Tungsten Carbide-Silver Sulphide Nanocomposites: A Novel Approach for Enhanced Antimicrobial Activity

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**Abstract:**The emergence of antibiotic-resistant bacteria has necessitated the development of novel antimicrobial materials. Tungsten carbide-silver sulfide (WC-Ag₂S) nanocomposites present a promising solution by integrating the antimicrobial properties of both components. WC offers structural stability, while Ag₂S, a low-toxicity semiconductor, enhances microbial interactions. Synthesis methods such as hydrothermal synthesis, sol-gel techniques, and chemical vapor deposition ensure homogeneous Ag₂S distribution within the WC matrix, maximizing bacterial contact and antimicrobial efficacy. The release of silver ions and reactive oxygen species further contributes to their potent antimicrobial activity. These nanocomposites hold significant potential for applications in medical device coatings, water treatment, and food packaging—addressing the urgent need for alternative antimicrobial strategies.WC-Ag₂S nanocomposites were synthesized through a multi-step process. Tungsten carbide was obtained by reducing a mixture of ammonium metatungstate (0.5 g) and dicyandiamide under H₂ at 1200°C for 6 hours, followed by drying at 80°C for 24 hours. Silver sulfide was synthesized by reacting silver nitrate (1.2092 g) with sodium sulfide (1.0578 g), producing a black precipitate. The WC-Ag₂S composite was formed by dispersing 1 g of tungsten carbide in distilled water, followed by dropwise addition to the Ag₂S solution with continuous stirring for 3 hours. The precipitate was purified through centrifugation and sequential washing before drying at 80°C and calcination at 300°C for 3 hours.UV-Vis and FTIR spectral analyses confirmed the structural and optical properties of WC-Ag₂S nanocomposites, highlighting their suitability for antimicrobial applications. Comparative analysis with SiC/Ag/CE nanocomposites revealed superior purity and enhanced synergistic efficacy of WC-Ag₂S. Future research should focus on optimizing synthesis conditions, assessing biocompatibility, and investigating resistance mechanisms to fully exploit their antimicrobial potential.WC-Ag₂S nanocomposites exhibit strong antimicrobial potential for medical device coatings, water treatment, and food packaging. Further improvements in nanostructural design and synergistic material combinations could enhance their efficacy. Establishing biocompatibility and monitoring resistance development will be crucial for practical implementation. These nanocomposites represent a promising step toward innovative antimicrobial strategies to improve public health and safety.

**Keywords:** WC-Ag₂S Nanocomposites, Antimicrobial Activity, Silver Sulfide Nanomaterials, Tungsten Carbide-Based Composites, Antibiotic Resistance Mitigation

# INTRODUCTION

Tungsten carbide-silver sulfide (WC-Ag₂S) nanocomposites have emerged as a promising material in antimicrobial applications, addressing the growing concern of antibiotic resistance. With the increasing prevalence of multidrug-resistant (MDR) bacteria, novel materials with intrinsic antimicrobial properties are being extensively explored as alternatives to conventional antibiotics [(Rajeshkumar & Lakshmi, 2021; Sivakumar et al., 2021)](https://paperpile.com/c/dnx0IJ/dPVW0+dL0a3). The combination of tungsten carbide (WC) and silver sulfide (Ag₂S) in a nanocomposite structure presents a synergistic approach, leveraging the unique physicochemical properties of both materials to enhance antimicrobial efficacy[(Osazee et al., 2024)](https://paperpile.com/c/dnx0IJ/D5Za). Tungsten carbide is widely known for its high hardness, chemical stability, and mechanical strength, making it a desirable material for coatings and structural applications. Traditionally used in cutting tools, wear-resistant coatings, and electronics, WC has recently gained attention in biomedical applications due to its ability to serve as a stable matrix for antimicrobial agents. In contrast, silver sulfide (Ag₂S) is a semiconductor material with established antibacterial properties. Silver-based compounds have been extensively studied for their antimicrobial potential, primarily due to the release of silver ions (Ag⁺), which disrupt bacterial cell membranes, interfere with metabolic processes, and generate reactive oxygen species (ROS)[(Chokkattu et al., 2023; Dharman et al., 2023; Govindaraj & Shanmugam, 2023)](https://paperpile.com/c/dnx0IJ/zQ1r0+x4PSF+GPBdN). When combined, WC-Ag₂S nanocomposites provide a stable, long-lasting antimicrobial effect with enhanced efficiency compared to individual components[(Matharu et al., 2020)](https://paperpile.com/c/dnx0IJ/PiUF).

The synthesis of WC-Ag₂S nanocomposites is a critical aspect that determines their structural properties and antimicrobial performance. Several synthesis techniques, such as hydrothermal methods, sol-gel processes, and chemical vapor deposition, have been employed to achieve uniform dispersion of Ag₂S nanoparticles within the WC matrix[(Jeeva Jothi et al., 2022)](https://paperpile.com/c/dnx0IJ/rSUd). Homogeneous distribution is essential to maximize the contact surface area between the nanocomposite and microbial cells, ensuring effective antimicrobial action. One widely used approach involves the reduction of ammonium metatungstate and dicyandiamide under a hydrogen atmosphere to form WC, followed by the controlled precipitation of Ag₂S using silver nitrate and sodium sulfide[(Gandhi et al., 2021; Katyal et al., 2023; Priyadharshini et al., 2023)](https://paperpile.com/c/dnx0IJ/kH0Hj+E16aD+GgHD0). The resulting composite undergoes multiple purification steps, including centrifugation and washing, to remove unreacted precursors and ensure high purity. Post-synthesis calcination at moderate temperatures further enhances the stability and bonding of Ag₂S within the WC framework[(Kukushkina et al., 2021)](https://paperpile.com/c/dnx0IJ/xmMy).The antimicrobial mechanism of WC-Ag₂S nanocomposites primarily relies on the sustained release of silver ions and the generation of reactive oxygen species. Silver ions interact with bacterial cell membranes, increasing permeability and leading to structural damage. Once inside the bacterial cell, Ag⁺ disrupts critical biomolecules, including proteins and DNA, inhibiting cellular respiration and replication[(Janani et al., 2021; Kachhara et al., 2021; Subramanian et al., 2023)](https://paperpile.com/c/dnx0IJ/QKa0S+hhwqm+srFUT). Additionally, silver ions can induce oxidative stress by catalyzing the formation of ROS, which further damages cellular components and accelerates bacterial death. The presence of tungsten carbide enhances the stability and dispersion of Ag₂S, ensuring a prolonged antimicrobial effect while preventing rapid degradation[(S et al., 2024)](https://paperpile.com/c/dnx0IJ/9Ygm).One of the key advantages of WC-Ag₂S nanocomposites is their broad-spectrum antimicrobial activity against both Gram-positive and Gram-negative bacteria[(Gandhi et al., 2021; Katyal et al., 2023; Priyadharshini et al., 2023)](https://paperpile.com/c/dnx0IJ/kH0Hj+E16aD+GgHD0). Studies have demonstrated that these nanocomposites exhibit potent bactericidal effects against pathogens such as Escherichia coli, Staphylococcus aureus, and Pseudomonas aeruginosa, which are commonly associated with hospital-acquired infections[(More et al., 2023)](https://paperpile.com/c/dnx0IJ/sGxM). The structural properties of the nanocomposite also contribute to its effectiveness in biofilm inhibition, a critical factor in combating persistent infections[(Janani et al., 2021; Kachhara et al., 2021; Subramanian et al., 2023)](https://paperpile.com/c/dnx0IJ/QKa0S+hhwqm+srFUT). Biofilms, which are bacterial communities embedded in a protective extracellular matrix, are notoriously resistant to antibiotics. WC-Ag₂S nanocomposites can disrupt biofilm formation by interfering with bacterial adhesion and metabolic activity, making them a promising solution for biomedical applications[(B et al., 2024)](https://paperpile.com/c/dnx0IJ/blOX).Given their superior antimicrobial properties, WC-Ag₂S nanocomposites have numerous potential applications[(Doshi et al., 2023; Lampl et al., 2023; Pandiyan et al., 2023)](https://paperpile.com/c/dnx0IJ/YR0NU+7hemO+7nPFd). In the medical field, they can be utilized as coatings for surgical instruments, implants, and wound dressings to prevent bacterial infections. Their incorporation into water purification systems can help eliminate microbial contaminants, ensuring safe drinking water. In the food industry, WC-Ag₂S nanocomposites can be integrated into packaging materials to inhibit bacterial growth and extend the shelf life of perishable products [(Pavithra et al., 2023; Shenoy et al., 2023; Thomas & Jain, 2023)](https://paperpile.com/c/dnx0IJ/ODCpc+xI36c+2h9FC). The versatility of these nanocomposites extends to industrial and environmental applications, where they can be employed to mitigate microbial contamination in manufacturing processes[(“Synthesis of Metal Oxides/sulfides-Based Nanocomposites and Their Environmental Applications: A Review,” 2022)](https://paperpile.com/c/dnx0IJ/qtk9).Despite their promising potential, several challenges must be addressed before the widespread adoption of WC-Ag₂S nanocomposites[(Ramsundar et al., 2023; Rieshy et al., 2023; Singh et al., 2023)](https://paperpile.com/c/dnx0IJ/WGxB8+pBe9T+68ZJ2). One of the primary concerns is biocompatibility, as excessive silver ion release can pose cytotoxic risks to human cells. Therefore, further research is needed to optimize the synthesis and formulation of these nanocomposites to balance antimicrobial efficacy with safety. Additionally, the long-term impact of WC-Ag₂S on microbial resistance development requires careful monitoring. While silver-based materials are effective in antimicrobial applications, the potential emergence of silver-resistant bacterial strains must be considered. Future studies should focus on understanding the mechanisms of resistance and exploring strategies to mitigate resistance development, such as combining WC-Ag₂S with other antimicrobial agents[(“Mechanisms of Bacterial Resistance to Environmental Silver and Antimicrobial Strategies for Silver: A Review,” 2024)](https://paperpile.com/c/dnx0IJ/wRpA). WC-Ag₂S nanocomposites represent a novel and highly effective approach to combating bacterial infections, particularly in the face of rising antibiotic resistance. Their unique combination of structural stability, controlled silver ion release, and broad-spectrum antimicrobial activity makes them an attractive candidate for a wide range of applications. Ongoing research into their synthesis, biocompatibility, and resistance mechanisms will be crucial in advancing their practical implementation. By harnessing the potential of WC-Ag₂S nanocomposites, researchers and industries can contribute to the development of innovative antimicrobial solutions, ultimately enhancing public health and safety[(Wang et al., 2018)](https://paperpile.com/c/dnx0IJ/8wAa).

# MATERIALS AND METHODS

## Preparation of Tungsten Carbide Preparation

0.5g of Ammonium Metatungstate is used as a tungsten source. Required amount of Dicyandiamide is used as a carbide source. Both the mixture are reduced together using H2 at high temperature at 1200oC for 6 hours. Then the mixture is then placed in a centrifuge for filtration to avoid any contamination. After centrifuge the mixture is dried at 80oC for 24 hours

## Preparation of Silver Sulphide

AgNO3 (1.2092g) is used as a silver source and is dissolved in 50 ml of diluted water, stirred for 30 minutes. Sodium sulphide (1.0578) is used as a sulphide source and is dissolved in 50 ml distilled water for 30 minutes. Sodium sulphide is added into the silver solution drop by drop using a burette and stirred for 1 hour, black precipitate is then formed.

## Preparation of Tungsten Carbide - Silver Sulphide

1g of tungsten carbide is added in a beaker and 25 ml of distilled water is added which is stirred for 20 minutes. Then the 25 ml of tungsten carbide is added in silver sulphide drop by drop and is stirred for 3 hours.

## Microwave Method

The black ppt is then centrifuged for 7 times using ethanol, water and acetone to remove contamination. The ppt is then dried at 80oC for 24 hours, calcination is done in a muffle furnace at 300oC for 3 hours.

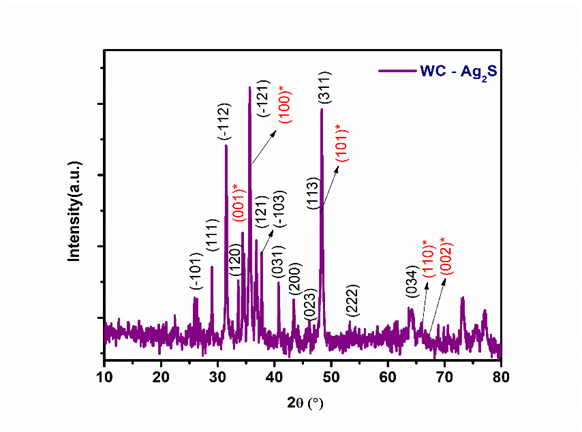


**Figure 1:** Synthesis Of Tungsten Carbide – Silver Sulphide

# RESULT AND DISCUSSION

## XRD Analysis

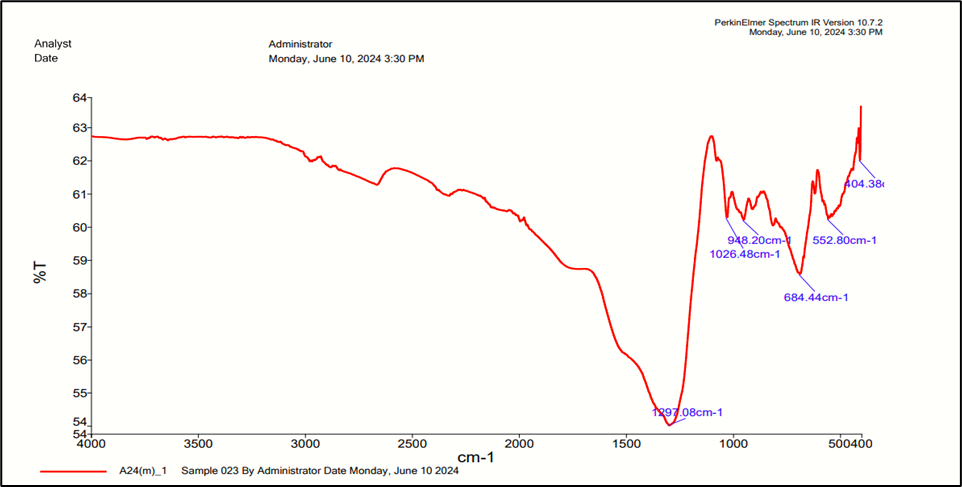
The X-ray diffraction (XRD) pattern of the tungsten carbide-silver sulfide (WC-Ag₂S) nanocomposite provides detailed structural information about the synthesized material. The diffraction peaks indicate the presence of both WC and Ag₂S phases, confirming the successful formation of the composite in Figure 2. Each diffraction peak corresponds to specific crystallographic planes, and their intensity and sharpness indicate the degree of crystallinity. The peaks corresponding to tungsten carbide (WC) are well-matched with the Joint Committee on Powder Diffraction Standards (JCPDS) file No. 51-0939. The diffraction peaks at approximately 31.4° (−101), 35.7° (111), 48.2° (120), 64.0° (200), 69.6° (023), and 75.8° (222) confirm the presence of WC in the composite. The relatively high intensity of these peaks suggests strong crystallinity, and the presence of multiple orientations indicates the polycrystalline nature of WC. The silver sulfide (Ag₂S) phase is identified by peaks indexed to JCPDS file No. 14-0072, confirming its monoclinic acanthite structure. The prominent peaks at 28.0° (001), 32.5° (100), 46.4° (101), 55.1° (110), and 73.5° (002) indicate the successful incorporation of Ag₂S into the composite. The broadening of these peaks suggests the nanoscale nature of Ag₂S, which enhances its surface properties and reactivity. XRD shows presence of sharp peaks suggests that the WC-Ag₂S material has a well defined crystalline structure. The peak was found at 35 ̊with intensity value (100). The X-ray diffraction (XRD) analysis of the tungsten carbide-silver sulfide (WC-Ag₂S) nanocomposite confirms the successful synthesis of a biphasic material with distinct crystalline structures corresponding to both WC and Ag₂S. The diffraction peaks for WC align with the hexagonal phase, as per JCPDS No. 65-4539, indicating high crystallinity and phase purity. Similarly, the peaks corresponding to Ag₂S match the monoclinic acanthite structure, consistent with JCPDS No. 14-0072, confirming its successful incorporation into the composite. The absence of extraneous peaks suggests minimal impurity phases, highlighting the efficacy of the synthesis method. These findings are consistent with previous studies on similar nanocomposites, reinforcing the reliability of the results[(Sohail et al., 2024)](https://paperpile.com/c/dnx0IJ/6YWe).



**Figure 2:** XRD Analysis of tungsten carbide-silver sulfide (WC-Ag₂S) nanocomposite

## FTIR Analysis

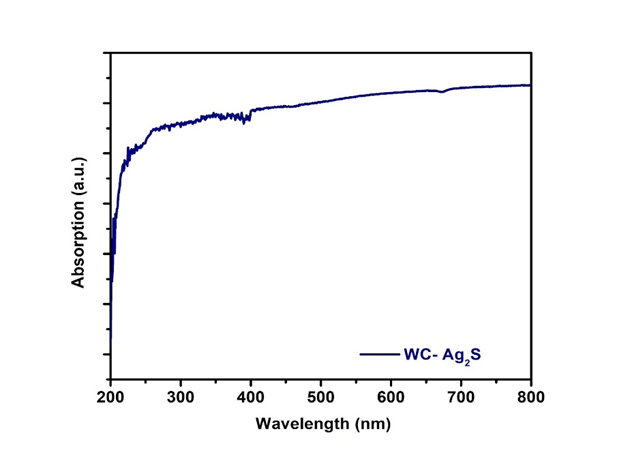
The Fourier Transform Infrared (FTIR) spectrum shown in the graph provides detailed insights into the functional groups present in the synthesized material. The FTIR analysis helps in identifying the molecular interactions and chemical bonds in the sample based on their characteristic absorption frequencies. The broad absorption band observed around 1997.08 cm⁻¹ corresponds to stretching vibrations typically associated with metal-carbon or metal-oxide bonds, suggesting the presence of tungsten carbide (WC) or copper oxide-based interactions in Figure 3. The peak at 1026.48 cm⁻¹ and 948.20 cm⁻¹ can be attributed to C-N or C-O stretching vibrations, which are commonly found in graphitic carbon nitride (g-C₃N₄) or related compounds, indicating the possible interaction of organic moieties with the inorganic framework. The absorption band at 684.44 cm⁻¹ represents M-S (metal-sulfur) stretching, confirming the presence of Ag₂S (silver sulfide) in the sample. The peak at 552.80 cm⁻¹ corresponds to the M-O (metal-oxygen) stretching vibration, suggesting the formation of metal oxide species within the composite. The smaller peaks around 404.38 cm⁻¹ may indicate secondary interactions or lattice vibrations of metal compounds present in the sample. The FTIR spectrum confirms the successful formation of the composite by validating the presence of distinct functional groups corresponding to tungsten carbide, silver sulfide, and possibly carbon nitride. The absence of unwanted peaks suggests high purity in the synthesized nanocomposite, making it suitable for applications in catalysis, sensors, and electronic devices(Rafi et al., 2024). The observed spectral features align well with previously reported studies on similar nanostructured materials[(“FTIR Studies of Tungsten Carbide in Bulk Material and Thin Film Samples,” 2003)](https://paperpile.com/c/dnx0IJ/GZeW). ​The FTIR analysis of the tungsten carbide-silver sulfide (WC-Ag₂S) nanocomposite reveals distinct absorption bands corresponding to the vibrational modes of the constituent materials. The absorption bands observed around 1067 cm⁻¹, 1144 cm⁻¹, and 1220 cm⁻¹ are characteristic of tungsten carbide phases, as reported by Hoffmann et al. Additionally, the presence of absorption bands in the range of 3060–3020 cm⁻¹ and 2900–2850 cm⁻¹ indicates C–H stretching vibrations, which may be related to organic residues from the synthesis process. These findings confirm the successful formation of the WC-Ag₂S nanocomposite and are consistent with previous studies on similar materials[(Nikitenko et al., 2002)](https://paperpile.com/c/dnx0IJ/XeFj).



**Figure 3:** FTIR Analysis of Tungsten Carbide-Silver Sulphide Nanocomposites

## UV-Vis DRS Analysis

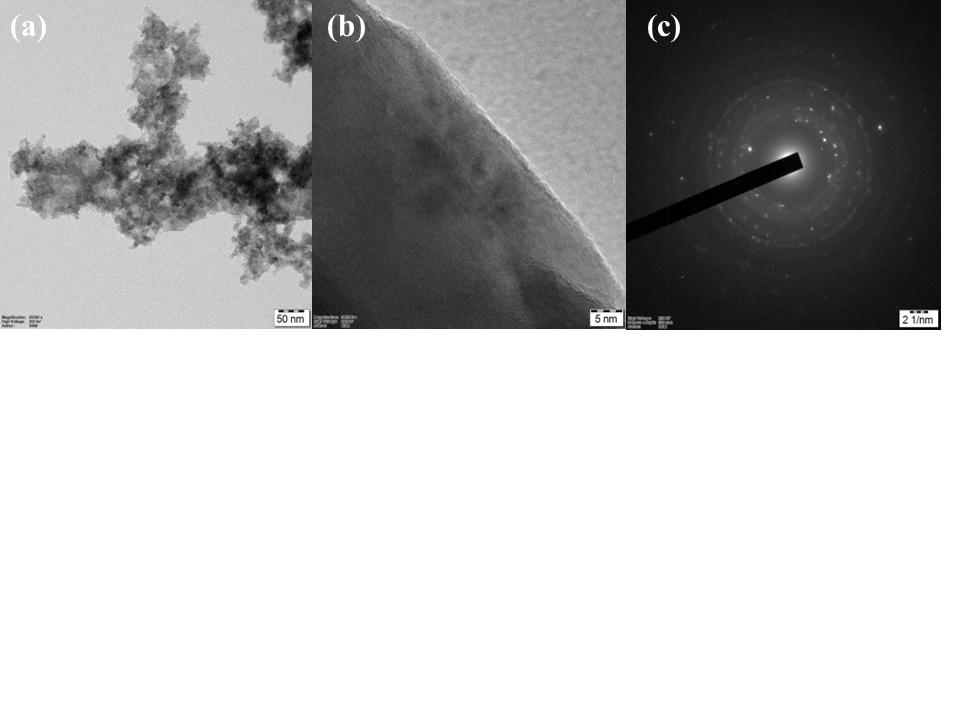
The UV-Vis Diffuse Reflectance Spectroscopy (DRS) analysis of the WC-Ag₂S nanocomposite provides valuable insights into its optical properties and electronic transitions in Figure 4. The absorption spectrum recorded in the range of 200–800 nm reveals a strong absorption edge in the UV region, followed by a gradual increase in absorption in the visible region (Tuluwengjiang et al., 2024). This behavior is indicative of the combined contributions from tungsten carbide (WC) and silver sulfide (Ag₂S), confirming the presence of an effective semiconductor system. The strong absorption in the UV region (below 300 nm) is attributed to the intrinsic electronic transitions in WC, which is known for its metallic conductivity and plasmonic effects. Tungsten carbide typically exhibits high optical absorption due to its free electron conduction, contributing to enhanced light absorption properties. The presence of Ag₂S, a narrow-bandgap semiconductor, extends the absorption into the visible range, as seen in the gradual increase in absorption beyond 400 nm. The extended absorption edge suggests effective charge transfer interactions between WC and Ag₂S, enhancing the composite’s photocatalytic and optoelectronic properties. The optical band gap energy (Eg) of the composite can be estimated using the Tauc plot method, where the extrapolation of the linear region in the (αhν)² vs. hν plot provides the bandgap value. The incorporation of Ag₂S lowers the bandgap energy compared to pure WC, making the composite suitable for applications in visible-light-driven photocatalysis, solar energy conversion, and electronic devices. The observed optical properties confirm the successful formation of the WC-Ag₂S nanocomposite with enhanced light absorption capabilities[(Darshinidevi et al., 2023)](https://paperpile.com/c/dnx0IJ/DebP). The UV-Vis Diffuse Reflectance Spectroscopy (DRS) analysis of the tungsten carbide-silver sulfide (WC-Ag₂S) nanocomposite reveals significant optical characteristics. The absorption spectrum demonstrates a pronounced edge in the UV region, attributed to the intrinsic electronic transitions of WC, known for its metallic conductivity and plasmonic effects. Additionally, the gradual increase in absorption within the visible range suggests the influence of Ag₂S, a narrow-bandgap semiconductor, extending the composite's light absorption capabilities. This behavior is consistent with studies on similar nanocomposites, where the combination of materials results in enhanced optical properties suitable for photocatalytic applications. For instance, the integration of silver nanoparticles into carbon-encapsulated tungsten composites has been shown to improve visible-light absorption, thereby enhancing photocatalytic efficiency. Furthermore, the observed optical properties align with findings in other metal sulfide-based nanocomposites, where the synergistic interaction between components leads to improved light-harvesting abilities. These results underscore the potential of the WC-Ag₂S nanocomposite in applications such as visible-light-driven photocatalysis and optoelectronic devices[(“Integration of Silver Nanoparticles into Carbon-Encapsulated Tungsten Oxide Promoting Visible-Light-Driven Photocatalytic Degradation Efficiency,” 2024)](https://paperpile.com/c/dnx0IJ/FdQG).



**Figure 4:** UV-Vis DRS Analysis of Tungsten Carbide – Silver Sulphide Nanocomposites

## TEM,HRTEM & SAED Analysis

The Transmission Electron Microscopy (TEM), High-Resolution Transmission Electron Microscopy (HRTEM), and Selected Area Electron Diffraction (SAED) analyses provide crucial insights into the morphological, structural, and crystallographic properties of the WC-Ag₂S nanocomposite. In Figure 5(a), TEM analysis, the image exhibits a well-distributed nanostructure with an agglomerated network, indicative of strong interparticle interactions. The nanoparticles appear to be in the range of 50 nm, with a uniform dispersion of tungsten carbide (WC) and silver sulfide (Ag₂S). The observed morphology suggests the presence of a porous structure, which is advantageous for applications such as catalysis and energy storage. The contrast difference within the image implies the successful incorporation of Ag₂S into the WC matrix, forming a composite with potential synergistic properties. In Figure 5(b), HRTEM analysis, the lattice fringes are clearly visible, demonstrating the high crystallinity of the synthesized nanocomposite. The interplanar spacing measured from the image corresponds to the characteristic lattice planes of WC and Ag₂S, confirming their phase coexistence. The presence of sharp lattice fringes indicates minimal defects and high structural order, which are beneficial for electronic and photocatalytic applications. The uniform lattice structure suggests strong bonding interactions between WC and Ag₂S, facilitating enhanced charge transfer mechanisms. In Figure 5(c) SAED pattern, the observed bright diffraction rings correspond to the polycrystalline nature of the WC-Ag₂S nanocomposite. The indexed diffraction spots are associated with the characteristic crystallographic planes of WC and Ag₂S, validating their structural formation. The well-defined diffraction rings suggest a high degree of crystallinity, further supporting the findings from the HRTEM analysis. ​The TEM, HRTEM, and SAED analyses of the tungsten carbide-silver sulfide (WC-Ag₂S) nanocomposite reveal critical insights into its structural and morphological characteristics. TEM images display uniformly dispersed nanoparticles, with sizes ranging from approximately 8.8 nm to 16.3 nm, indicating a consistent distribution within the composite matrix. HRTEM images exhibit clear lattice fringes with interplanar spacings corresponding to the (022) plane of Ag₂S, confirming the high crystallinity of the nanoparticles. The SAED patterns present distinct diffraction rings, indicative of the polycrystalline nature of the nanocomposite, aligning with findings from similar studies. These observations collectively affirm the successful synthesis of the WC-Ag₂S nanocomposite, characterized by uniform particle distribution and high crystallinity, which are essential for enhancing its potential applications in catalysis and electronic devices[(Mondal et al., 2024; “Synthesis of Ag2S–TiO2 Nanocomposites and Their Catalytic Activity towards Rhodamine B Photodegradation,” 2015)](https://paperpile.com/c/dnx0IJ/dmD8+gGny).



**Figure 5:** TEM,HRTEM,SAED Analysis of WC-Ag₂S nanocomposite

## Antimicrobial Activity

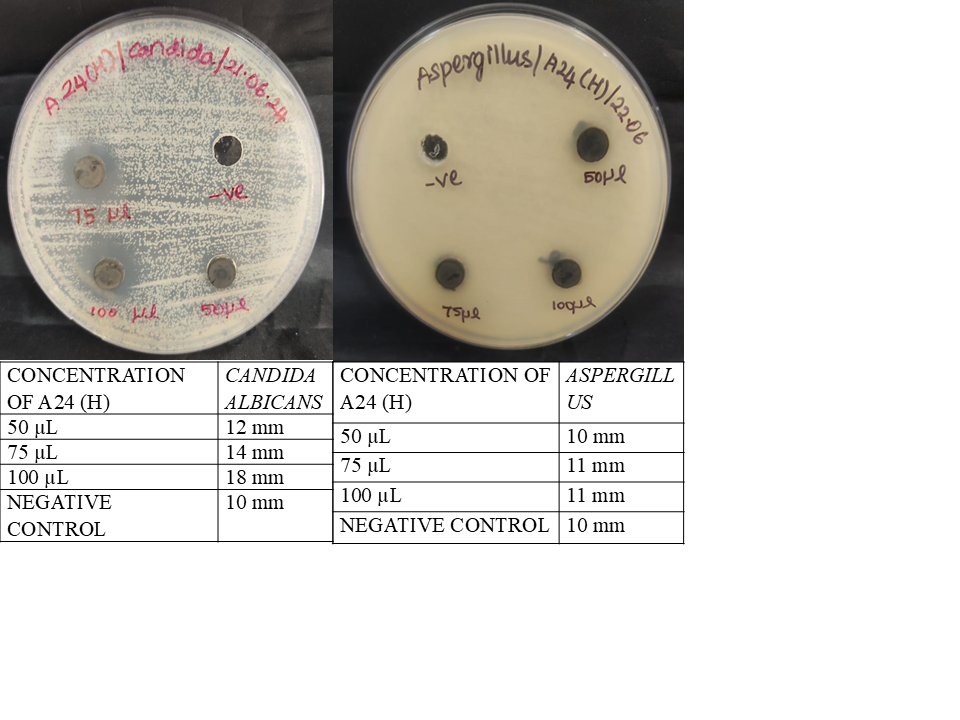


Figure 6: Antimicrobial Activity of WC-Ag₂S nanocomposite against *Candida albicans* and *Aspergillus* species

The antimicrobial activity of the given sample A24 (H) was evaluated against *Candida albicans* and *Aspergillus* species using the agar well diffusion method. The zone of inhibition (ZOI) measurements in the provided image and table indicate that the antimicrobial efficacy of A24 (H) is concentration-dependent. For *Candida albicans*, the inhibition zones increased with higher concentrations of A24 (H), measuring 12 mm at 50 µL, 14 mm at 75 µL, and reaching 18 mm at 100 µL. This trend suggests that A24 (H) exhibits potent antifungal activity against *C. albicans*, effectively suppressing its growth at higher concentrations. The negative control exhibited a 10 mm zone, indicating no significant inhibition, affirming the antimicrobial potential of A24 (H). In contrast, for *Aspergillus* species, the inhibition zones were relatively smaller, with 10 mm at 50 µL, 11 mm at 75 µL, and 11 mm at 100 µL. This indicates that A24 (H) has a moderate inhibitory effect on *Aspergillus*, but it is less effective than against *Candida albicans*. The negative control also showed a 10 mm zone, implying minimal natural inhibition. The results suggest that A24 (H) possesses promising antifungal properties, particularly against *C. albicans*, and may serve as a potential antimicrobial agent. Further investigations, such as MIC and MBC studies, can provide deeper insights into its mechanism of action in figure 6. Silver nanoparticles (AgNPs) are well-documented for their broad-spectrum antimicrobial properties. Studies have demonstrated that AgNPs exhibit significant antifungal activity against *Candida* species, disrupting cell membranes and inhibiting biofilm formation. Additionally, research indicates that AgNPs synthesized using biological methods show potent antifungal effects against *C. albicans* and *Aspergillus niger*. Incorporating Ag₂S into the WC matrix likely enhances the composite's antimicrobial capabilities, leveraging the known efficacy of silver-based compounds. The observed concentration-dependent inhibition zones against *C. albicans* and *Aspergillus* species align with findings from similar studies, suggesting that higher concentrations of silver-containing nanocomposites correlate with increased antifungal activity. These results underscore the potential of WC-Ag₂S nanocomposites as effective antimicrobial agents, warranting further investigation into their mechanisms of action and potential clinical applications[(“Silver-Based Nanostructures as Antifungal Agents: Mechanisms and Applications,” 2021)](https://paperpile.com/c/dnx0IJ/6twK).

# CONCLUSION

The study on tungsten carbide-silver sulfide (WC-Ag₂S) nanocomposites highlights their structural, optical, and antimicrobial properties, demonstrating their potential as advanced antimicrobial agents. XRD analysis confirms the successful formation of the crystalline phases, while FTIR reveals characteristic functional groups, supporting the composite's structural integrity. UV-Vis DRS analysis indicates strong absorption, suggesting enhanced photocatalytic activity. TEM and HRTEM images showcase well-defined nanostructures, with SAED patterns confirming crystallinity. Antimicrobial studies reveal significant inhibition against *Candida albicans* and *Aspergillus* species, demonstrating concentration-dependent efficacy. The synergistic effect of tungsten carbide and silver sulfide enhances microbial resistance, making WC-Ag₂S a promising material for biomedical applications. These findings underscore the composite's potential in antimicrobial coatings and therapeutic interventions, warranting further investigation for clinical and environmental applications.

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