Quest: Journal of Geometry, Mathematical and Quantum Physics
e-ISSN: 3064-7282 Vol.2 Issue 6|2025

# Observation of Microstructure and mechanical properties of Cu-Sic composite prepared by PM techniques

**Luma J Abbas**
College of energy and environmental sciences, Al-karkh University of science, Baghdad, Iraq

**Lubna abduljabbar Mahmoud**
Supervision and Scientific Evaluation Apparatus, Ministry of Higher Education and Scientific Research

**Mustafa A Mahmood**
Department of medical physics, College of sciences, Al-karkh University of science, Baghdad, Iraq

**Abstract:** In this work, copper matrix reinforced with Sic was prepared using powder metallurgy technique. Samples were prepared by adding 5, 10, 15, 20, 25, and 30 weight % Sic to copper and compacted at 7 tone pressure. PVA was the binding material and mixed in for 30 minutes. Microstructure observation showed that Sic placed around Cu. Moreover, agglomeration of particles was not observed and fine particle had good distribution in SEM micrographs. The sintered compacts hardness ranged from 90 to 102 HV. The compression was increased by 26% as the volume of Sic percent increased by 30%, but the relative density was decreased.

**Keywords:** copper: Sic: Microstructure: Hardness: Compressibility.

## 1. Introduction

Metal matrix composites may be used at higher service temperatures compared to their base metal equivalents. The reinforcement may improve certain attributes like strength, creep resistance, resistance to abrasion, thermal efficiency, and dimensional stability. Cu-Sic composites made from metal matrix have undergone substantial investigation owing to their superior electrical and mechanical characteristics. These composites have several uses across various sectors, including fusion reactors, welding electrodes, and electrical connections (Celebi, 2011).

Powder metallurgy methods include several processes, including mixing, compacting, and sintering. Blending is a critical aspect in powder metallurgy, where metallic powders are combined with ceramic-reinforced particles. Effective blending results in the absence of agglomeration of both ceramic and metallic powders (Kang, 2003). To accomplish this, numerous criteria must be considered, including particle size, blending speed, and time. Traditional melting and casting have significant limits owing to inadequate wettability between copper and ceramic, resulting in the agglomeration of dispersions. Copper has a favorable mix of physical and electrical qualities, making it the second most conductive element, surpassed only by silver. Copper-based materials are widely used in thermal and electronic devices due to their superior electrical and thermal insulation, exceptional corrosion resistance, and elevated melting point (Akbarpour, 2014).

The integration of ceramic particle reinforcement may substantially enhance high-temperature mechanical properties and wear resistance, without considerably compromising the thermal and electric conductivity of the matrix. Consequently, such materials are regarded as attractive choices for applications necessitating high conductivity, superior mechanical properties, and excellent wear resistance (Zhang, 2003).

Several researchers reported the microstructure of Cu-Sic. G.Celebi carried out the sintering effect on microstructure of Cu/Sic .M.R.Akbarpour preformed the compressibility on microstructure properties. H.R.Akramifard investigated the mechanical properties of Cu-Sic composite. The objective of the research was to enhance the hardness of malleable copper by blending it with silicon carbide, which has high stiffness at an appropriate volume percentage. This work aimed to construct Cu composites supplemented with SiC particles using the PM method and to investigate the influence of the temperature of sintering on the mechanical and electrical characteristics of the composites. The morphology, microstructure, microhardness, and electrical properties of the Cu-SiC composite are examined, along with an analysis of the correlation between microstructure and composite performance (Yun, 2001).

## 2. Experimental procedures

Copper and silicon carbide has been provided by BDH Ltd England,HIMEDIA Company respectively(<30µm and <µ25m). copper and silicon carbide were both mixed with volume fraction 0%,5%,10%,15%,20%,25% and 30 % sic , PVA was added as a binder. Next ,the mixture were blended mechanically by mortar for 5 minutes and compacted with compressive force at 7 tone in a stain steel mold 10 mm in diameter for 2 minutes. Samples were sintered at 950$^{o}$C at vacuum furnace for 2 hours. Hardness test was carried out using Vicker indentation (**tester TH714)** from Innova test hardened, Holland and the compression is carried out using Mel system; Germany. Using an agate mortar, to investigate the existence of any crystalline phases in the sintered Cu-Sic ceramic composites samples were crushed and milled into powder to look for any crystalline phases in the sintered Cu-SiC composites. After that, an XRD examination was performed on the powder.

## 3. Results and discussion

### 3.1 Relative density

The maximum green density was attained at a compaction pressure of 8 tons. Post-sintering, specimens had around 2.1% volumetric shrinkage, with density nearing 92% of the theoretical maximum. In this experiment, the die radius measures 10 mm.The relative density has been computed using the formula.

$$PC = \frac{\rho 1 \rho 2}{x1\rho 2 + x2\rho 1} * 100\%$$

*PC*: calculated density

$\rho_1$: copper density

$\rho_2$: silicon carbide density

$X_1$, $X_2$: weight percent of copper and silicon carbide

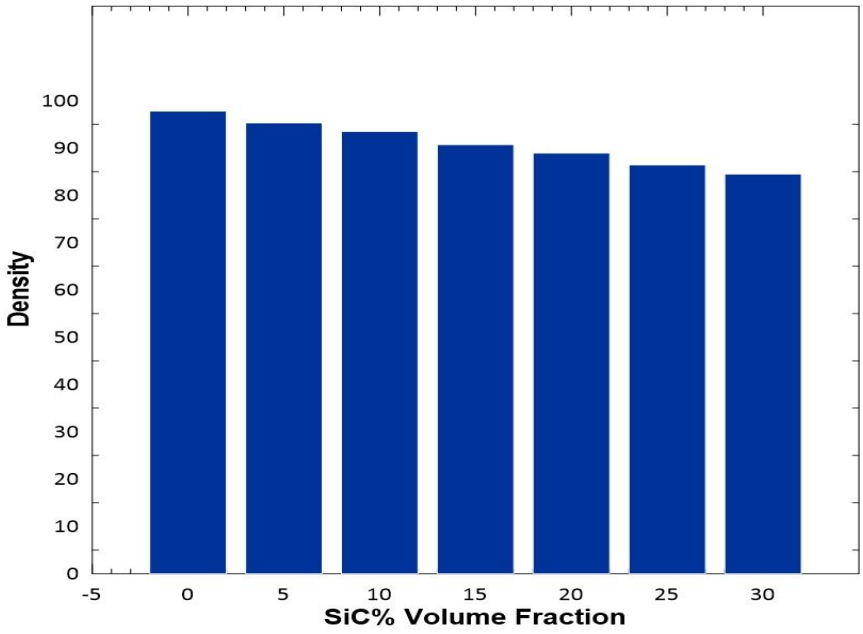
$$P = \frac{M}{V}$$

P: True density

M: sample weight after compact

V: sample volume

Relative density is determined by dividing genuine density by computed density. The reduction in the average density of composite is attributable to oxide development. The ratio of density of Cu was measured at 97.8%, but the densities of combinations decreased from 97.8% to 84.5% as the concentration climbed from 0% to 30%. This is due to the much lower density of Sic when compared to copper. In composites with a low SiC volume percentage, a reduced Cu-SiC interface results in a diminished diffusion barrier for copper atoms, allowing them to migrate easily and occupy the spaces between the SiC particles, hence enhancing the densification process of the composites.




### 3.2 Hardness

The hardness test was conducted using the Vickers hardness method. The Vickers hardness test employs a diamond indenter shaped like a square pyramid, which is applied to the specimen's surface for 15 seconds under a load of 500 grams, following refinement with 1000 grit silicon carbide paper to minimize machining scratches and mitigate the impact of surface imperfections on the hardness measurements.The findings are shown in Table 1.

Table: 1 shows Hardness, compression and relative density of Cu-Sic for different volume fractions.

| Vol. fraction of Sic | Hardness HV | Compression MPa | relative density |
|---|---|---|---|
| 0% | 86.1 | 624 | 97.8% |
| 5% | 88.7 | 626 | 95.3% |
| 10% | 88.9 | 738 | 93.5% |
| 15% | 90.13 | 798 | 90.7% |
| 20% | 91 | 828 | 88.9% |
| 25% | 95.5 | 764 | 86.4% |
| 30% | 98.2 | 789 | 84.5% |

The examination was conducted at ambient temperature. The findings are the average values derived from three assessments. The Vickers hardness values were derived directly from these tests. The hardness of ductile copper may be enhanced by the dispersion of a secondary hard phase.The samples hardness was typically increased with the rising volume percentage of SiC. The material exhibited elevated hardness values attributable to the homogeneous distribution of SiC particles, which augmented the hardness of the reinforcing copper (86 HV to 98HV) for 0% to 30% volume fraction at 950$^{o}$ c increased 12% as volume goes from 0% to 30%.this result from dispersion of Sic as a second hard phase.

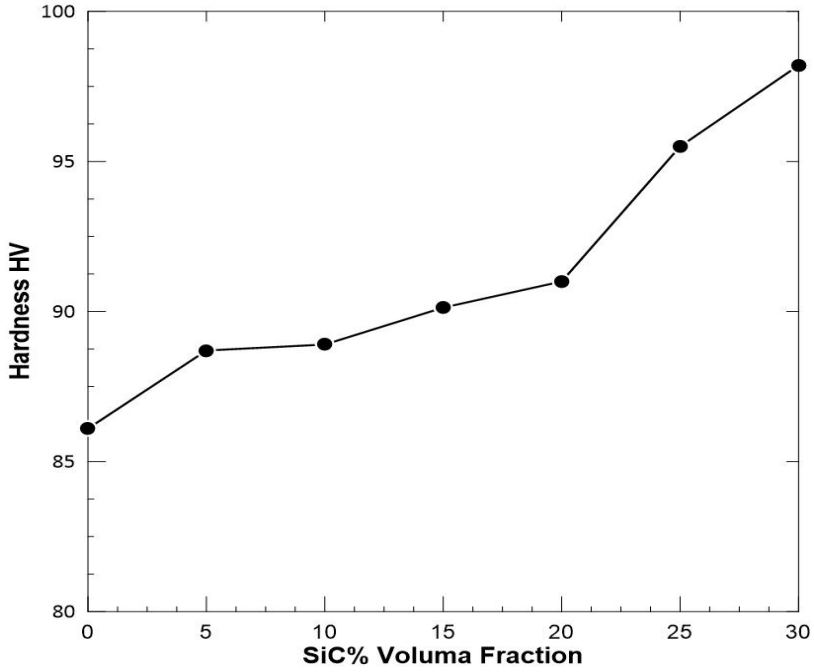



Fig-1 shows hardness versus different Sic% volume fraction.

### 3.3 Compression

The strength were substation ally effected to SIC addition as shown in table 1, which illustrate that the yield strength of Cu-Sic composite is much higher than pure Cu. The compressive strength augmented with the increase of reinforcement. The yield strength varied from 624 to 789 as the volume fraction increased from 0% to 30%. The compressive strength increased 26% as the Sic volume increased 30%. The improvement of compression is due to attribute of the good adhesion between Sic particle and Cu matrix, in addition to the higher density, homogenous distribution of Sic particles and low porosity.

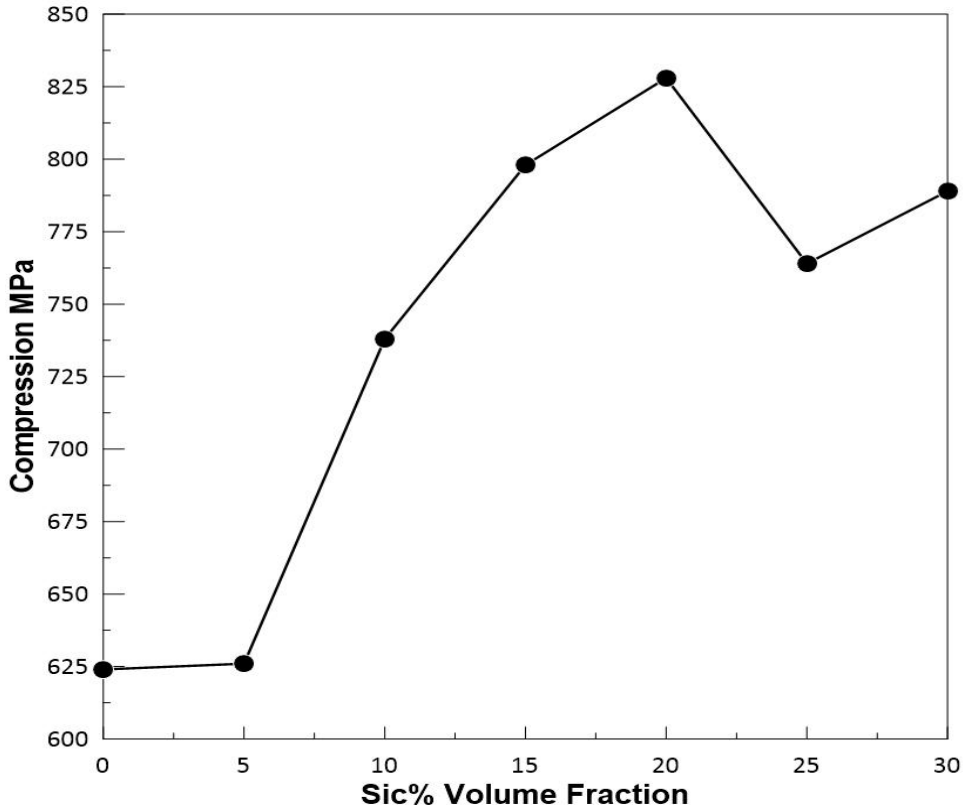



Fig-2 Compression of different Sic %volume fraction.

### 3.4 microstructure investigation

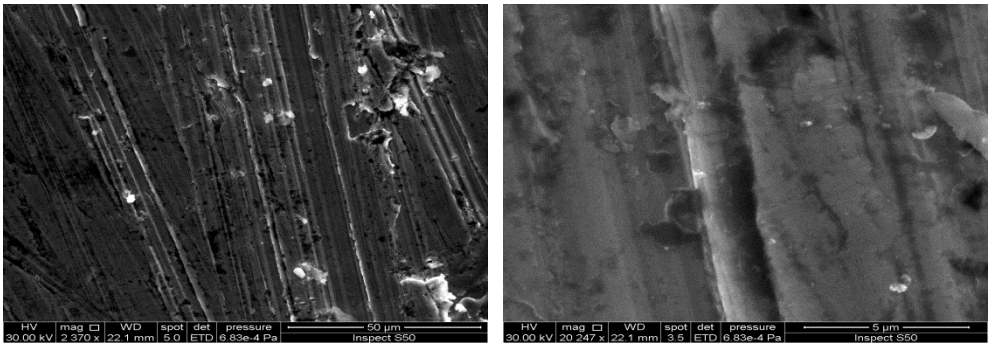
SEM microstructures of 0% to 30% SiC volume fraction with 50 µm inspection were uniformly dispersed inside the copper matrix. In Cu–SiC composites with a 30% volume percentage of SiC, free copper areas predominate owing to the SiC content, and there is strong adhesion between the copper matrix and SiC. Consequently, the oxygen concentration in the surface maps decreased as the particle size of SiC increased. In Figure 3. Areas rich in iron appear pale gray, perhaps due to the cementation process and oxidation at sintering temperatures. SEM examination of Cu–5 wt%SiC reveals that the dark forms represent the coexistence of SiC particles and copper.

The SEM micrographs provide insights on reinforcement distribution, interface condition, clustering, and mechanical phenomena such as twinning. The black regions of the SEM micrograph denote the SiC-reinforced particles, whereas the white areas correspond to the copper matrix, as shown in backscattered electron mode. As the volume proportion of SiC increases, the clustering of reinforcement also rises, as seen in Fig. 2. This phenomenon may be ascribed to the dispersion of SiC near the borders of the copper particles, owing to the ductile characteristics of copper .

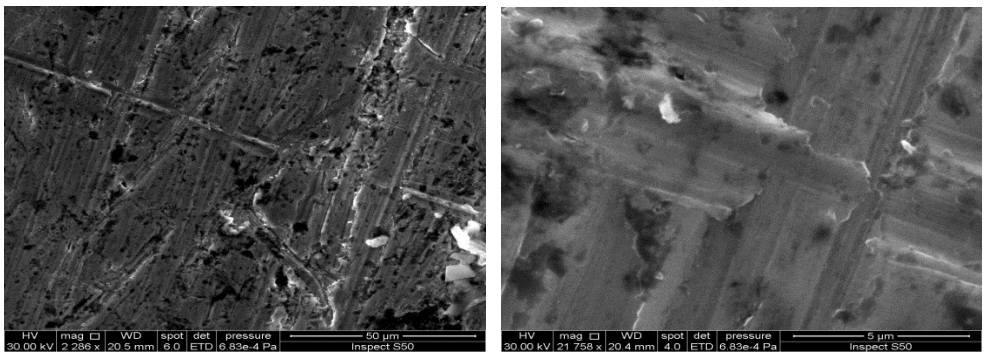
Figure 3 depicts the spatial distribution of reinforcement inside the copper matrix as reinforcement concentration increases at a sintering temperature of 950°C. As the volume proportion of SiC grows, the likelihood of clustering likewise rises. This may result from an insufficient ratio of the surface area of matrix particles to reinforcement particles, together with a density disparity between the matrix and reinforcement, leading to the development of clusters at high volume percentages of reinforcement. Clustering may be reduced by keeping the ratio of the particulate particle size to the matrix particle size nearly equal to one.

Fig-3 SEM of Cu and Cu/Sic composite for different weight percent.

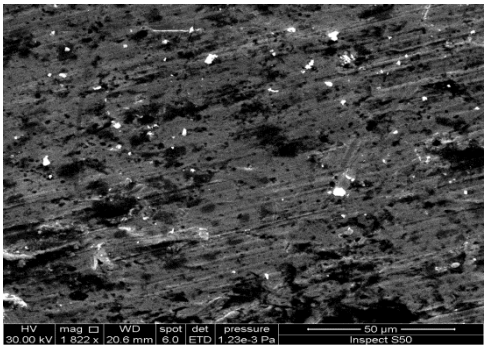
a- Pure Cu

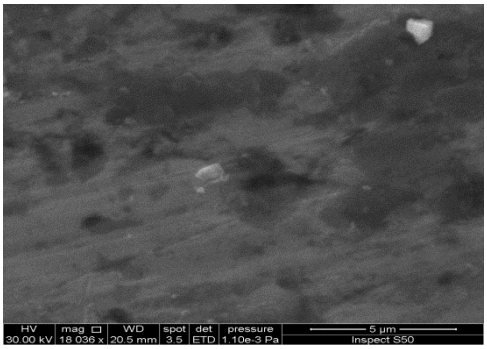



b- 5% Sic

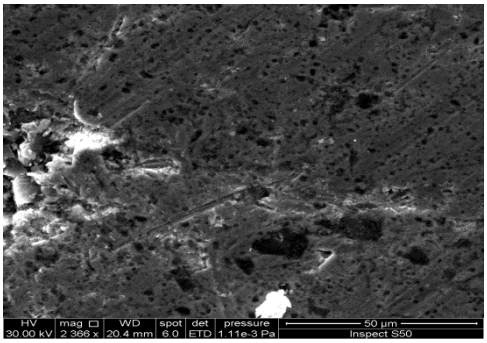


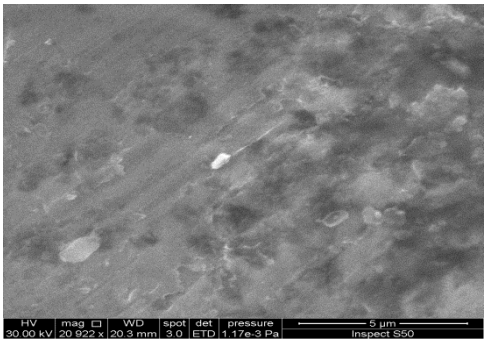
c- 10% Sic



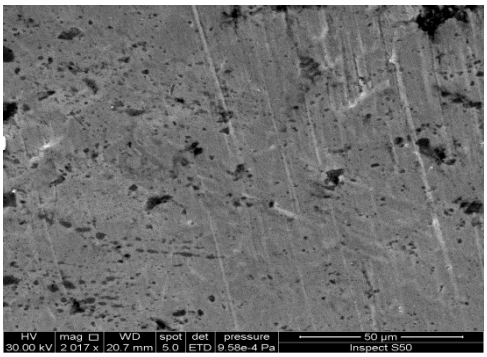



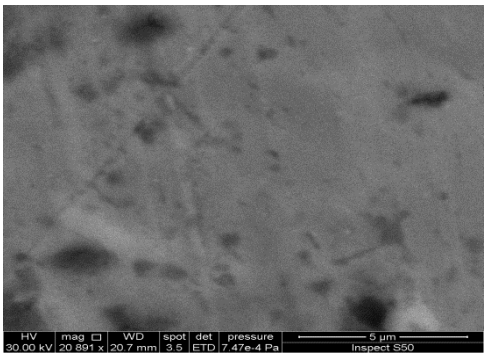

d- 15%Sic



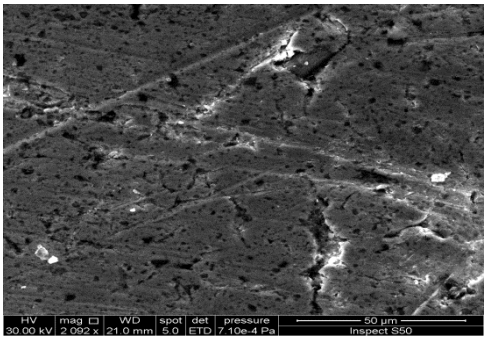



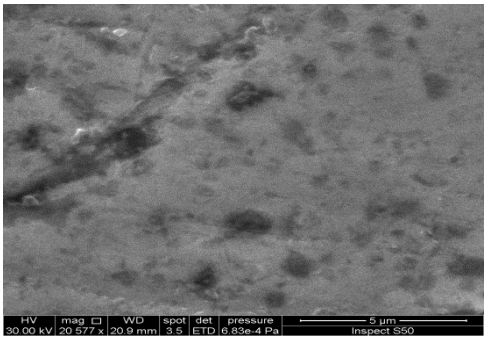

e- 20%Sic%



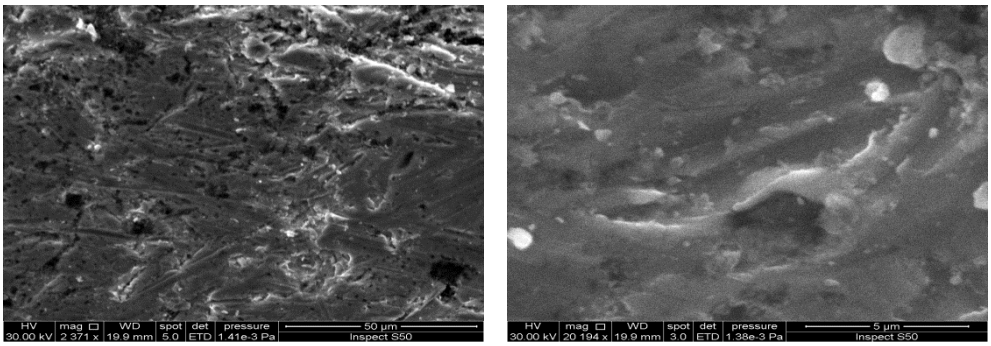




f- 25% Sic



g- 30%Sic



Energy Dispersive X-ray (EDX) spectra of Al particles and Cu/SiC illustrates in Table 2. A pure sample of Cu first from the up,5%,10%,15%,20%, and finally 25% Cu/SiC are shown in Fig 4. These graphs make it clear that the samples' chemical purity and stoichiometry are suggested by the energy-dispersive spectra of SiC and Cu/SiC nanoparticles. These graphs provide unmistakable proof that Cu, Si, and C components are present.

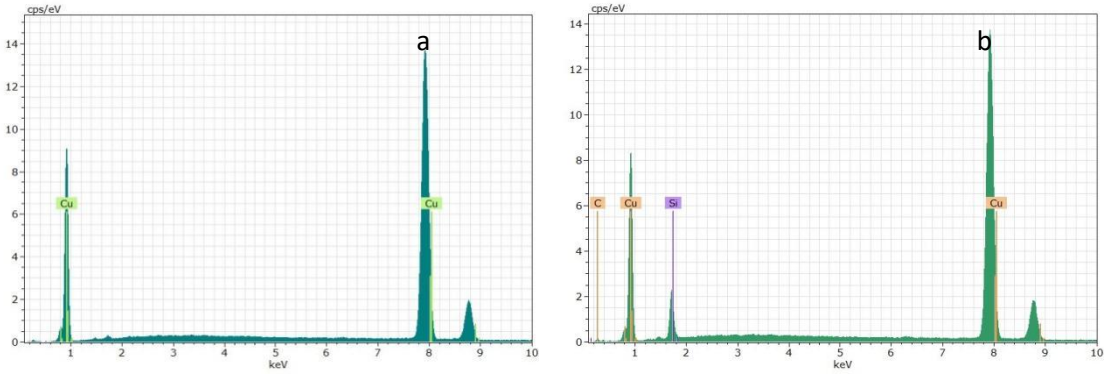
The gradual decrease in Cu concentration and the gradual increase in silicon and carbon concentrations in the new mixed and compressed material is evidence of regular arrangement and mixing. The strong peaks related to Cu and Si are found in the spectrum. The presence of impurities or contamination during the preparation process is the reason for the appearance of C and Fe in figs in comparison .Cu and Sic detection was confirmed by EDX analysis as shown in fig- 4. In EDS analysis, relatively cornered component indicate Sic while others represent Sic. EDS also, revealed that that the dominant component of composites are Cu and Sic.

**Table 2.** EDX table of pure Cu and of mixtures of Cu/SiC at different concentrations of SiC.

| Material | 100% Cu | SiC 5% | SiC 10% | SiC 15% | SiC 20% | SiC 25% |
|---|---|---|---|---|---|---|
| Cu-concentration | 1.11 | 1.12 | 1.02 | 1.12 | 0.93 | 0.97 |
| Si-concentration | | 0.47 | 0.78 | 0.92 | 1.80 | 1.01 |
| C-Concentration | 1.02 | 1.36 | 1.80 | 1.30 | 0.78 | 1.49 |
| Fe-Concentration | | | | 0.13 | | |

**Table 3. EDX analysis of atomic percentages of the Cu/SiC elements.**

| Material | 100% Cu | SiC 5% | SiC 10% | SiC 15% | SiC 20% | SiC 25% |
|---|---|---|---|---|---|---|
| Cu | 9 | 8.75 | 8.5 | 5.75 | 6.5 | 6 |
| Si | 2 | 2 | 2 | 2 | 2 | 2 |
| C | --- | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 |
| Fe | --- | --- | | 6.5 | --- | --- |



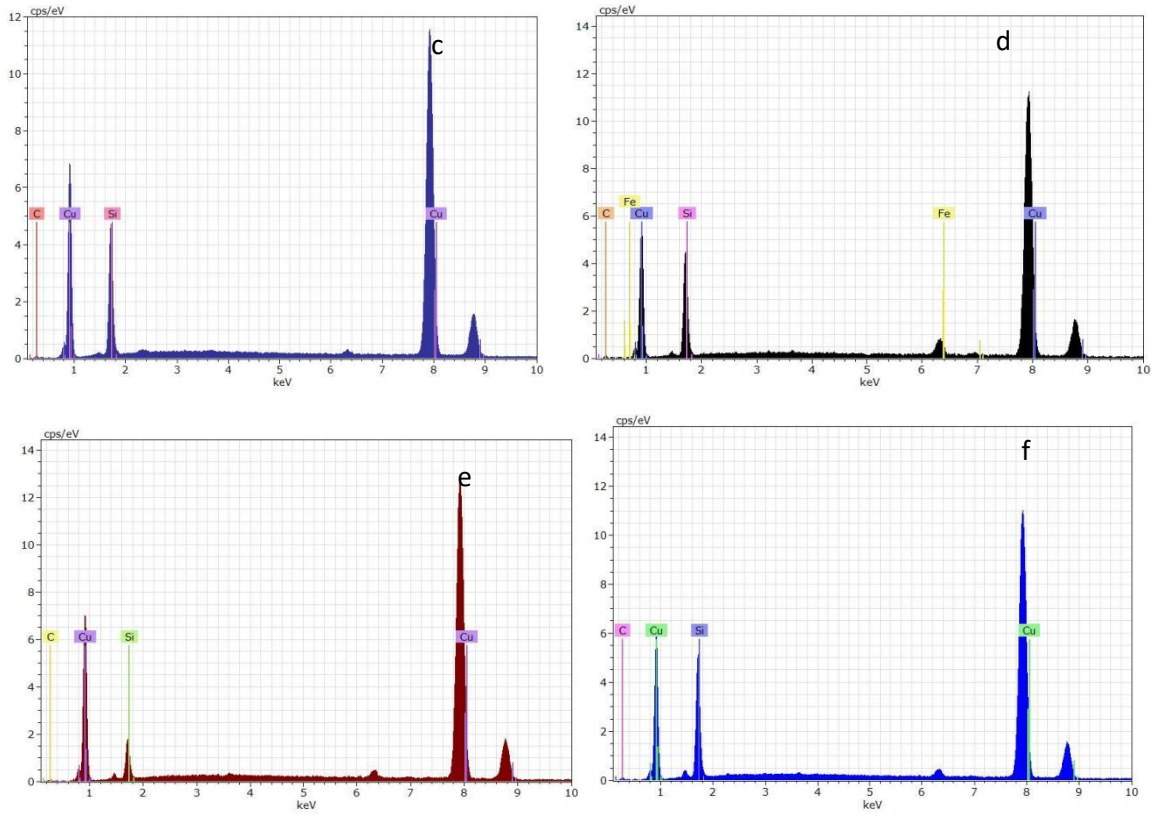



Fig-4 SEM-EDS analysis of Cu and Cu/Sic composites for different weight percent (a)Cu, (b) 5%Sic, (c) 10% Sic, (d) 15% Sic, (e)20% Sic, (f) 25% Sic.

## 4. Conclusion

1. Cu-Sic alloys reinforced with 5, 10, 15, 20, 25, and 30 weight % of Sic were effectively fabricated using the powder metallurgy approach.
2. SEM reveals that Sic particles were homogenously distributed in copper grains.
3. EDS analysis showed that the Cu and Sic are dominant.
4. The average density of pure copper was measured at 97.8%, but the densities of composites decreased from 97.8% to 84.5% as concentration climbed from 0% to 30%.
5. Hardness of the composites was increased as Sic weight percent increased and it is possible to claim that there is a direct relationship between the weight percent and hardness.
6. More compressibility obtained at 15 and 20 % Sic weight percent. Therefore it can be claimed that this is the best weight percent to be added.

## References

1. G.F. Celebi Efe, I. Altinsoy, M. Ipek, S. Zeytin, C. Bindal, 2011, Some Properties of Cu–SiC Composites Produced By Powder Metallurgy Method, Kovove Materialy- Metallic Materials vol, 5, p. 49.
2. G.Celebi Efe, T.YENER, I.Altinsoy,M.IPek,S.ZEYTIN,C.Bindal,2011, the effect of sintering temperature on some properties of Cu-Sic composite,Journal of Alloys and Compounds, Kovove Materialy 49(2):131-136 .
3. G.F. Celebi Efe,2010, Development of Conductive Copper Composites Reinforced with SiC, Ph.D. thesis, Sakarya University, Institute of Science and Technology, June 2010.
4. G. Celebi Efe, T. Yener, I. Altinsoy, M. Ipek, S. Zeytin, C. Bindal, 2010, The fabrication and properties of SiC particulate reinforced copper matrix composites, in: 13th International Materials Symposium, 13–15th October 2010, Denizli, Turkey.

5. H.K. Kang, 2003, Surface and Coatings Technology vol, 190 P. 448–452.
6. H.K. Kang, 2006, S.B. Kang, Materials Science and Engineering, vol 428 P.336– 345.
7. LZhu, H.Lin, B.Zhao, W.Shen,Hu,2007, Microstructure and performance of electroformed Cu/nano-Sic composite.Mater.Des.,Vol,28,P.1958-1962.
8. M.R.Akbarpour,E.Salahi,F.Alikani,Hesari,A.Simchi,H.S.Kim,2014,Microstructure and compressibility of Sic nanoparticles reinforced Cu nanocomposite powder processed by high energy mechanical milling, Ceramics international, Ceramics International 40(1):951-960.
9. R. Zhang, L. Gao, J. Guo, 2003, Surface and Coatings Technology 166 p. 67–71.
10. WANG Zhang-wei, SONG Min, SUN Chao, HE Yue-hui,2011, Effects of particle size and distribution on the mechanical properties of SiC reinforced Al−Cu alloy composites [J]. Materials Science and Engineering A, 25: 1131−1137.
11. Yun-Han, Ling,JiangTao, Li,Chang-Chun ,Ge,Xin-De Bai,2001, Frabrication and evaluation of Sic/Cu functionally graded material used for plasma facing components in a fusion reactor, Journal of nuclear material Vol,303 P.188-195.