Utilization of waste steel scrap in powder metallurgy

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Keywords: Steel scrap; planetary milling; sintering

ABSTRACT
Utilization of waste steel scrap in powder metallurgy

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Abstract

Most production processes of steel tools like machining and forging generate large amount of steel scrap in the form of chips. From the economic, strategic and environmental point of view, these steel scrap should be reused and recycled. Powder metallurgy provides a very suitable and economical way for the utilization of waste steel scraps. In the present investigation, an attempt has been made to prepare steel powder from the waste steel scrap by high energy planetary milling and finally the consolidation of the powder has been carried out to study the feasibility of a useful product.

Both ultralow carbon and low carbon steel chips were milled separately in a dualdrive planetary mill for 5 hours using stainless steel balls with ball to powder weight ratio of 12:1. Toluene was added to avoid high temperature oxidation during milling. Samples were collected for the intervals of 0.5, 1.5, 3, 4 and 5 hours for analysis. Samples were characterized by XRD, SEM and TEM.

A 1 wt. % nano yttria dispersed and yttria free ultralow and low carbon steel powders were cold compacted under a hydraulic press at the pressure of 874 MPa. PVA was used as binder during compaction. The compact samples were sintered at 1100 °C for 1 h in a tubular furnace under Ar atmosphere. The sintered samples were polished and then density, hardness values were measured and microstructures were revealed in optical and SEM. Fig. 1 shows XRD spectra which present the presence of ferrite as the main constituent in ultralow carbon steel after 5 hours of milling. Phase analysis was also reconfirmed from SAED ring pattern diffraction obtained from TEM. Fig. 2 shows the SEM micrographs which exhibit gradual refinement of powder during milling and an average particle size of 5 μm were obtained in both cases.

Deformation behaviour study of Cu-graphite-SiC metal matrix composite prepared by powder metallurgy

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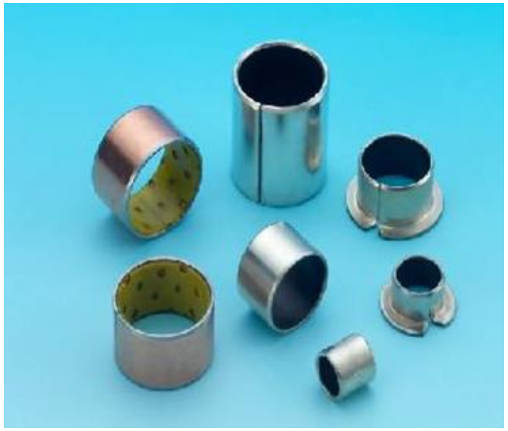
PM 17 INTERNATIONAL CONFERENCE ON POWDER METALLURGY & PARTICULATE MATERIALS
New Delhi, 20th-22nd February 2017

Introduction

- Cu-graphite-SiC hybrid metal matrix composite possesses the properties of Cu (excellent thermal and electrical conductivity), graphite (wear resistance as graphite acts as a lubricating film on contact surface) and SiC (improves hardness).
- Copper based MMC is mainly used in thermal and electronics packing and for electrical contact application because of its excellent thermal and electrical conductivity.
- Copper based hybrid metal matrix composites are used in many electrical contact applications like contact bushes and bearing materials.

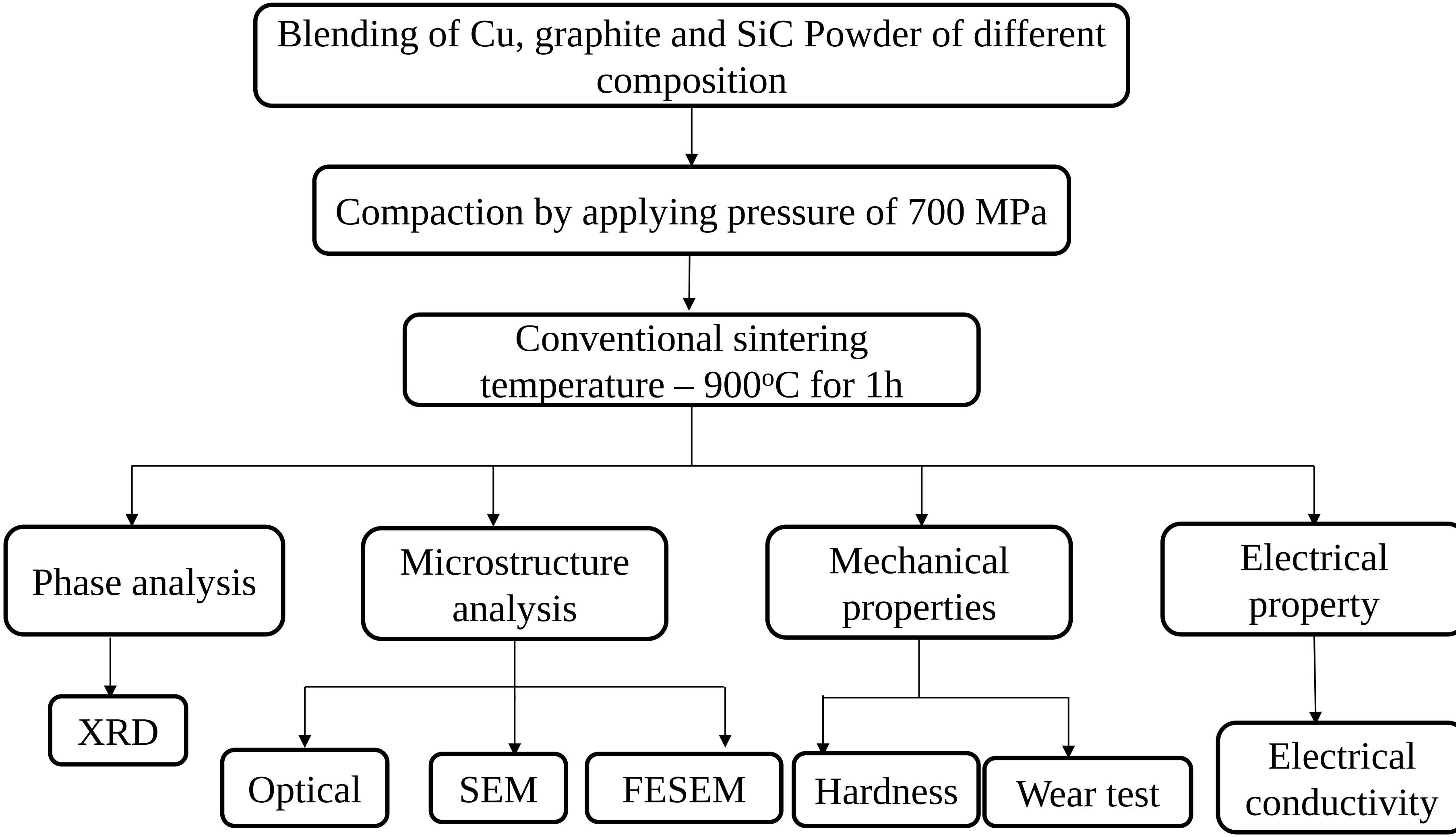
Contact bushes

Spring Bushes

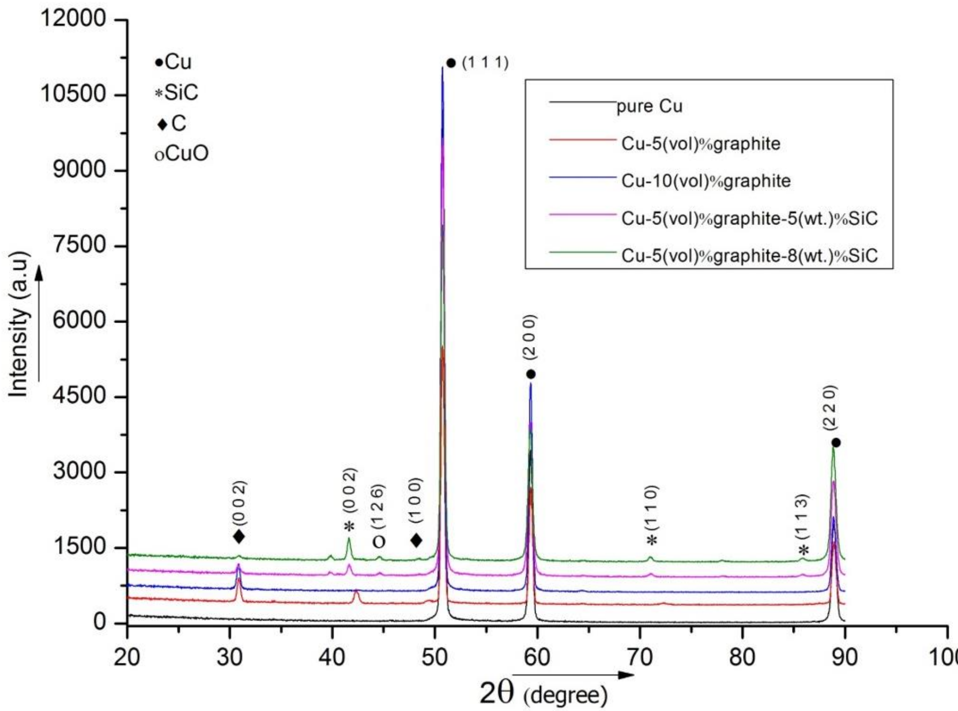


Sleeve bearing

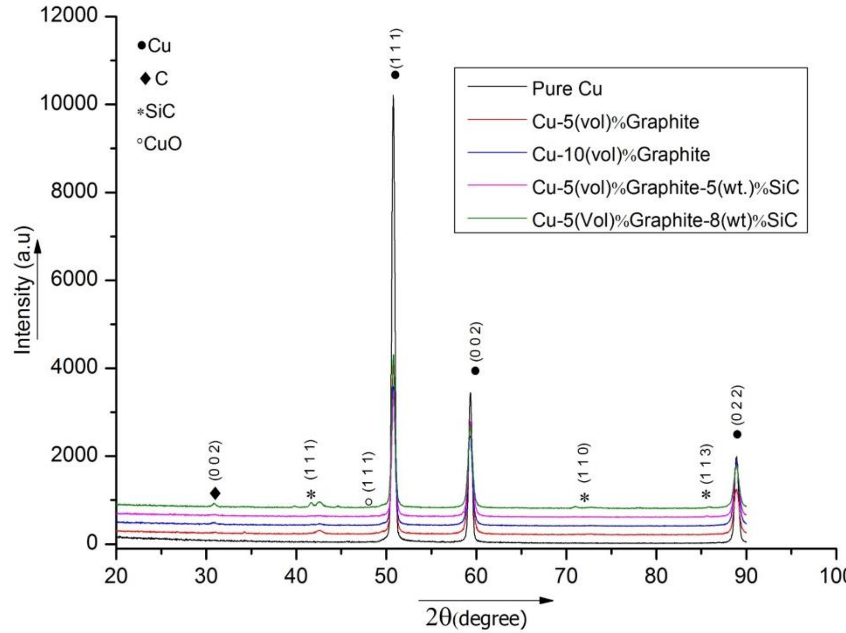
Experimental Lay Out



XRD Study

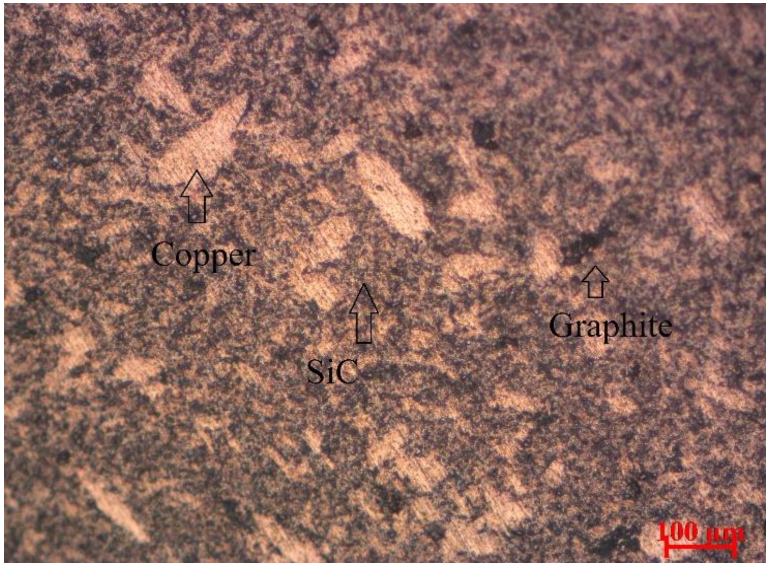


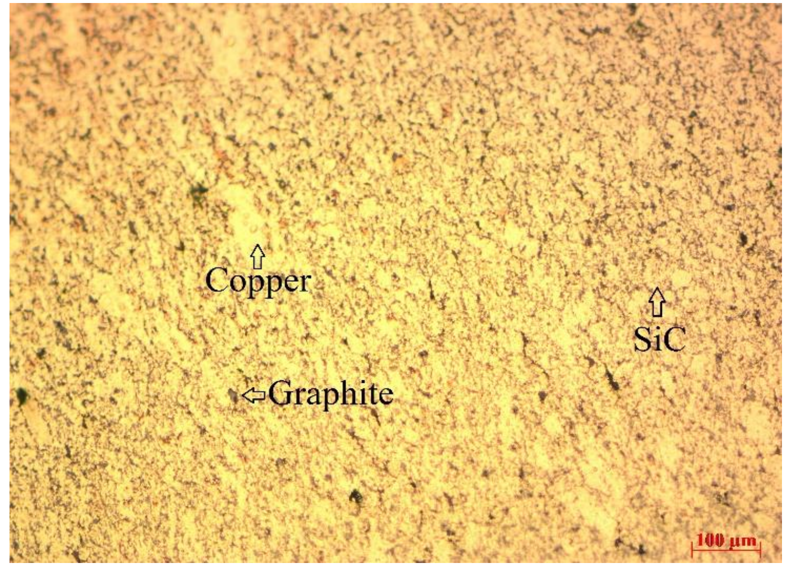
XRD spectra of fabricated composites



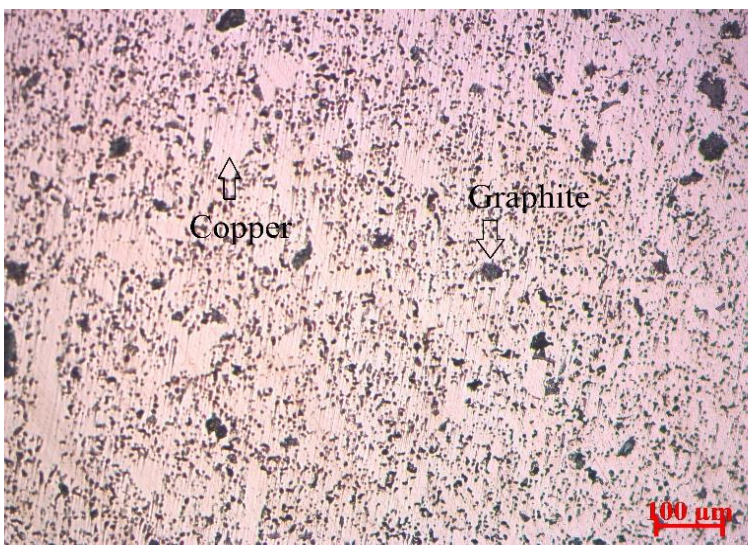
XRD spectra of rolled composites

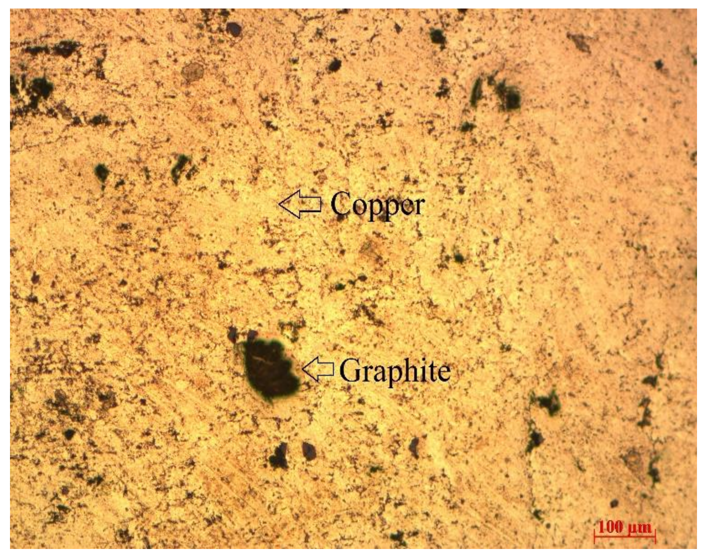
Optical Micrographs





Optical micrograph of Cu-5 vol.% Gr-8 wt.% SiC



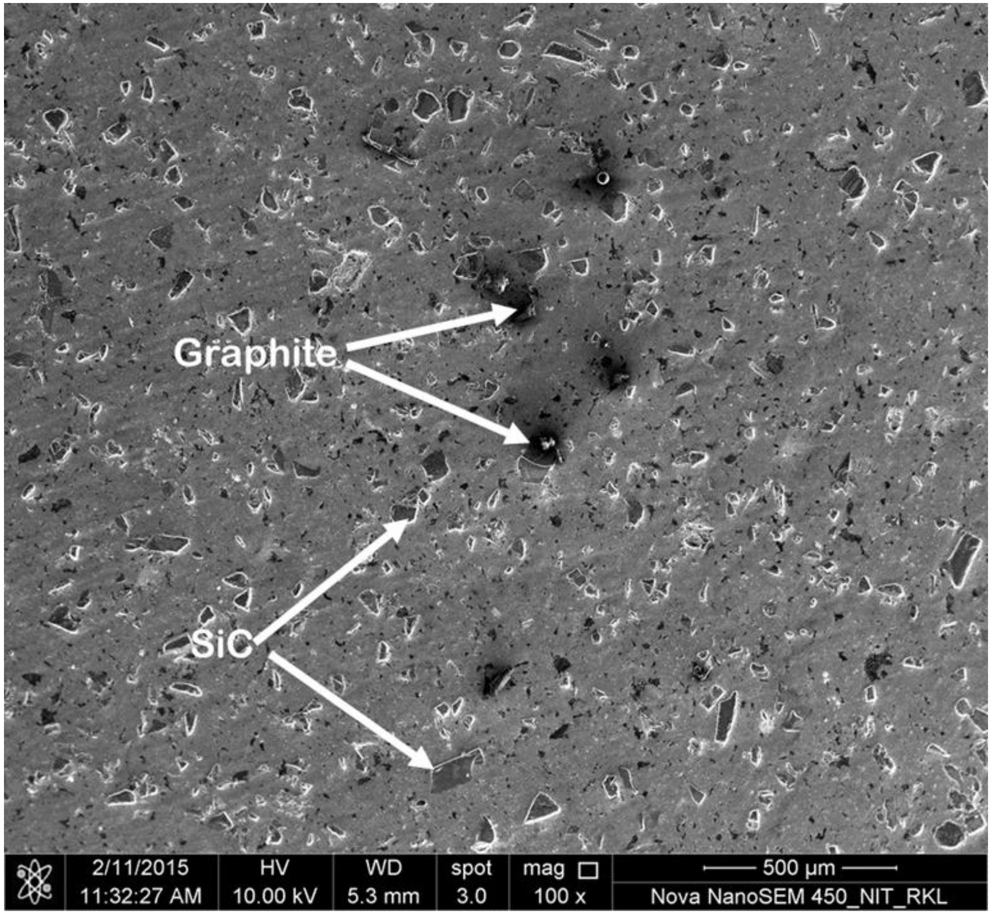


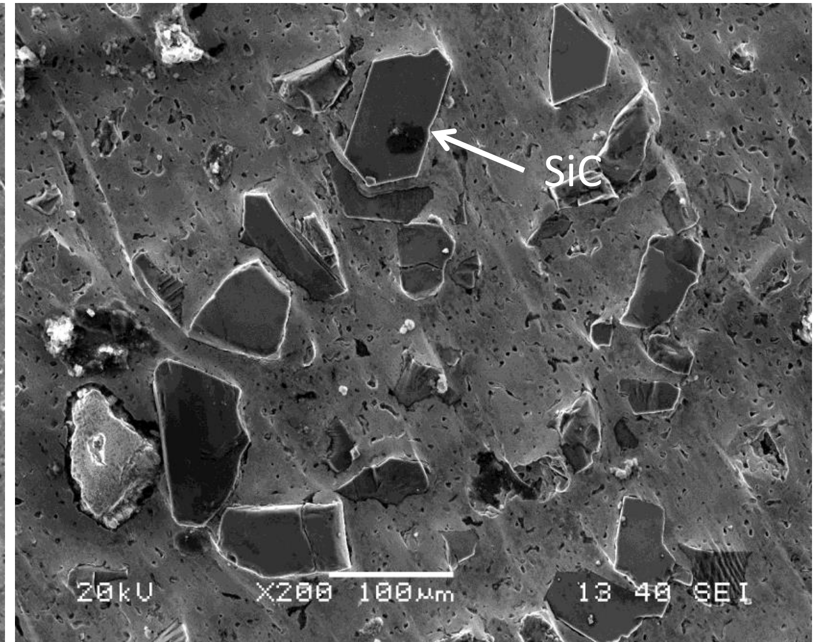
Optical micrograph of Cu-5 vol.% Graphite

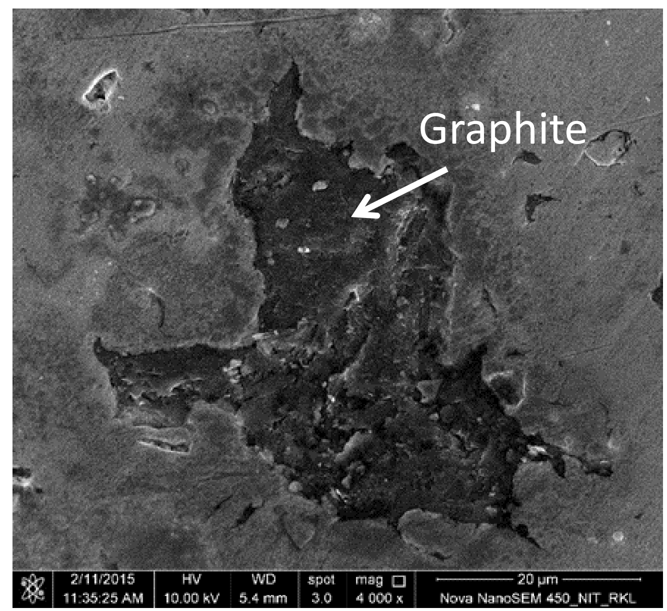
After fabrication

After rolling

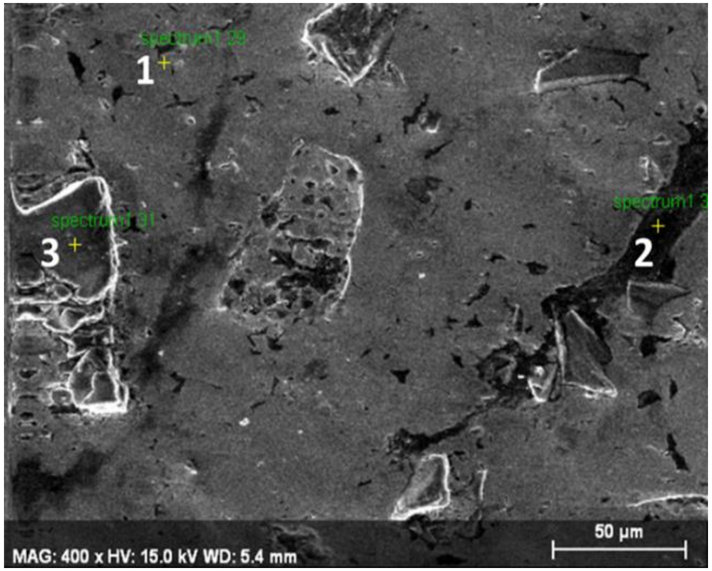
FESEM Micrographs





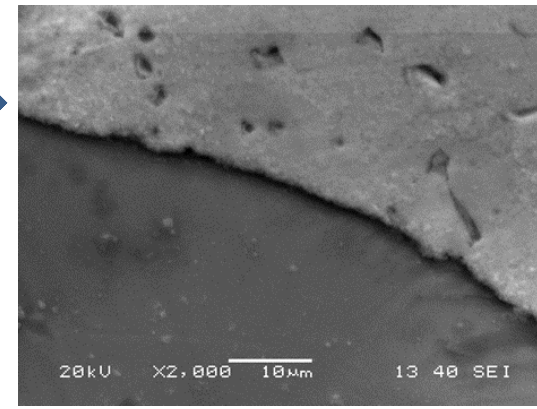


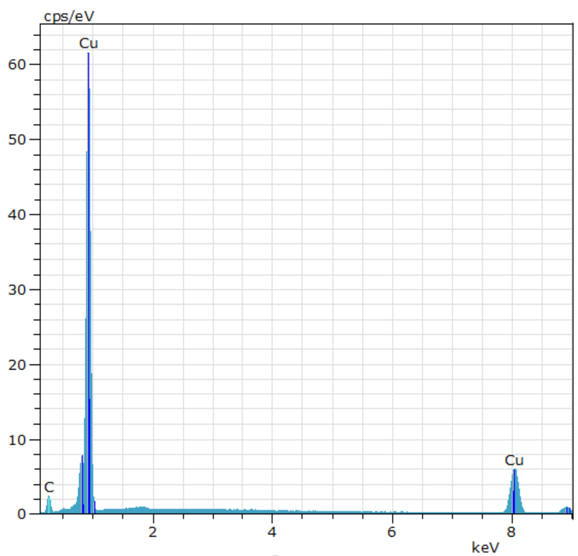
FESEM micrograph of Cu-5vol. % graphite-5wt.% SiC composite



Element / Spectrum	Cu (wt. %)	C (wt. %)	Si (wt. %)	O (wt. %)
1	95.58	4.42	-	-
2	-	91.67	3.20	5.13
3	-	37.38	62.62	-

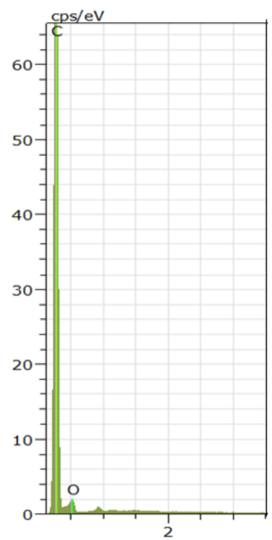
Cu-graphite interface





1

Cu matrix



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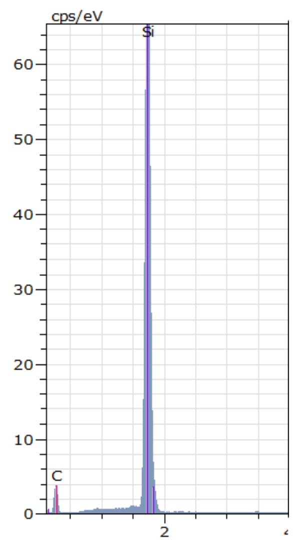
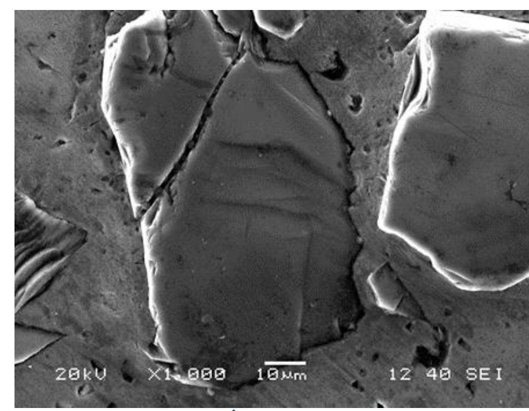
Graphite



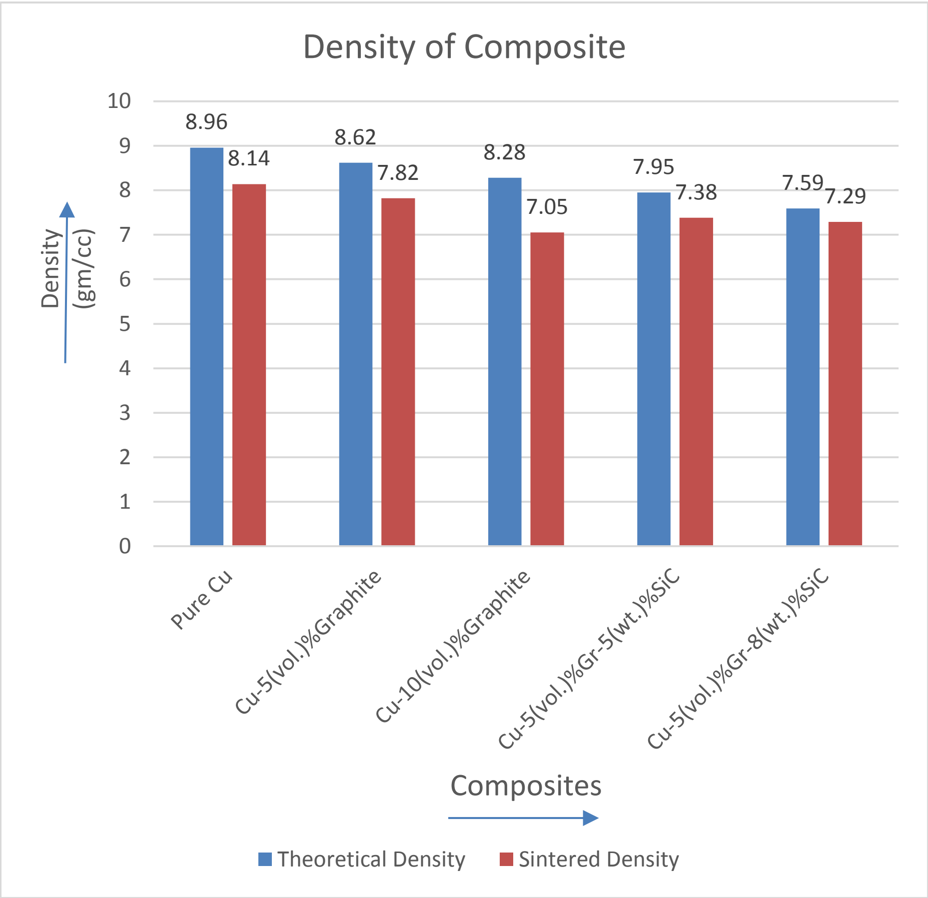
3

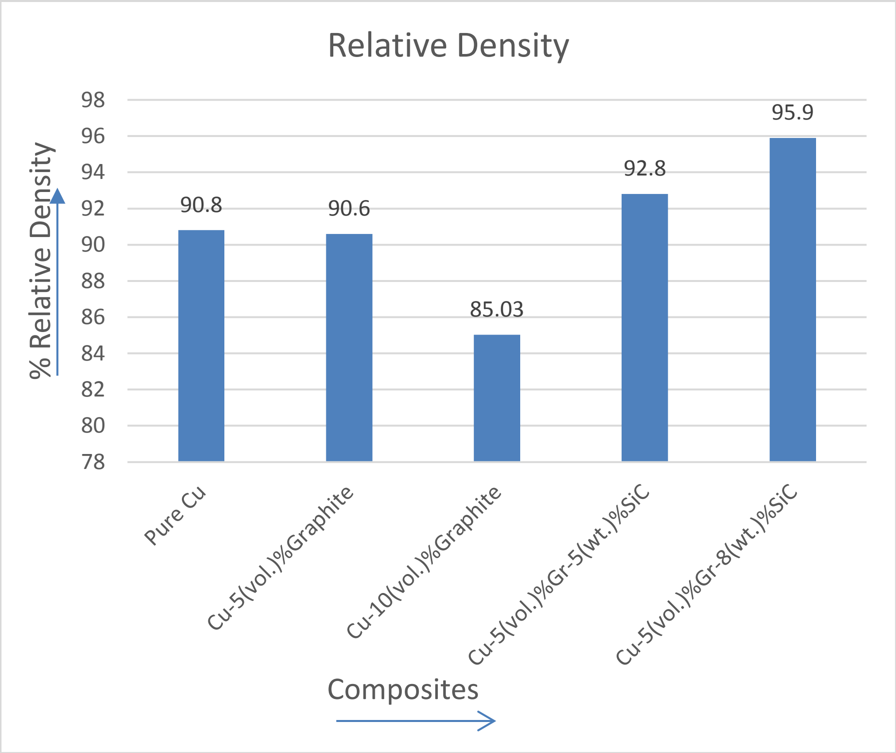
SiC



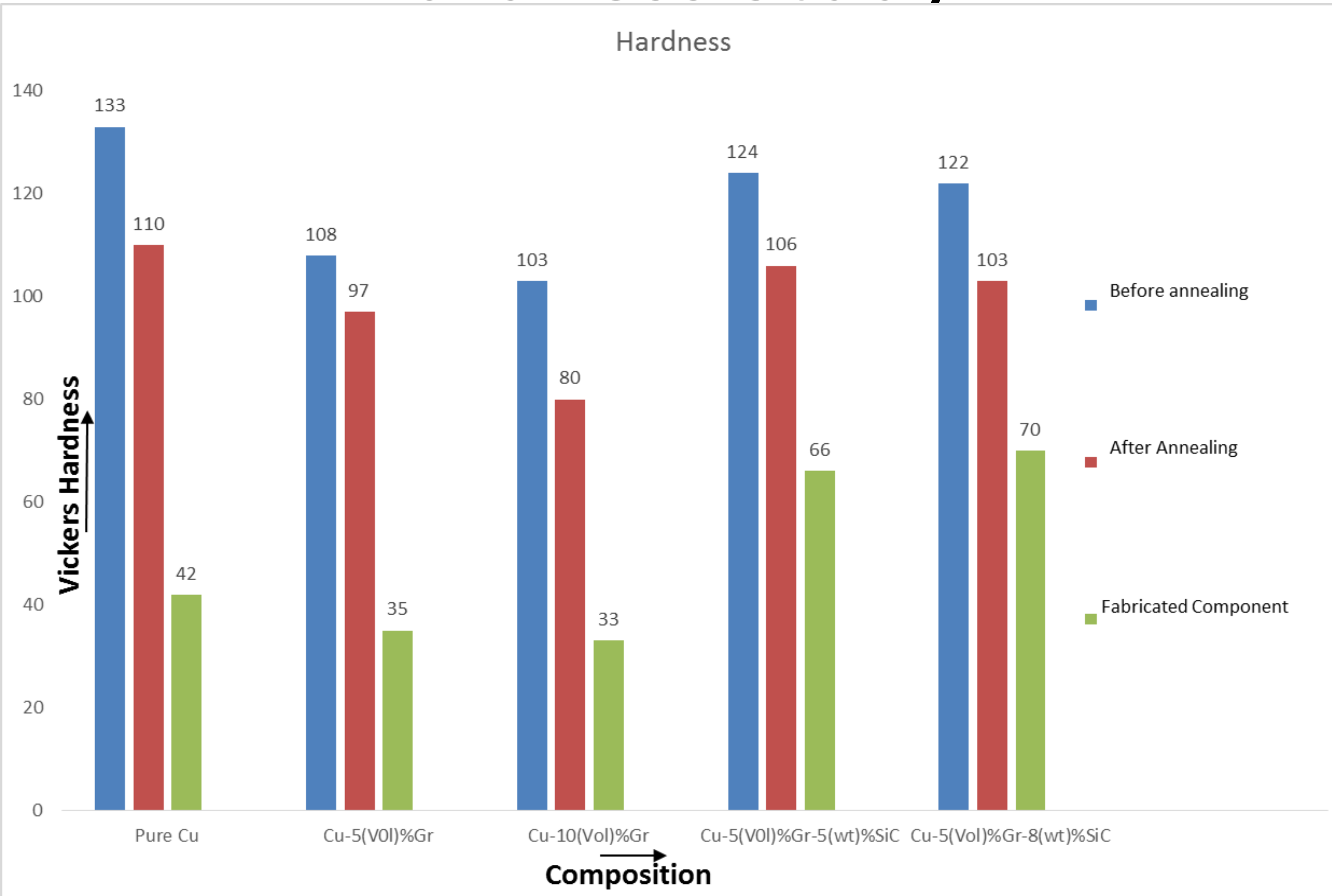
Cu-SiC interface

Density Study



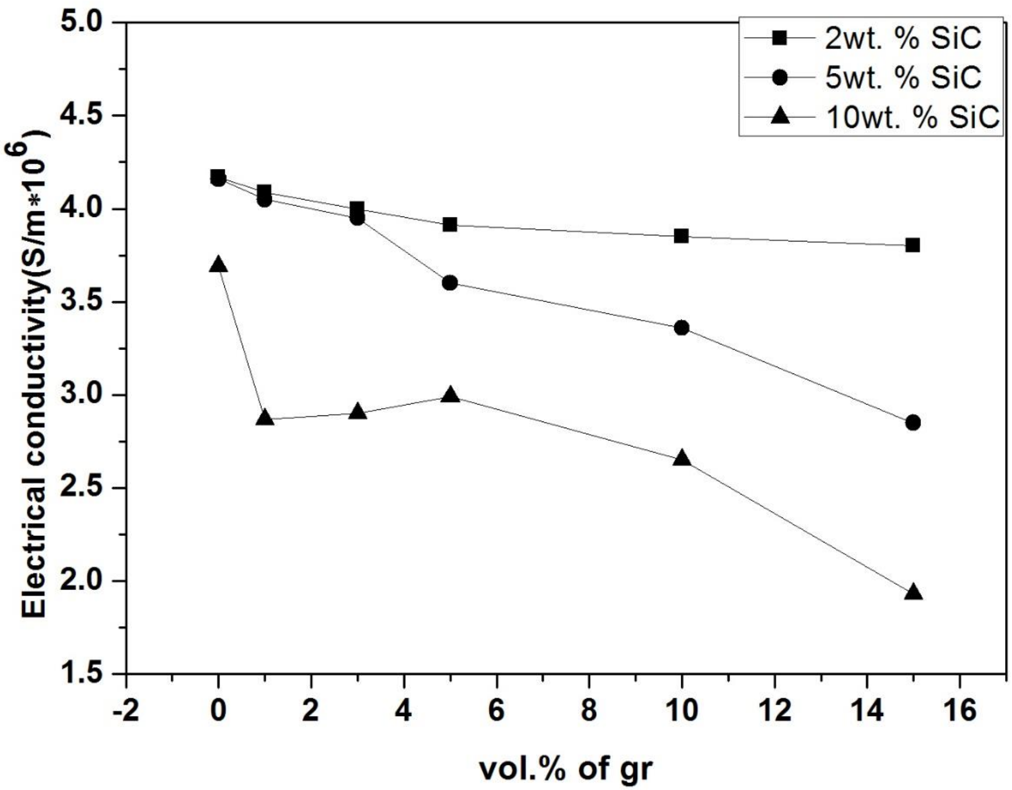


Hardness Study



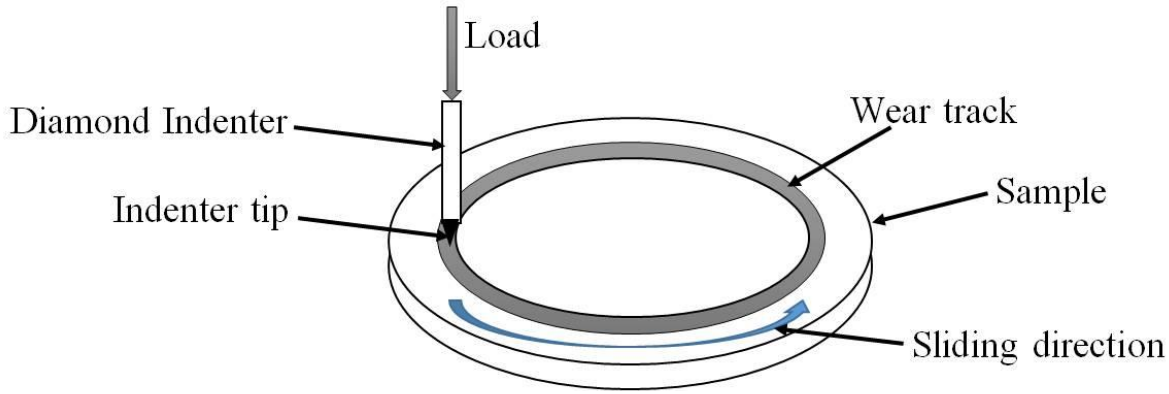
- Hardness of pure Cu decreases with addition of graphite. Again hardness of Cu-graphite-SiC hybrid MMC increases with the addition of SiC-As fabricated samples
- Hardness is maximum for rolled samples
- After annealing, hardness value decreases

Electrical Conductivity Study



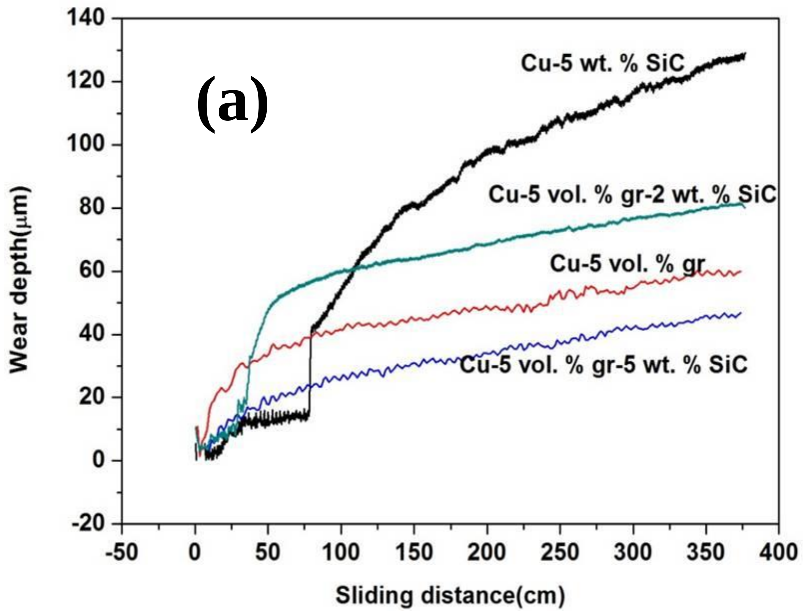
- Four probe electrical resistivity measuring instrument was used to measure the electrical resistance of the sample in which two probes were connected with the ammeter (Keithly 6221, DC) and another two with the voltmeter (Keithly 2182A).
- Electrical conductivity decreases with increasing the amount of reinforcements (both graphite and SiC)

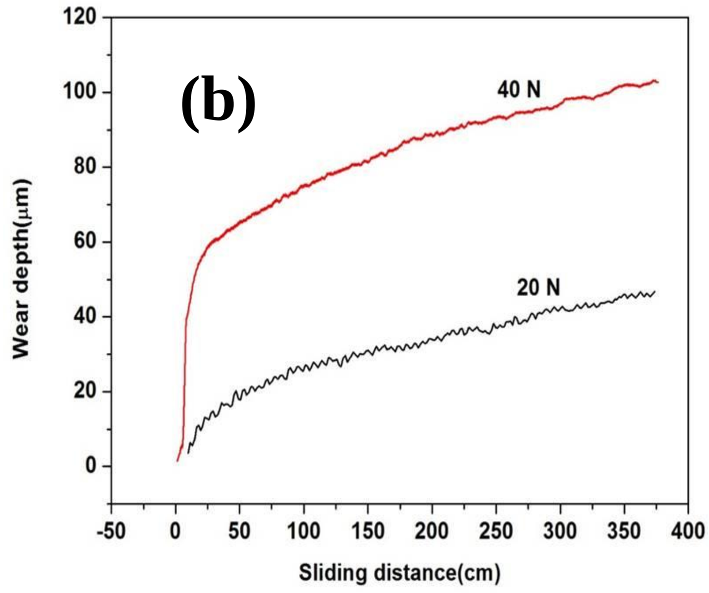
Non-Lubricated Sliding Wear Study



- Diamond indenter slides against the composites
- Speed- 20 rpm
- Load- 20N, 40 N
- Sliding time - 15 minutes

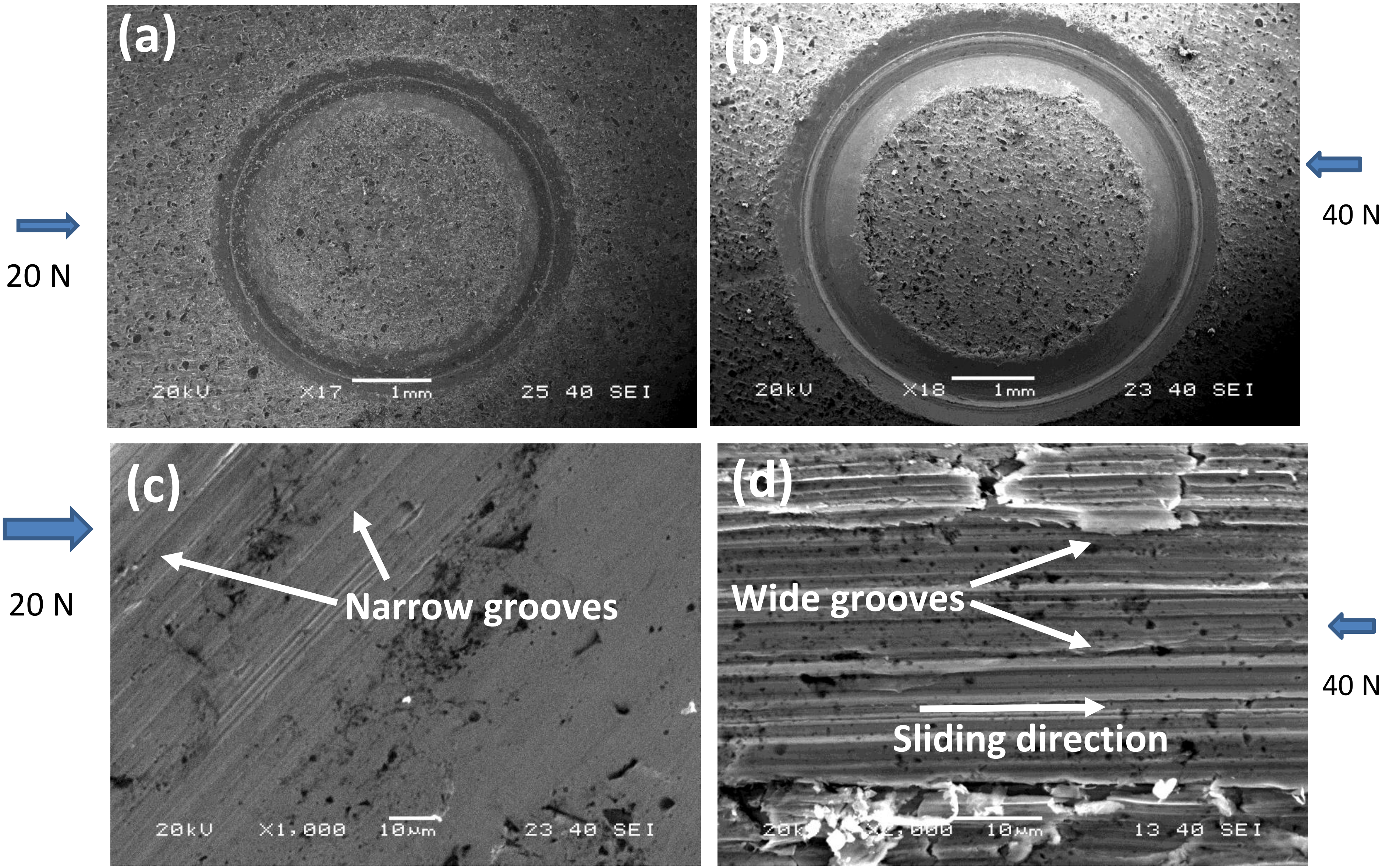
Schematic diagram of ball on plate (Ducom) wear testing set up



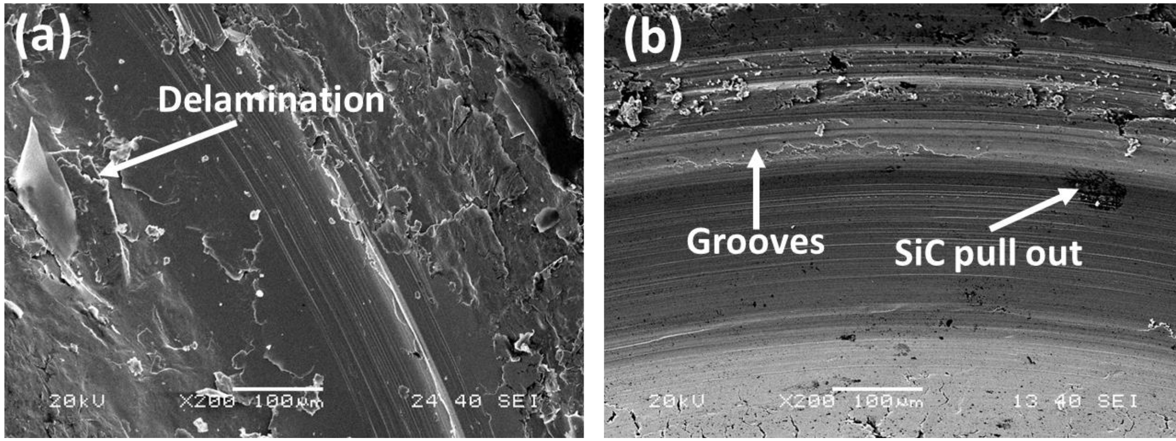


Variation of wear depth with sliding distance for (a) Cu-graphite, Cu-SiC and Cu-graphite-SiC composite (b) Cu-5 vol. % gr-5 wt. % SiC tested at 40 N and 20 N

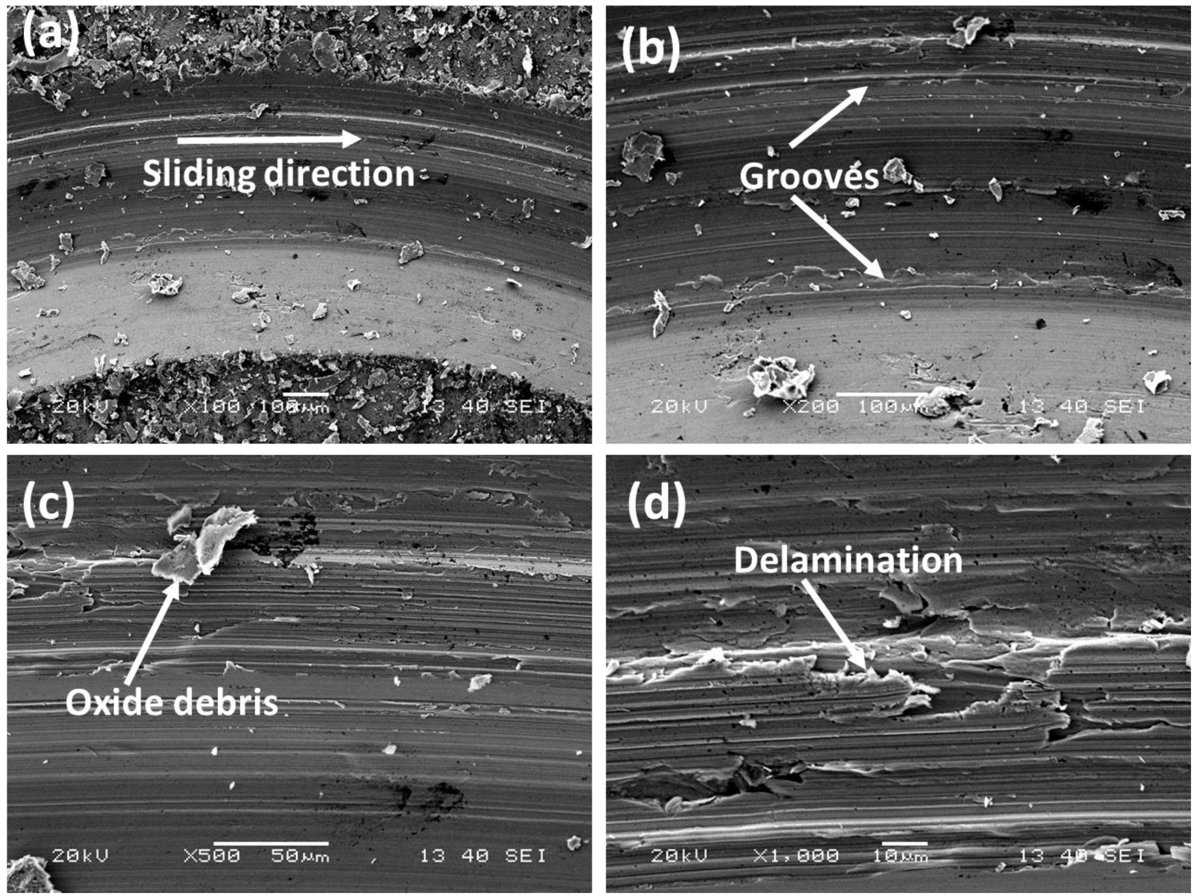
Wear Track and Worn Surface



SEM micrographs of wear track of Cu-5 vol. % gr-5 wt. % SiC when (a and c) 20N and (b and d) 40N load applied

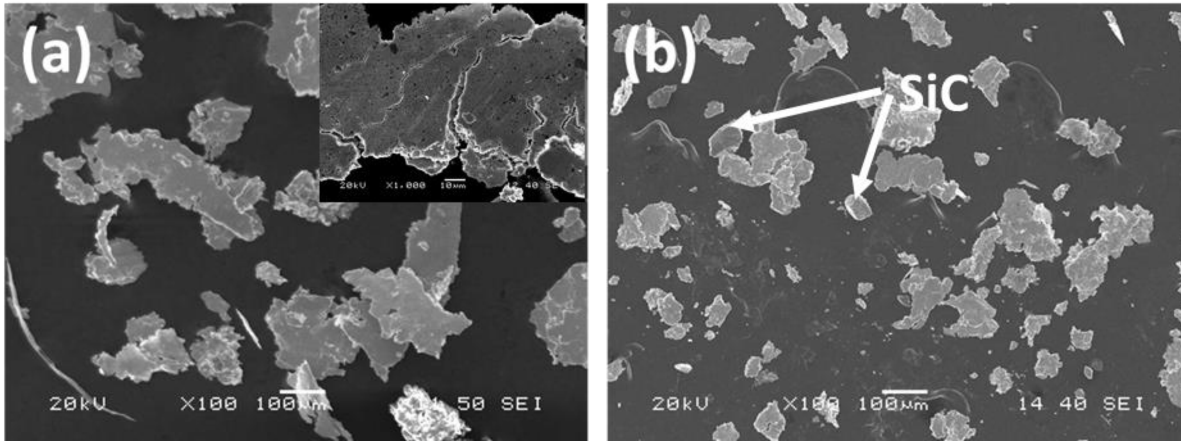


SEM micrograph of worn surface (a) Pure Cu, (b) Cu-5 wt. % SiC

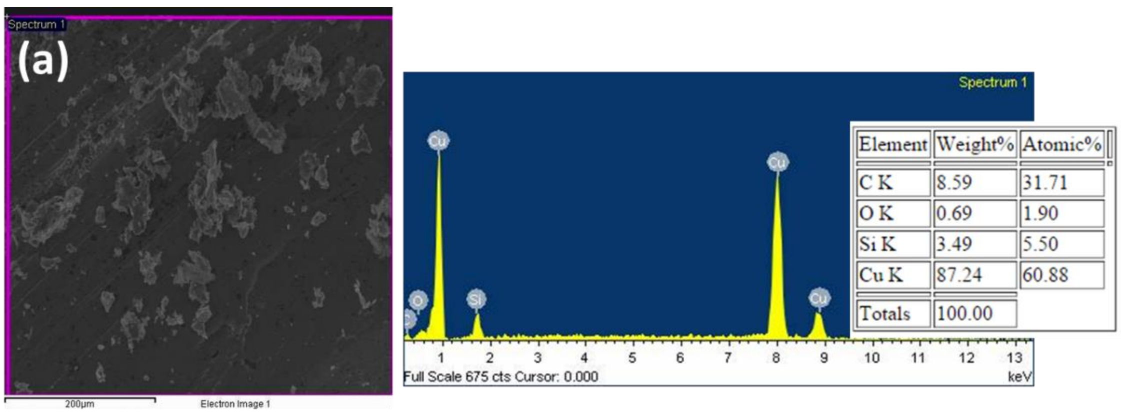


SEM micrograph of worn surface of Cu-5 vol. % gr-2 wt. % SiC

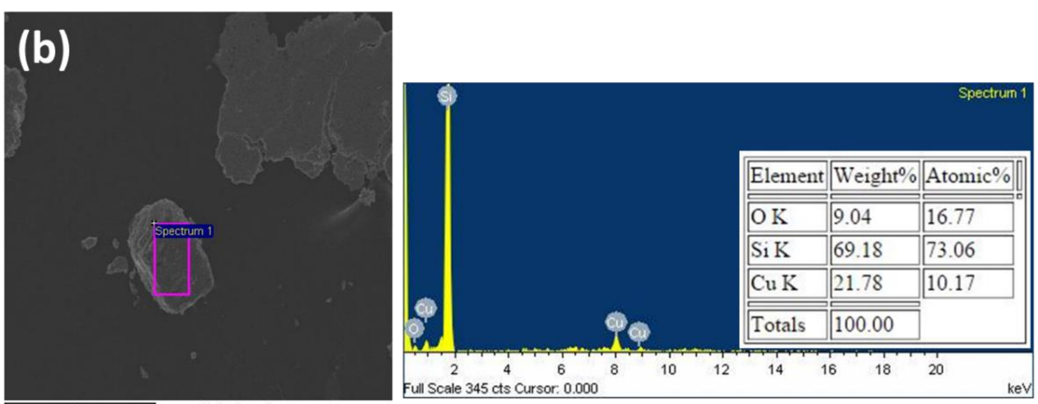
Wear Debris Study



Wear debris of (a) Pure Cu, (b) Cu-3 vol. % graphite-5 wt. % SiC



Element	Weight%	Atomic%
C K	8.59	31.71
O K	0.69	1.90
Si K	3.49	5.50
Cu K	87.24	60.88
Totals	100.00	



Element	Weight%	Atomic%
O K	9.04	16.77
Si K	69.18	73.06
Cu K	21.78	10.17
Totals	100.00	

SEM-EDX analysis of wear debris of (a) Cu-5 vol. % gr-5 wt. % SiC,
(b) Cu-5 wt. % SiC

Conclusions

- Cu-graphite-SiC hybrid composite was successfully fabricated by powder metallurgy route using conventional sintering technique.
- The hardness value of the fabricated composites increases with rolling and decreases after annealing.
- It has been observed that grains are oriented along rolling direction and refined after rolling
- The hardness of the composites decreases with addition of graphite but it increases with addition of SiC
- Electrical conductivity of the fabricated composites decreases with addition of both the reinforcements (graphite and SiC)
- The lowest wear depth is obtained for Cu-graphite-SiC composite. The main wear mechanisms are-abrasion, de-lamination and pull out of SiC

Acknowledgement

- Financial support for this work from the Department of Science and Technology (DST), India (Grant No. SR/FTP/ETA-100/2010) is gratefully acknowledged
- Mr. Biswajit Mishra, M.Tech student, NIT Rourkela
- Dr. Rajib Saha, Tata Steel, Jamshedpur