

## Powder Metallurgy Processed W-Cu Composites: A Microstructural Study

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This study assesses the microstructure and elemental concentration of W-Cu composites with fixed ratios of tungsten and copper (W80Cu20, W70Cu30, W60Cu40) using Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS). Backscatter electron mapping through SEM shows the dispersion and characteristics of the tungsten and copper-phase carried in the matrix, whereas EDS characterizes semiquantitatively and identifies the W, Cu, C, and O content in the compositions. The distribution of which portrays an increased Cu content as well as reduced W content with increased Cu ratio, with minor carbon and oxygen present, possibly pre-process contamination. The results obtained here are in line with previous works established from this research that SEM and EDS are suitable methods of analyzing phase distribution, homogeneity and elemental composition in W-Cu composites for enhancing the processing parameters and mechanical and functional properties. Thus, the combination of SEM and EDS allows a deep investigation of the influence of the microstructure on the properties of W-Cu composites and accomplishments of their intended aims and tasks in the frame of modern science and engineering.

**Keywords:** EDS, SEM, Powder Metallurgy, W-Cu Composites, Characterization, Microstructure

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## 1. Introduction

Tungsten-copper composites also known as W-Cu composites which are comprised of Tungsten and copper offers high melting point and strength near to Tungsten and electrical and thermal conductivity nearly as good as copper on the other hand making them useful in electrical applications such as electrical contacts and heat sink and in other engineering application that require high performance. The properties of W-Cu composites depend profoundly on their microstructure and the arrangement of constituent phases, which, in their turn, depend on the synthesis methods and parameters [1].

SEM and EDS are relevant tools being used to analyze the microstructure and chemical composition of W-Cu composites. SEM also gives the characteristics such as homogeneity, particle size, phase distribution and agglomeration as well as the interface between tungsten and copper phases. When linked to SEM, EDS provides the elemental analysis and the spatial distribution identified quantitatively and qualitatively [2-5].

As stated earlier, literatures have shown that SEM and EDS are efficient in characterizing W-Cu composites synthesized using different methods such as; powder metallurgy, electroless plating, mechanical alloying and spark plasma sintering [6]. For instance, SEM micrographs have shown a homogeneous distribution of copper phase within the tungsten matrices in the synthesized composites fine and agglomerated particle structures, and the ability to disperse the reinforcing phase effectively [7]. They also enable determination of the interfacial phase distribution and qualitatively in determining the intermetallic phase in complex microstructure composites.

SEM and EDS helps in understanding the dependence of processing, microstructure and properties and assists in arriving the necessary modification in the composites design for improvement of performance in severe operating conditions [8].

## 2. Literature Review: SEM and EDS Analysis for W-Cu Composites

### 2.1 Role of SEM and EDS characterization of W-Cu composite

SEM coupled with EDS is basic characterization techniques for determining microstructure and composition of tungsten-copper (W-Cu) composites. These methods are used for measuring phase distribution, quality of the interface, and the impact of processing parameters on the properties of the composite [9, 10].

### 2.2 Microstructural Insights from SEM

SEM is quite useful for studying the morphology, distribution and the phase distribution of both tungsten and copper. These tests have shown that, in relation to the SEM micrographs, the features such as the uniform dispersion of tungsten and other reinforcements (for example, fly ash) in the copper matrix, the quantity of the voids and the quality of the interface between the phases. For instance, SEM analysis established that W and fly ash distributed uniformly in Cu matrix and the results in enhanced microhardness and compressive strength. In another study by SEM to understand the microstructure of sintered W-Cu composites, it was described that higher sintering temperature is associated with higher density and shocking mechanical properties. SEM has also been used to investigate the topography of composite powders and coatings, and it has been found that the cold spraying technique and electroless plating to produce coatings with uniform and low porosity [11].

### 2.3 EDS – Elemental Mapping & Phase Analysis

In conjunction with SEM, EDX spectra offer elemental mapping and quantitative proportional analysis of the given composite. EDS also proves the existence and location of tungsten and copper, checks the effectiveness of the coating and alloying process, and reveals the presence of certain intermetallic phases or the homogeneity of elemental distribution. For example, EDS mapping has shown that Cu and W are well-mixed in sintered sample, thus confirming that powder mixing and sintering process can indeed provide well dispersed composites. Cross-sectional views of W-Cu composite coatings have also been prepared and studied by EDS to determine the dispersion of different elements up to the penetration thickness and supplement the evaluation of the coatings [12, 13].

**2.4 Influence of Processing Parameters**

SEM and EDS analysis have confirmed that the P/M techniques like mechanical alloying, electroless plating, and cold spraying along with powder metallurgy techniques offer adequate bonding, dense and uniform W-Cu composites with improved mechanical and functional properties [15-19]. The bottom of the joined region of the Tungsten and Copper is mechanically fitted and formation of any new phase at the interface is not prominent which are supported by EDS. Morphology of the composites mainly depends on size, temperature of sintering and time period of milling and also the composition examined by using SEM/EDS [14-19].

SEM and EDS are quite useful tools that help in the characterization of tungsten-copper composites. It offers information on the size of the interfacial phases, distribution of elements in the synthesized phase and quality of the interface that enables a guide on how best to process them to have the best mechanical and functional properties.

**Table 1:** SEM and EDS Analysis for W-Cu Composites in tabulated form

| Author Name & Year        | SEM Analysis Findings  | EDS Analysis Findings   | Key Insights/Applications  |
|---------------------------|--|---|--|
| (Rajan, S et al., 2020).  | SEM micrographs revealed uniform distribution of W and fly ash in the Cu matrix; worn surface SEM used to study wear mechanisms. | EDS confirmed the presence of W and fly ash in the Cu matrix.                   | Enhanced microhardness, compressive strength, and corrosion resistance with W addition; lowest wear rate for Cu-6FA-6W composition |
| (Meng, Y S et al., 2015). | SEM showed fully dense, uniform triple-layer W-Cu coatings metallurgically bonded to Cu substrate.                               | EDS used to study elemental and phase composition across graded layers.         | Improved microhardness and wear resistance; gradual property transition in coatings [2].   |
| (Huang, L et al., 2014).  | FE-SEM revealed surface defects aiding Cu grain nucleation and evenness of W-Cu powder.  | EDS analyzed composition of W, pretreated W, W-Cu powder, and sintered samples. | Optimized pretreatment improved density and electrical conductivity of sintered composites   |

|                              |   |   |  |
|------------------------------|---|---|--|
| (Selahshorrad et al., 2024). | SEM examined microstructure changes at different sintering temperatures; observed work hardening and wear layers. | EDS used to analyze elemental distribution and phase changes post-sintering.                      | Higher sintering temperature improved hardness, density, and corrosion resistance.     |
| (Stalin et al., 2020).       | SEM showed even dispersion of TiB <sub>2</sub> in Cu-W matrix; microstructure correlated with wear resistance.    | EDS confirmed presence of TiB <sub>2</sub> , W, and Cu; detected oxides formed during sintering.  | TiB <sub>2</sub> addition enhanced hardness, impact strength, and minimized wear rate. |
| (Wang, C et al., 2020).      | SEM revealed formation of multiple interfacial transition zones and intermetallic compounds.                      | EDS, along with SEM, identified AlCu, Al <sub>2</sub> Cu, and Al <sub>4</sub> W at the interface. | Provided guidance for controlling interfacial microstructure in novel composites.      |
| (Lima, M et al., 2017).      | SEM revealed fine, agglomerated particles and good homogenization of Cu in W.                                     | EDS mapping showed homogeneous distribution of Cu and W in sintered samples.                      | Achieved high density and microhardness; effective phased dispersion.                  |
| (Yusefi et al., 2017).       | SEM and image analysis showed up to 97% densification and clear layer structure.                                  | EDS mapping determined composition in each layer.   | SPS improved density and hardness, especially in intermediate layers.                  |
| (Machkale et al., 2024).     | SEM analyzed microstructure of W-Cu coatings before and after wear testing.                                       | EDS assessed elemental composition of coated layers.  | Coatings improved microhardness and reduced friction coefficient.                      |

**3. Results & Discussion**

SEM-EDS (Scanning Electron Microscopy with Energy-Dispersive X-ray Spectroscopy) combine the imaging capabilities of SEM with the elemental analysis of EDS. This technique allows researchers to analyze the surface morphology and elemental composition of materials. SEM provides high-resolution images by scanning the sample with an electron beam, while EDS analyzes the X-rays emitted when the electron beam interacts with the sample, revealing the elements present and their relative concentrations.

**3.1 Compositional Analysis**

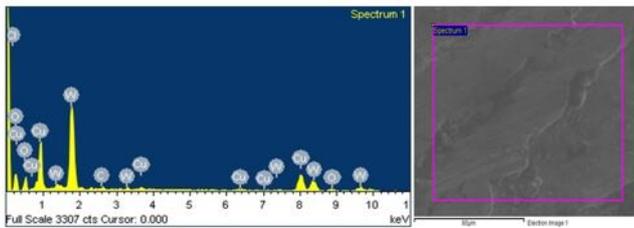
**[1] W80Cu20 Composite EDS Analysis**

The EDS analysis of W80Cu20 indicates that it is a W-rich material,

containing 74.35 wt% W and 18.15 wt% Cu which concurs with the nominal composition of the alloy. Such concentration of 6.43 wt% or 34.04 at% oxygen indicates moderate level of surface oxidation that can probably develop WO<sub>3</sub> phase at the grain boundaries during processing. Carbon content seems to be negligible at 1.07 wt% (7.55 at%) probably due to the residual lubricants used while pressing powders. A higher atomic percentage of oxygen in comparison with the weight percentage can predict that this light element segregates in surface preferential, which can have a bearing on interfacial behaviors at high-temperature environments.

**Table 2:** W80Cu20 composite analysis

| Composition | C (wt%) | O (wt%) | Cu (wt%) | W (wt%) |
|-------------|---------|---------|----------|---------|
| W80Cu20     | 1.07    | 6.43    | 18.15    | 74.35   |



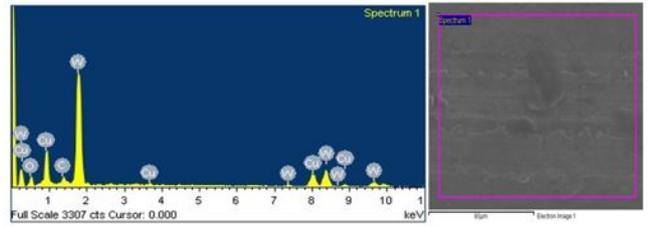
**Figure 1:** W80Cu20 EDS mapping with SEM image

**[2] W70Cu30 Composite EDS Analysis**

The trends in the sample W70Cu30 are meaningful to have 67.28 wt% composition of W and 26.67 wt% composition of Cu while the atomic percentage calculated to be 30.87%W and 35.37%Cu. The content of the oxygen is lower compared to the sample W80Cu20: 4.98 wt % against 26.24 at % indicative of higher chances of improved sintering conditions but still detrimental to properties of the weld metal. Carbon concentration has negligible variation of 1.07 wt% (7.52 at%) and, therefore, remains systematic, which may originate from the processing tools. As expected, the weight percentage of copper is lower than the atomic percentage, while the atomic percentage of copper increases, which could be attributed to copper atomic mass and its progression in the formation of interconnected net like structure as seen from the SEM images.

**Table 3:** W70Cu30 composite analysis

| Composition | C (wt%) | O (wt%) | Cu (wt%) | W (wt%) |
|-------------|---------|---------|----------|---------|
| W70Cu30     | 1.07    | 4.98    | 26.67    | 67.28   |



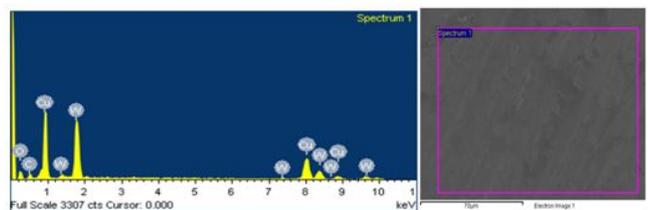
**Figure 2:** W70Cu30 EDS mapping with SEM image

**[3] W70Cu30 Composite EDS Analysis**

It could therefore be deduced that the composition of the prepared alloy W60Cu40 is as expected with weight percent of 54.68W and 36.08Cu while the atomic percent is 20.12W and 38.48Cu respectively. The oxygen content increases to 7.63wt% (32.32at%) perhaps due to the fact that more surface area of copper is available for oxidation. Carbon content rises to 1.61 wt% (9.08 at%), which could be due to higher carbon acquisition from the consumables during the prolonged treatment of Copper containing mixtures. The atomic per cent of tungsten decreases sharply to 20.12 % suggesting further break from the copper continuous microstructure that is associated with better electrical conductivity but lower High Temperature Strength. The low atomic ratios of C,O as compared to W also shows that weight dependent values and atomic concentrations must be taken into consideration at the surface when analysing EDS data.

**Table 4:** W80Cu20 composite analysis

| Composition | C (wt%) | O (wt%) | Cu (wt%) | W (wt%) |
|-------------|---------|---------|----------|---------|
| W60Cu40     | 1.61    | 7.63    | 36.08    | 54.68   |



**Figure 3:** W80Cu20 EDS mapping with SEM image

**[4] Interpretation Analysis**

The EDS analysis incorporates elemental mappings to show concentration trends in the W-Cu matrix based on increasing Cu content. The results support the trend of the copper concentration rising in relation to the high Cu ratios and the concentration of tungsten decreasing in relation to the high Cu ratios. This is attributed to the fact that samples are usually contaminated by C and O at the surface.

The above results are in accordance with the previous studies approving the efficiency of SEM and EDS to investigate W-Cu composites for application in electrical, thermal and mechanical fields.

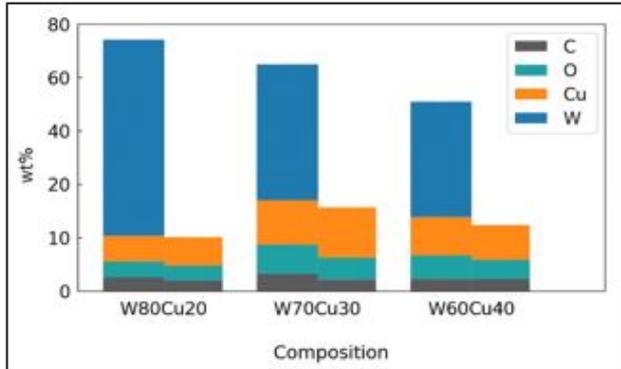


Figure 4: EDS Data Summary

### 3.2 Microstructural Analysis

Scanning Electron Microscopy (SEM) is a technique used to study the morphology, or shape and surface features, of materials at a nanoscale resolution. It utilizes a focused beam of electrons to scan the surface of a sample, interacting with its atoms and generating signals that reveal the sample's surface morphology, topography, and other characteristics.

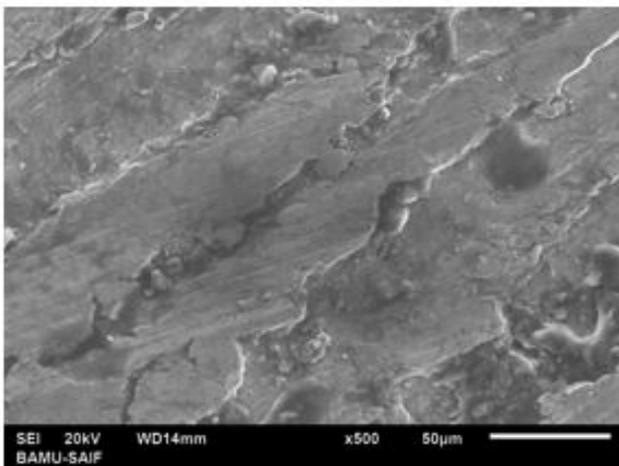


Figure 5: Scanning Electron Microscopy for W-Cu Composite

SEM micrograph shows that the examined specimens possess a typical tungsten-copper microstructure with clear segregation of dark copper matrix and bright tungsten particles. Tungsten particles showing uniform distribution in the continuous copper matrix and that shows good mixture of b ticker and consolidation during the processing.

The copper phase on the other hand, forms a continuous network around the tungsten particles which show that there is enough sintering to achieve electrical percolation. Anomalous microstructures including splintering at the phase interfaces as well as phase boundaries are clearly observed, which might be due to the PM processing from powder. The counter is characterised by angular tungsten particles with different sizes and an almost homogeneous matrix containing copper where no large-scale copper segregation is visible. There is blurring of interface at some regions of tungsten-copper which may arise from oxide phase or incomplete wetting. At this magnification, the cross-section sample shows no substantial signs of the clustering of either of the phases, obeying the FESEM result. The scale bar corroborates that the image enables examination of the individual particles' properties and phases distribution patterns at once. Such microstructure is typical for W-Cu composites prepared under normal conditions, however, the interfacial phenomena and porosis observed in this investigation might be further enhanced to improve the material properties of W-Cu composites. The image contrast enables improvements in phase contrast with clear definition along with the additional differentiation of microstructures which are crucial in analysis.

## 4. Conclusion

The SEM and EDS analyses of tungsten-copper (W-Cu) composites with varying compositions W80Cu20, W70Cu30, and W60Cu40 provide comprehensive insights into their microstructural characteristics and elemental distribution. The SEM images revealed the dual-phase microstructure where tungsten formed a continuous or dispersed phase depending on its concentration, while copper increasingly dominated the matrix with higher Cu content. EDS results confirmed a systematic increase in Cu and corresponding decrease in W content with increasing copper proportion, along with minor traces of carbon and oxygen, likely from surface contamination or sample handling. These findings validate that SEM combined with EDS is an effective technique for evaluating phase distribution, compositional uniformity, and microstructural integrity. This knowledge is essential for optimizing processing parameters to achieve the desired mechanical and thermal properties of W-Cu composites for advanced engineering applications.

**Conflicts of Interest**

The authors declare no conflicts of interest about the publication of this research paper.

**References**

[1] Rajan, S., Balaji, A., R, R., Nagarajan, K., & Vettivel, S. (2020). Investigation and characterization of Copper-Fly ash-Tungsten hybrid composites synthesized through P/M process. *Materials Research Express*, 7. <https://doi.org/10.1088/2053-1591/ab8030>.

[2] Meng, Y., Zhang, J., Duan, C., Chen, C., Feng, X., & Shen, Y. (2015). Microstructures and properties of W-Cu functionally graded composite coatings on copper substrate via high-energy mechanical alloying method. *Advanced Powder Technology*, 26, 392-400. <https://doi.org/10.1016/J.APT.2014.11.009>.

[3] Huang, L., Luo, L., Ding, X., Luo, G., Zan, X., Cheng, J., & Wu, Y. (2014). Effects of simplified pretreatment process on the morphology of W-Cu composite powder prepared by electroless plating and its sintering characterization. *Powder Technology*, 258, 216-221. <https://doi.org/10.1016/J.POWTEC.2014.03.027>.

[4] Selahshorrad, E., Alavi, S., Zangeneh-Madar, K., Samadi, M., Yazdanshenas, M., & Afshari, M. (2024). Investigation of the effect of sintering process parameters on the corrosion, wear and hardness of W-Cu composite. *Sādhanā*. <https://doi.org/10.1007/s12046-024-02559-z>.

[5] Stalin, B., Ravichandran, M., Sudha, G., Karthick, A., Prakash, K., Asirdason, A., & Saravanan, S. (2020). Effect of titanium diboride ceramic particles on mechanical and wear behaviour of Cu-10 wt% W alloy composites processed by P/M route. *Vacuum*, 109895. <https://doi.org/10.1016/j.vacuum.2020.109895>.

[6] Wang, C., Liang, S., Cao, F., & Zhang, Q. (2020). Interface microstructure evolution of a novel CuW/Al composite fabricated by an infiltration method. *Journal of Alloys and Compounds*, 816, 152506. <https://doi.org/10.1016/j.jallcom.2019.152506>.

[7] Lima, M., Silva, F., Souto, M., Mashhadikarimi, M., Silva, A., Gomes, U., & Souza, C. (2017). Obtaining and characterization of w-cu composite powder produced by mixing and sintering of ammonium paratungstate (Apt) and copper nitrate.

*Materials Research-ibero-american Journal of Materials*, 20, 97-101. <https://doi.org/10.1590/1980-5373-MR-2016-1003>.

[8] Yusefi, A., & Parvin, N. (2017). Fabrication of three layered W-Cu functionally graded composite via spark plasma sintering. *Fusion Engineering and Design*, 114, 196-202. <https://doi.org/10.1016/J.FUSENGDES.2016.11.013>

[9] Machkale, P., & Dabade, B. (2020). Morphological studies and wear behavior of electro discharge coated steel. *Materials Today: Proceedings*, 27, 640-648. <https://doi.org/10.1016/j.matpr.2020.01.292>.

[10] Manubolu, V., & Vanimireddy, D. (2023). Experimental study on mechanical behaviour of arhar-reinforced composites using GRA with PCA. *J. Exp. Res. Rev.*, 36, 232-243. <https://doi.org/10.52756/ijerr.2023.v36.023>.

[11] Deng, N., Tang, J., Xiong, T., Li, J., & Zhou, Z. Fabrication and characterization of W Cu composite coatings with different W contents by cold spraying. *Surface and Coatings Technology*. <https://doi.org/10.1016/J.SURFCOAT.2019.04.034>.

[12] Bhowmick, D., Chatterjee, K., Mandal, P., Rudra, A., & Das, I. (2023). A Scanning Electron Microscopic (SEM) study of the evaluation between the results by gracey curette and Er,Cr:YSGG laser on periodontally involved root surfaces. *J. Exp. Res. Rev.*, 30, 66-74. <https://doi.org/10.52756/ijerr.2023.v30.008>.

[13] Kumar, J., Sharma, S., Singh, J., Singh, S., & Singh, G. (2022). Optimization of wire-edm process parameters for Al-Mg-0.6Si-0.35Fe/15%RHA/5%Cu hybrid metal matrix composite using topsis: Processing and characterizations. *Journal of Manufacturing and Materials Processing*. <https://doi.org/10.3390/jmmp6060150>.

[14] V. Danilenko et al. (2021). Cu-Al metal matrix composite fabricated by accumulative HPT. *Materials Letters*, 300, 130240. <https://doi.org/10.1016/J.MATLET.2021.130240>.

[15] Rizvi, S. A., Sahu, R., Siddiqui, S., Shah, K., Bajpai, V., & Lal, B. (2024). Assessment of recast layer while machining die Steel D3 on EDM. *International Journal of Experimental Research and Review*, 41(Spl Vol), 96-105. <https://doi.org/10.52756/ijerr.2024.v41spl.008>.

[16] He, J., Meng, Q., & Xu, H. (2024). Exploring material selection and applications for embedded carbon reduction in the built environment. *Applied Science and Engineering Journal for Advanced Research*, 3(6), 51–59. <https://doi.org/10.5281/zenodo.14242407>.

[17] Manubolu, V., & Vanimireddy, D. (2023). Experimental study on mechanical behaviour of arhar-reinforced composites using GRA with PCA. *J. Exp. Res. Rev.*, 36, 232-243. <https://doi.org/10.52756/ijerr.2023.v36.023>.

[18] Dande, K., & Jawale, P. (2025). Experimental and regression-based wear analysis of MWCNT reinforced AA7075 using box-behnken design. *Applied Science and Engineering Journal for Advanced Research*, 4(2), 45–54. <https://doi.org/10.5281/zenodo.15348294>.

[19] Jain, A., Kumar, C. S., & Shrivastava, Y. (2023). An effort for identifying suitable machining range during drilling of a novel al-based composite using electric discharge machine. *Int. J. Exp. Res. Rev.*, 36, 327-346. <https://doi.org/10.52756/ijerr.2023.v36.030>.

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