structures. So in metal-ceramic composites the overall composite properties depend critically on the properties of metal-ceramic interface. The particulates reinforced metal matrix composite (MMC) is one of the new structural materials, and a rapid development that can be seen in recent years because of excellent properties like specific strength, specific stiffness, wear resistance, corrosion resistance and elastic modulus etc. and wide application prospects in the near future. For several years research on fabrication methods and material property estimations for particulates reinforced metal matrix composites has been one of the focuses in composite fields, and many excellent research results have been obtained. A metal matrix composite system is generally designated simply by the metal alloy designation of the matrix and the material type, volume or weight fraction and form of the ceramic reinforcement. Various Metal Matrix Materials have been combined with each other and give intended properties that are different from their base materials. But, neither matrix nor reinforcement can't be alone, but only MMC can be able to fulfill the requirement. MMCs are exciting materials which find increasing applications in aerospace, defense, transportation, communication, power, electronics, recreation, sporting, and numerous other commercial and consumer products. Rapid advancements in the science of the fibers, matrix materials, processing interface structure, bonding and the effect of their characteristics on the final properties of the composite have taken place in the recent years. MMC's differ from other composite materials in several ways.

## II. LITERATURE REVIEW

Zhan and Zhang suggested that both graphite and silicon carbide particles can act as hybrid reinforcements and effectively improve the mechanical as well as tribological properties of copper based hybrid composites. They also reported that addition of graphite is an important precondition for the formation of a graphite-rich mechanical mixed layer, which restricts the wear of such hybrid composites. [1].

G.Arslana and R.Janseen suggested that the localization of frictional heat on the sliding surface may cause thermally induced micro-cracking and concomitant reduction in the wear resistance and fracture toughness. So, to withstand the high interface temperatures, brake materials should possess

high thermal stability and thermal conductivity to effectively dissipate the generated heat. Further the crack resistance of the composites should be high to avoid catastrophic failure during emergency brake conditions, while the presence of ceramic particles improves the wear resistance; it proves the detrimental to the overall thermal conductivity and crack resistance. [2].

F.F.O.Orumwense, B.A.Okorie and E.O.Okeakpu are studied the spherical precipitated copper powders and flake like graphite powders generated by mechanical comminution and the results reveal that particles that are nearly spherical in shape have lower friction, lower compression ratios and higher electrical resistivity's in sintered compacts than powders with acicular or flake like particles. The spherical powders also suffers from more particle deformation and also have high level of porosity. Also, the effects produced by the small additions of lead and zinc (upto weight-%2.5) on the electrical resistivity and hardness of sintered copper-graphite compacts are also presented. [3].

Hassan AM and Alrashdan A suggested that after his studies on addition of SiC to Al-Mg-Cu alloy leads to increase in wear resistance property. He also said that wt.-%, of reinforcement is the most significant parameter for influencing the wear behavior.[4].

### III. PREPARATION OF SAMPLES

#### 3. 1. Details of Materials:

##### 3.1.2. Copper:

Copper is mostly used industrial and functional metal for thermal and electronic packaging, electrical contacts and resistance welding electrodes as it has very good electrical and thermal conductivity. Copper-graphite powder compacts are useful for the manufacture of electrical contact parts, notably carbon brushes for automobile kick starters. The amount of graphite in these parts may range from 5–15%. There is need to keep porosity down to a minimum in order to optimize electrical conductivity, and since these brushes rub on rotating metal parts (the commutation of a DC generator or motor, or the slip rings of an AC motor or generator), some wear resistance is necessary. The advantage of the copper-graphite composites is the combination of the positive characteristics of both elements, such as electrical and thermal conductivity from the copper and a low thermal expansion coefficient and lubricating properties from the graphite. The advantages of using powder metallurgical processes over other processes are the possibility of obtaining uniform brushes and of reducing the tedious and costly machining processes. Most of the bearing alloys that are presently used contain a soft phase like lead, which give the required anti-friction property. Due to its harmful effects, restrictions have been imposed on the use of lead. This has prompted researchers to find alternative materials, which impart tribological properties similar to those of lead. Certain metal matrix composites (MMCs) containing soft particles have been investigated for tribological properties.

These MMCs have not only reduced friction but also lead to reduced wear of the counter face.

Faced with all these challenges like low mechanical properties of pure Cu, Cu based alloys and harmful effects of Pb, a suitable alternative material copper-Silicon Carbide-Graphite metal matrix composite has been developed in the present investigation.

Although certain metals, metal oxides and non-metallic materials have desirable characteristics for contact applications, such as erosion and welding resistance, but are of low conductivity. Combination of these with copper, to give acceptable conductivity, should therefore produce a material with optimum properties. Unfortunately the metals concerned are of high melting point and do not alloy with copper, consequently it is not possible to produce them by conventional melting techniques. This also applies to the metal oxide and non-metal combinations with copper. The only viable manufacturing procedure at room temperature to produce such combinations is powder metallurgy.



##### 3.1.2 Silicon Carbide:

Silicon carbide (SiC), also known as carborundum, is a compound of silicon and carbon with chemical formula SiC. SiC Powders are specifically manufactured to be used for general abrasive applications in bonded abrasive tools, lapping and polishing processes. With a lower hardness and abrasive capacity than diamond or boron carbide, it is widely used for grinding nonferrous materials, finishing tough and hard materials, as well as filling up ceramic parts due to its lower cost. Generally grit sizes range from coarse grades down to a 1500 mesh size.



Fig 1: Silicon carbide

Pure SiC is offered in HR, MR and LR grades for applications where high, mid-range or low electrical resistivity is required. It occurs in nature as the extremely rare mineral moissanite. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests. It is available in two

forms. They are green sic and black sic. Green SiC is made from Silica sand and coke, and is extremely pure. Hexagonally shaped, it breaks into very sharp particles. Green SiC is 99.5% pure, exceeding JIS, ISO, & FEPA standards & Green SiC is harder than black, coming in at a 9.4 Mohs and 2600 on the Knoop scale. Green SiC is often the media of choice when it comes wire sawing. The micronization process of manufacturing green SiC is controlled by a computer. Then the material is water classified/separated - this produces a very tight particle size distribution, as well as a reduction in fines, as preferred for accurate wire sawing applications. Green SiC powder can also be used to make heating elements, electrical resistors and light-emitting diodes. Black SiC is a man-made mineral with a high thermal conductivity rating of 100 W/m-K. It is extremely hard, around a Mohs 9.1 or 2550 Knoop. It has high strength at elevated temperatures.

### 3.1.3 Graphite:

Generally, there are three forms of carbon. They are diamond, charcoal and graphite. Graphite is a crystalline form of carbon, a semimetal, a native element mineral, and one of the allotropes. Graphite is the most stable form of carbon under standard conditions. Therefore, it is used in thermo chemistry as the standard for defining the heat of formation of carbon compounds. It can be classified as disseminated flake, crystalline vein (fibrous or columnar) and amorphous. The flakes when well crystallized have a black metallic lustre, whereas the amorphous material is black and earthy with a microcrystalline compactness. Synthetic graphite is produced from petroleum coke and pitch. Graphite is an excellent conductor of heat and electricity and has a high melting point of 3,500°C.

It is extremely resistant to acid, chemically inert, and highly refractory. Graphite may be considered the highest grade of coal, just above anthracite and alternatively called meta-anthracite, although it is not normally used as fuel because it is difficult to ignite. Generally prices for flake graphite concentrates are higher than those for microcrystalline (amorphous) graphite. Prices for flake graphite vary depending on the carbon content, the size of the flakes, their distribution, and the ash content.

Initially, the powder is filled in the die which is of 13 mm in order to know the quantity of powder required for each sample as per the defined aspect ratio. The filled powder is measured in an electronic weighing machine as shown in the above figure. The details are as follows:

- Diameter of die=13 mm
- No. of samples to be prepared = 3
- Powder required per each sample =6.2gms
- Powder required for 3 samples = 6.2 \* 3 =19gms

After defining the powder requirement, then selection of the composition percentages are to be decided.

S.NO	Cu %	Sic %	Gr %	Code
1	80	10	10	P
2	85	7.5	7.5	Q
3	90	5	5	R
4	85	10	5	S

Table 1 Weight Percentage Compositions

Code	Total Quantity	Material	Quantity (grams)
P	19 gm	Cu	15.2
		Sic	1.9
		Gr	1.9
Q	19 gm	Cu	16.15
		Sic	1.425
		Gr	1.425
R	19 gm	Cu	17.1
		Sic	0.95
		Gr	0.95
S	19 gm	Cu	16.15
		Sic	1.9
		Gr	0.95

Table 2 Total Quantity for each material based on Weight percentage compositions

Process for preparation of samples is,

- Agate mixing,
- Compaction,
- Sample preparation and
- Sintering.

## IV. RESULTS AND DISCUSSIONS

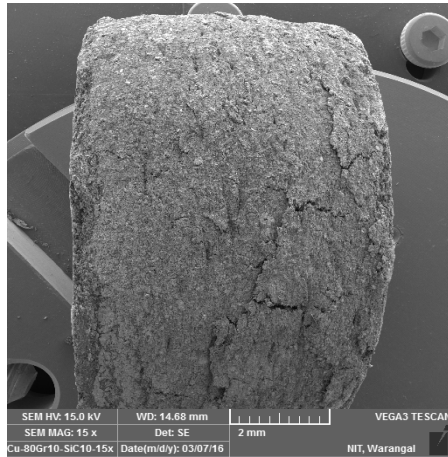
Scanning Electron Microscopy (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the sample's surface topography and composition. The electron beam is generally scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image. SEM can achieve resolution better than 1 nanometer. Specimens can be observed in high vacuum, in low vacuum, in wet conditions (in environmental SEM), and at a wide range of cryogenic or elevated temperatures.

The most common SEM mode is detection of secondary electrons emitted by atoms excited by the electron beam. The number of secondary electrons that can be detected depends, among other things, on the angle at which beam meets surface of specimen, i.e. on specimen topography. By scanning the sample and collecting the secondary electrons that are emitted using a special detector, an image displaying the topography of the surface is created.

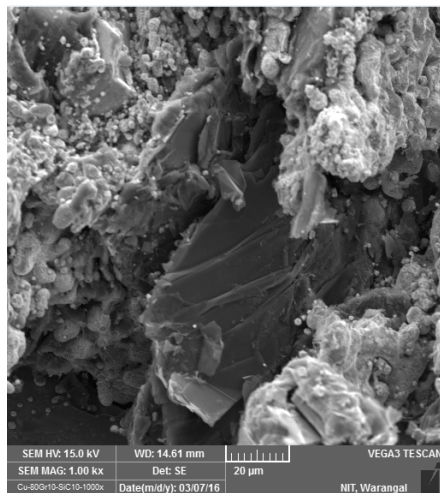
Magnification in an SEM can be controlled over a range of about 6 orders of magnitude from about 10 to 500,000 times. In SEM, as in scanning probe microscopy, magnification results from the ratio of the dimensions of the raster on the specimen and the raster on the display device. Assuming that the display screen has a fixed size, higher magnification results from reducing the size of the raster on the specimen, and vice versa.



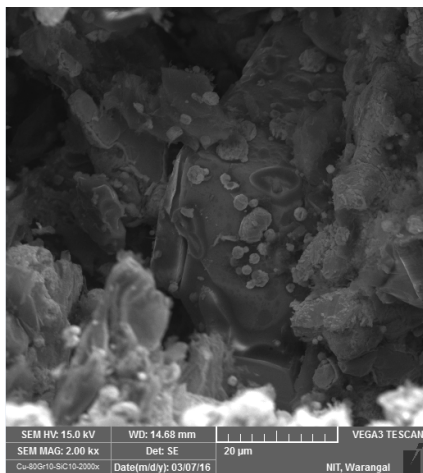
Magnification is therefore controlled by the current supplied to the x, y scanning coils, or the voltage supplied to the x, y deflector plates, and not by objective lens power.



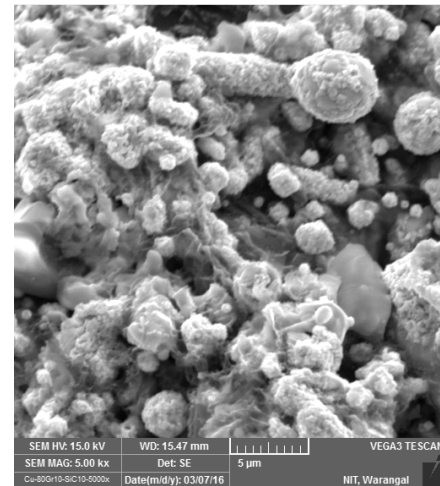
(a)



(b)



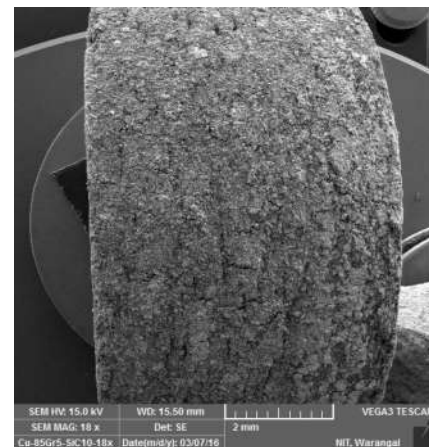
(c)



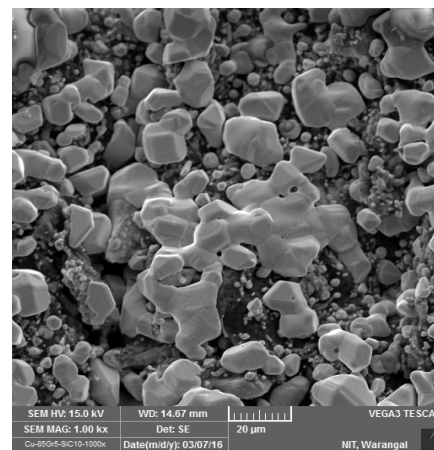
(d)

Fig. 2: SEM images of Cu-80 % Gr-10 %-SiC-10%

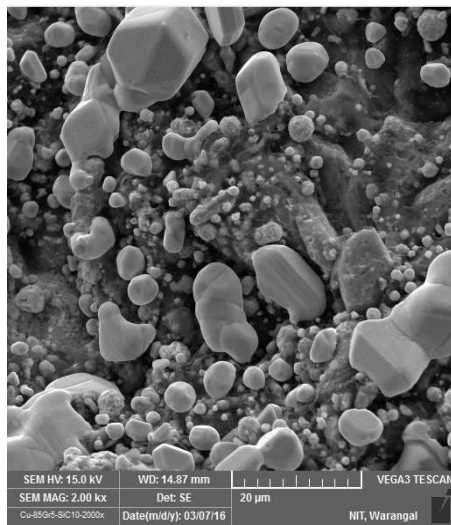
- a) 15x
- b) 1000x
- c) 2000x
- d) 5000x



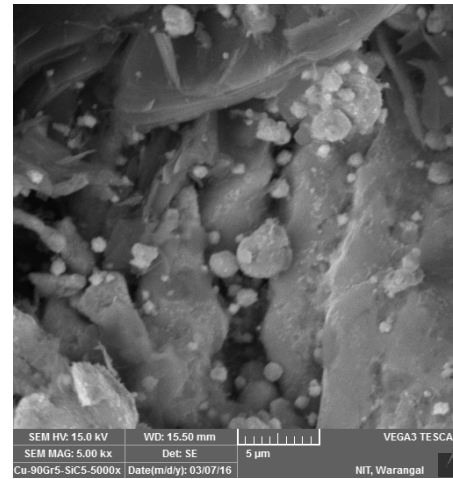
(a)



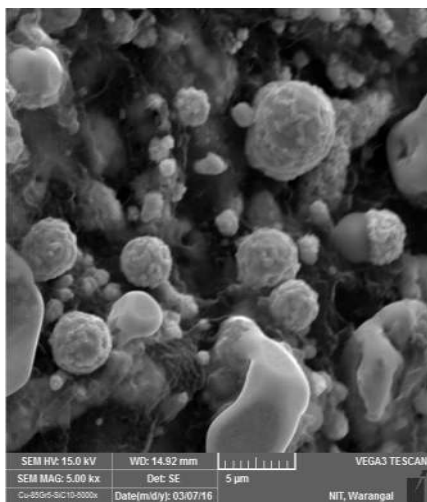
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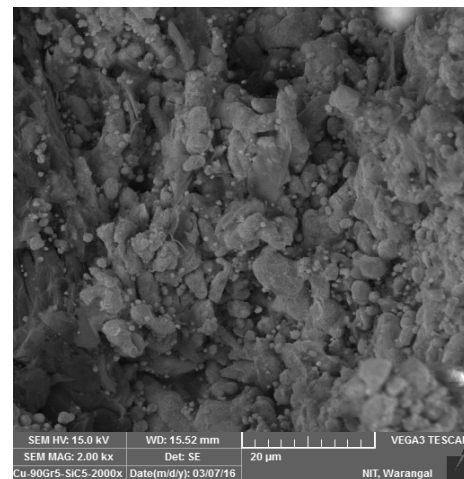
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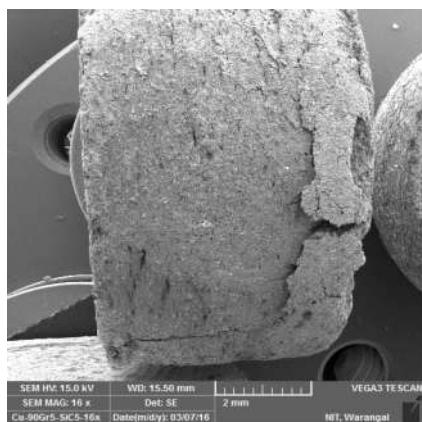
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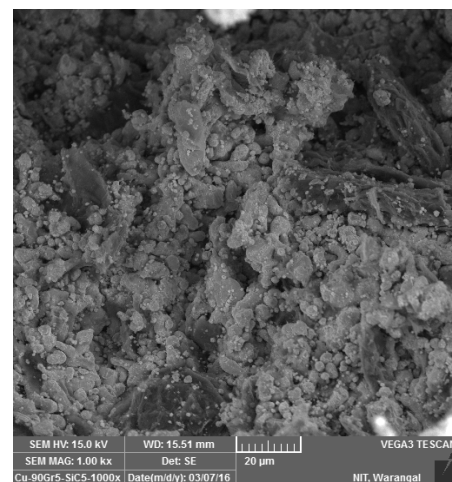
(c)

Fig. 3: SEM images of Cu-85 % Gr-5 %-SiC-10%

- a) 15x
- b) 1000x
- c) 2000x
- d) 5000x



(a)



(d)

Fig. 4: SEM images of Cu-90 % Gr-5 %-SiC-5%

- a) 15x
- b) 1000x
- c) 2000x
- d) 5000x

## V. CONCLUSIONS

.From this work we conclude that Copper-Silicon Carbide-Graphite MMCs were fabricated by mixing wt. % of 5, 7.5 and 10 Silicon Carbide and Graphite powder into copper powder followed by powder metallurgy. The composite powder mixture were cold compacted by Hydraulic press and then sintered in tubular furnace using argon gas. SEM analysis revealed the good bonding between copper matrixes, Sic, graphite reinforcement. Out of all the composites Cu-85 % Gr-5 %-SiC-10% composite has good bonding between all the particles and can be used for the components related to tribological applications.

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