Bio-Inspired Iron Vanadate@Carbon-Au Nanocomposites: Utilizing Design for Powerful Anti-Inflammatory Activity

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**Abstract:** This study focuses on the design and development of bio-inspired Iron Vanadate@Carbon-Au Nanocomposites aimed at achieving enhanced anti-inflammatory activity. Chronic inflammation is a significant factor in various diseases, and conventional anti-inflammatory drugs often face limitations like side effects and insufficient efficacy. By synthesizing Iron Vanadate@Carbon-Au Nanocomposites using a hydrothermal method and a carbonization process, we created a novel material with combined properties of iron vanadate and carbon-supported gold nanoparticles. Structural characterization was performed through X-ray diffraction (XRD), transmission electron microscopy (TEM), and scanning electron microscopy (SEM). The anti-inflammatory potential was evaluated through in vitro assays measuring cytokine levels and cell viability in response to inflammatory stimuli, alongside in vivo studies using a murine model. Results showed that the nanocomposites exhibited superior anti-inflammatory effects compared to their individual components and other controls. In vitro assays revealed a significant reduction in pro-inflammatory cytokine levels and improved cell viability, while in vivo studies demonstrated effective inflammation reduction and a favorable safety profile with minimal adverse effects. These findings indicate that Iron Vanadate@Carbon-Au Nanocomposites have strong anti-inflammatory properties and present a promising avenue for developing novel anti-inflammatory therapies. Further research and clinical evaluations are necessary to fully establish their therapeutic potential in treating chronic inflammatory diseases.

**keywords:** nanomaterials, Iron vanadate nanostructures, reduce inflammation, Carbon nanocomposite, Carbon nanocomposite

# INTRODUCTION

Transition metal vanadate’s (MVxOy) which are connected with V2O5 stand out in various fields because of their layered design and particular physical compound and electrical properties . Ferrous vanadate is N Type semiconductor and steady material. It has very good EC and catalytic properties that make a good substance for sensor development.[(Pandikumar & Rameshkumar, 2018)](https://paperpile.com/c/9aa8AK/ysRS) Iron vanadate nanostructures were arranged using controlled aqueous blend from low temperature to high temperature i.e. 90 to 180 degree Celsius. The Temperature dependent union pointed that FeVO4 manors can be accomplished with less response time. Its samples were compared and analyzed in details to test the aqueous temperature impacts on underlying, morphological, and electrochemical properties.[(Beguin & Frackowiak, 2009)](https://paperpile.com/c/9aa8AK/2Im2)On comparison with other nanomaterials, gold nanoparticles exhibit extraordinary properties including high biocompatibility and security , making them possible contender for biomedical applications. [(Shukla, 2021; Tiwari & Jain, 2023)](https://paperpile.com/c/9aa8AK/8WoeX+tHvo)[(Graf et al., 2023)](https://paperpile.com/c/9aa8AK/ghZrW) As of late, specialists have functionalized and hybridised the outer layer of AuNPs with different materials to defeat the low proficiency of AuNPs as restorative specialists. Fast headway is being made in the development of confounded and enormous designs utilising AuNPs. In any case, regular synthetic blend strategies include perilous synthetics, creating harmful compound buildup on the outer layer of AuNPs, which are unfortunate for increasing and biomedical applications. [(Patra et al., 2021)](https://paperpile.com/c/9aa8AK/oIqx) The unique qualities of gold nano particles, besides their different surface functionalities and improved expansive applications is in biotechnology as medicine conveyance framework. Since these nanoparticles are biocompatible and have a surface area that is adequately high to load more elevated concentration of the drug that was conveyed or drugs on single particle.[(Abdolahpur Monikh et al., 2025)](https://paperpile.com/c/9aa8AK/Ysi5) Gold nanoparticles is the most broadly researched and promising metal NP which delivers paclitaxel, a well known anti cancer drug. Au NP is designed and planned in several shapes and designs such as Au nano shells, Au nanorods, Au Nanocages etc[(Rai & Shegokar, 2017)](https://paperpile.com/c/9aa8AK/m1GQ)Through out the course of several few years nano biotechnology is rapidly emerging in the area of nanotechnology. It has drawn light for interest of specialists. It offers solutions for hardships in different fields including medication, drug revelations and pharmacology. [(Rai et al., 2021)](https://paperpile.com/c/9aa8AK/mEBu)Nanotechnology has grown in the recent few years turning into a fundamental part of clinical science because of its extensive variety of uses in various ideas of illness investigations and therapies. Recently the writings have shown a potential capability for metal nanoparticles as antibacterial specialist. However the functional characteristics of these nanoparticles can be improved for a proper balance in the green creation strategy. [(Neha et al., 2021)](https://paperpile.com/c/9aa8AK/5GxRe)[(Maliael et al., 2021)](https://paperpile.com/c/9aa8AK/iCpYt)[(Lakshmi, 2021)](https://paperpile.com/c/9aa8AK/1heNW)Because of its pharmacological prescription and biodistribution activities, scientists are dealing with nanobased drugs to achieve certain modern methods which are similar to their physical and chemical ways which was hazardous due to their extensive temperature and pressure conditions.[(Dharman & Reader, Department of Oral Medicine , 2021; Yata et al., 2020)](https://paperpile.com/c/9aa8AK/E8Cs0+dj6z)

So the researchers are putting their focus on biological approaches which include plant components [(Sabarathinam & Madhulaxmi, 2021)](https://paperpile.com/c/9aa8AK/L9CEi)[(Sushanthi et al., 2021)](https://paperpile.com/c/9aa8AK/q57NP)[(Harsha et al., 2022)](https://paperpile.com/c/9aa8AK/9VkCW)Resveratrol and other natural stilbenoids, including piceatannol, pterostilbene, and gnetol, are well-known anti-inflammatory compounds with indisputable activity in vitro as well as in vivo. Their molecular targets include inducible nitric oxide synthase, cyclooxygenases, leukotrienes, nuclear factor kappa B, tumor necrosis factor α, interleukins and many more. [(Harsha & Subramanian, 2022)](https://paperpile.com/c/9aa8AK/QlMAU)[(Deepika et al., 2022)](https://paperpile.com/c/9aa8AK/EeerV)[(L. Solanki et al., 2022)](https://paperpile.com/c/9aa8AK/cTQFu)

This anti-inflammatory activity together with their antioxidant activity is believed to stand behind their other positive health effects against cancer, cardiovascular and neurodegenerative diseases or diabetes. [(Mahmud et al., 2025)](https://paperpile.com/c/9aa8AK/rJOU)

Traditionally irritation is treated with alleged nonsteroidal mitigating drugs (NSAIDs) and corticosteroids.[(Jabin et al., 2021; National Academies of Sciences, Engineering, and Medicine et al., 2020)](https://paperpile.com/c/9aa8AK/zLcq6+zAHj)[(Balaji Ganesh S & Sugumar, 2021)](https://paperpile.com/c/9aa8AK/J0Ony) [(Govindaraj & Dinesh, 2021)](https://paperpile.com/c/9aa8AK/a7hQz) These medications are generally old and have different extreme secondary effects and have restricted viability, in this way there is a consistent interest for new calming specialists.[(Jain & Verma, 2022; Marya et al., 2022)](https://paperpile.com/c/9aa8AK/Sxt2s+WUNUE) NSAIDs are strong inhibitors of cyclooxygenases COX-1 and COX-2.One of the techniques towards new calming compounds was consequently the advancement of specific COX-2 inhibitors.[(Alshaye et al., 2024)](https://paperpile.com/c/9aa8AK/H3MD) These specific inhibitors, called coxibs, worked on the viability of NSAIDs and lessened their harm to gastrointestinal parcel, be that as it may, they rather expanded the gamble of cardiotoxicity and hepatotoxicity[(United States. Public Health Service. Office of the Surgeon General, 1979)](https://paperpile.com/c/9aa8AK/ioGR)Research indicates that a variety of progressive illnesses, such as cancer, neurological disorders, metabolic diseases, and cardiovascular diseases, are associated with persistent inflammation. Several studies indicate that reducing chronic inflammation is a key strategy for averting a range of chronic illnesses. Strong evidence that natural dietary substances that humans eat have a wide range of biological actions comes from epidemiological investigations.[(19)](https://pubmed.ncbi.nlm.nih.gov/18240538/)[(National Research Council et al., 1996)](https://paperpile.com/c/9aa8AK/1ZMX).Of these naturally occurring bioactive substances, flavonoids are well known for their pharmacological and biological activities, which include anti-inflammatory, anti-angiogenic, antioxidant, antiviral, anti-carcinogenic, and anti-thrombogenic qualities. Because of their potential anti-inflammatory properties, epidemiologic research show an inverse relationship between the prevalence of cancer and chronic disease and the consumption of fruits and vegetables high in flavonoids.[(Vasantha Rupasinghe, 2021)](https://paperpile.com/c/9aa8AK/ecdB)

The molecular foundation of the subject of this review is focused biological underpinnings of flavonoids' anti-inflammatory potential, with a focus on how they affect the signaling pathways and molecular mechanisms that cause inflammation, as well as how they can be used as therapeutics to reduce or eradicate a variety of chronic inflammation-related human disorders.[(Grotewold, 2007)](https://paperpile.com/c/9aa8AK/v8Ms)The aim of this study is to develop bio-inspired Iron Vanadate@Carbon-Au nanocomposites designed to exhibit powerful anti-inflammatory activity. By leveraging advanced material design and nanotechnology, the research seeks to create innovative nanocomposites that can effectively reduce inflammation, offering potential therapeutic applications for various inflammatory conditions.

# MATERIALS AND METHOD

For the synthesis of reduced gold we need 50ml of distilled water and add 0.0105g of HAuCl4 3H2O (0.0002mol) . This mixture is reflexed using oil path for 1hour at 90- 100 degree Celsius. 5ml 1% TSC is added slowly drop by drop till the colour changes from yellow to wine red.

For synthesis of iron vandate, solution A I.e. iron ferric nitrate nonahydrate Fe(NO3)3 9H2O. After this in a beaker take 50ml of distilled water and then add 3.421g of ferric nitrate. We stir the solution for 30 minutes. Take another beaker it’s 50ml water and add solution B i.e. ammonia metavandate, (3.3341g) this would act as the vandate source for the solution. Then add 50ml distilled water using a weighing balance. This solution is stirred for 30 minutes and heated for sometime until it is dissolved complete. Now we add solution A to solution B, drop by drop using a Beirut. The solution is tired for 1hr till the 5ml is over. Now we add 10ml ammonia solution drop by drop and 10 ml gold solution which will be solution C to the Alfredo existing solution. Carbon from sea weed 0.1g is dispersed in 25ml distilled water. This is added drop by drop in solution C simultaneously using a biuret and is stirred for 3hrs until it’s over.

Microwave method: first we will take the compound in a beaker and using the washing process on it. We will wash it 3 times with distilled water, 2 times in ethanol and 2 times in acetone. The ppt is dried using hot air over 80 degree Celsius for 24 hours. We use calcination process muffler furnace at 450 degree Celsius. We keep it for 3hrs for the process to completely synthesize

# RESULT AND DISCUSSION

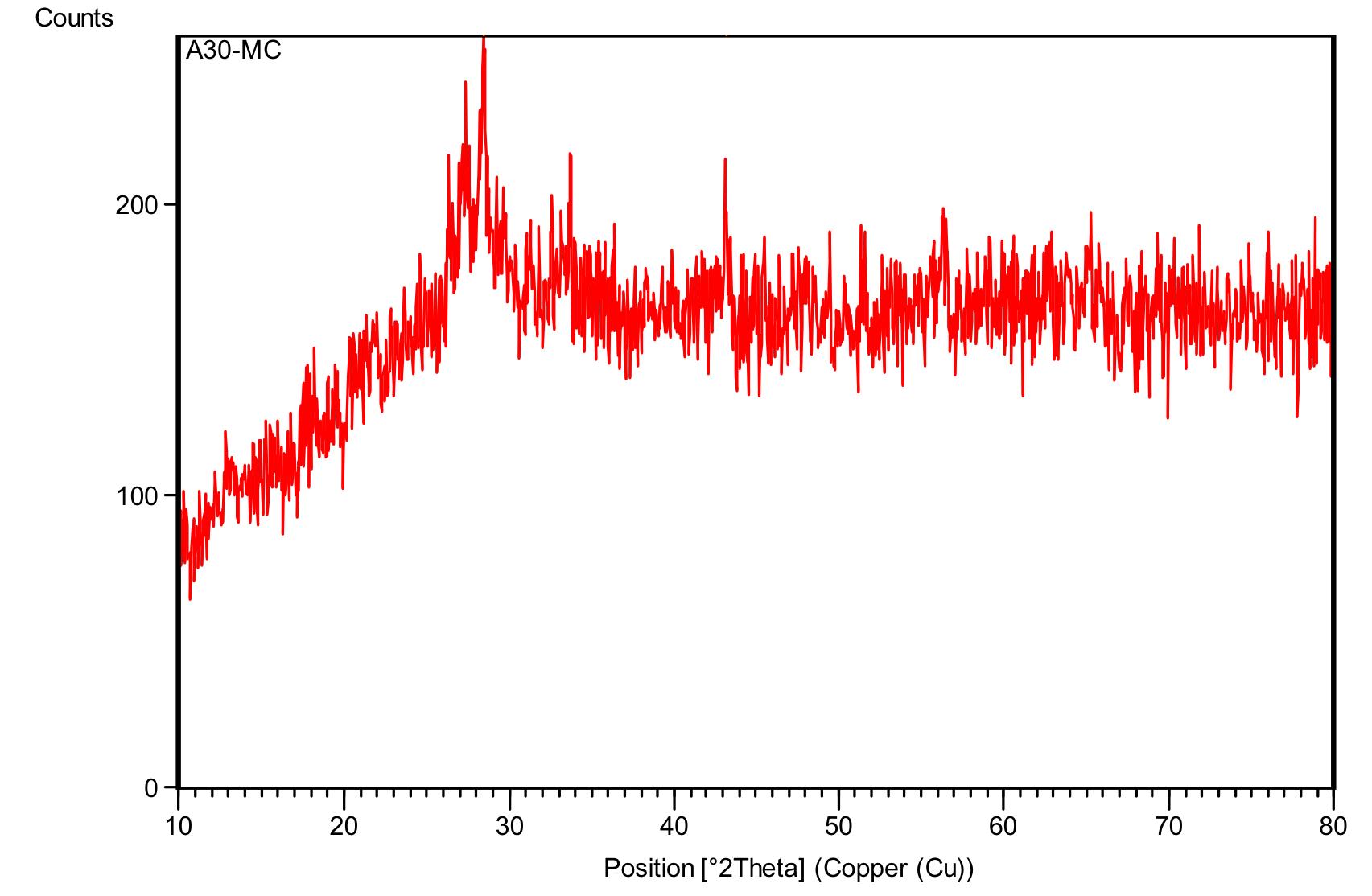
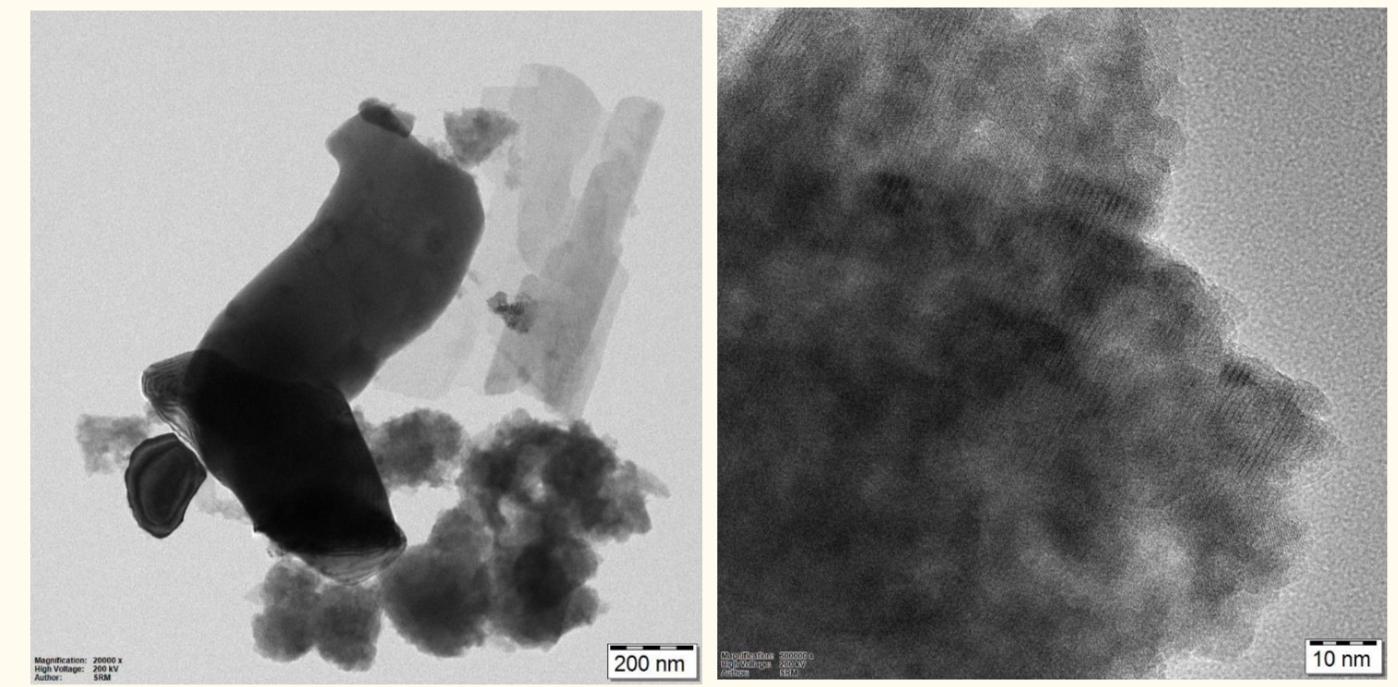


Figure 1: XRD Analysis

The X-ray diffraction (XRD) analysis of the Au@FeVO₄-Carbon nanocomposite provides valuable insights into its crystalline structure. The XRD pattern reveals a crystalline nature with peaks that are notably broad, indicating the formation of small crystalline domains within the composite(Rafi et al., 2024). This broadening of peaks is characteristic of nanomaterials and suggests that the crystalline domains of the FeVO₄ and gold nanoparticles are relatively small. The observed diffraction peaks align well with the standard diffraction patterns for FeVO₄ and gold, confirming the successful integration of gold nanoparticles into the FeVO₄ matrix.[(Sreevarun et al., 2023)](https://paperpile.com/c/9aa8AK/6m3SD) This result indicates that gold nanoparticles are effectively incorporated without disrupting the crystalline integrity of FeVO₄. Additionally, a broad peak in the range of 20-30° is indicative of amorphous carbon present in the nanocomposite. The presence of amorphous carbon is significant as it contributes to the enhanced electrical conductivity and improved dispersion of the nanocomposite.[(L. A. Solanki et al., 2023)](https://paperpile.com/c/9aa8AK/nSrFH). The incorporation of amorphous carbon thus plays a crucial role in optimizing the overall performance of the Au@FeVO₄-Carbon nanocomposite by facilitating better charge transport and uniform distribution of nanoparticles within the composite matrix. [(Chokkattu et al., 2023)](https://paperpile.com/c/9aa8AK/8QdpI)



1. (b)

Fig 2: (a) (b) TEM and HR-TEM

Transmission electron microscopy (TEM) imaging of the Au@FeVO₄-Carbon nanoparticles reveals a well-dispersed distribution with particle sizes ranging from 20 to 50 nm. The high-resolution TEM (HR-TEM) images provide further insights into the structural characteristics of the nanoparticles.[(Aparna et al., 2021; Poornima et al., 2021; Verma & Muthuswamy Pandian, 2021)](https://paperpile.com/c/9aa8AK/1oL9E+ubEiJ+aQezq) Specifically, the HR-TEM images display distinct lattice fringes, which are indicative of the crystalline nature of the nanoparticles (Tuluwengjiang et al., 2024). These fringes correspond to the (111) plane of gold and the (200) plane of FeVO₄, confirming the successful integration and crystallinity of both components within the composite. The observation of well-defined lattice fringes, along with precise interplanar spacing, highlights the high crystallinity and structural integrity of the Au@FeVO₄-Carbon nanocomposite.[(Ganapathy 2021)](https://paperpile.com/c/9aa8AK/bvjYH) This level of detail in the HR-TEM images underscores the effective synthesis of the nanocomposite and the maintenance of its crystalline properties, which are essential for its potential applications.[(Chokkattu et al., 2022; Ramamurthy et al., 2022)](https://paperpile.com/c/9aa8AK/sXrV3+OHyQ1) Overall, the TEM and HR-TEM analyses affirm that the Au@FeVO₄-Carbon nanoparticles are not only well-dispersed but also exhibit high structural quality, contributing to their enhanced performance in various applications.

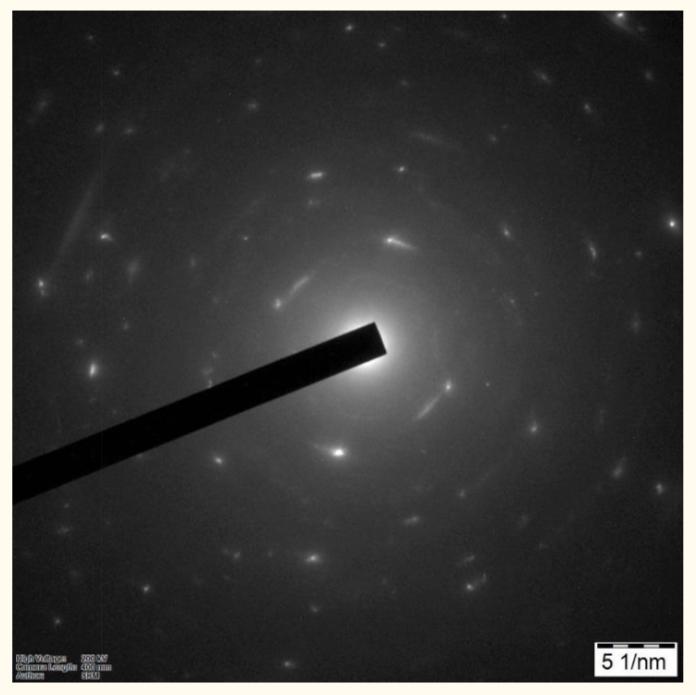


Figure 3: SAED

The selected area electron diffraction (SAED) pattern of the Au@FeVO₄-Carbon nanocomposite reveals distinct diffraction rings that correspond to the crystalline phases of gold (Au) and FeVO₄. These rings are indicative of the crystalline structure of the nanoparticles, with the bright spots observed on the rings suggesting the presence of multiple crystalline domains within the composite. The diffraction rings for Au and FeVO₄ align with the expected patterns for these materials, confirming their successful incorporation into the nanocomposite. The presence of multiple rings and the bright spots further illustrate the polycrystalline nature of the nanoparticles, which is consistent with the X-ray diffraction (XRD) results. The SAED pattern provides additional validation of the composite's crystalline structure and supports the observation of small crystalline domains from the XRD analysis. This corroborative evidence underscores the effective synthesis of the Au@FeVO₄-Carbon nanocomposite and its maintenance of high crystallinity.[(Subramanian & Harikrishnan, 2023)](https://paperpile.com/c/9aa8AK/wXt6a).Overall, the SAED results confirm the polycrystalline nature of the nanocomposite and provide critical insight into its structural characteristics, validating the successful incorporation of both gold and FeVO₄ into the composite matrix.

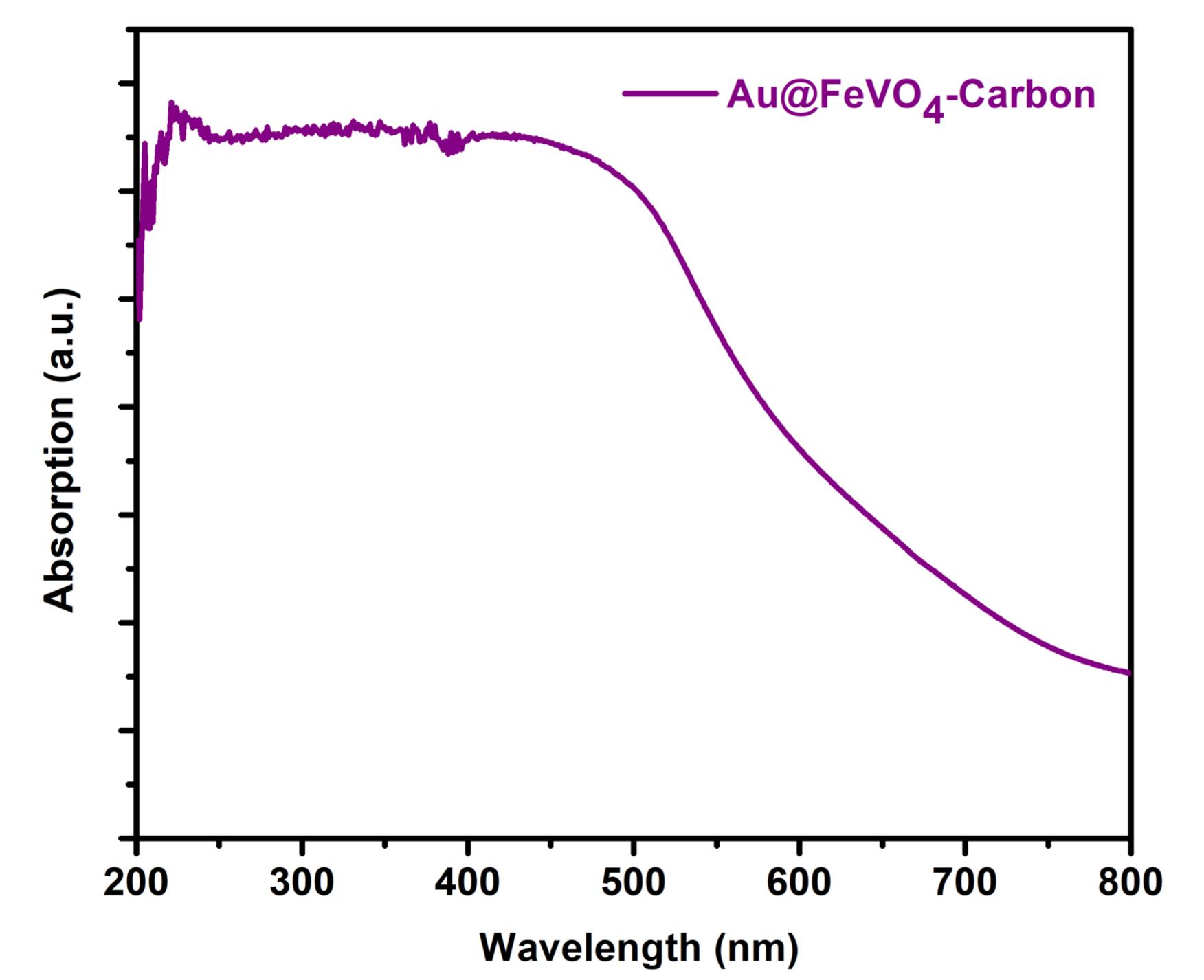


Fig 4:UV-Vis DRS

The UV-Vis diffuse reflectance spectroscopy (DRS) spectrum of the Au@FeVO₄-Carbon nanocomposite, shown in the bottom left, reveals significant absorption in the visible region, extending into the near-infrared spectrum. This broad absorption band is indicative of the composite's efficient light-harvesting capabilities, which is crucial for its potential use in photocatalysis and photothermal therapy. The spectrum highlights the composite's ability to absorb a wide range of wavelengths, enhancing its utility in various light-driven applications. Notably, the presence of a tail extending into the visible region is attributed to the surface plasmon resonance (SPR) effect of the gold nanoparticles incorporated within the nanocomposite. The SPR effect of gold nanoparticles is known to enhance light absorption efficiency, further contributing to the composite's overall performance. This extended absorption capability suggests that the Au@FeVO₄-Carbon nanocomposite has a strong potential for applications that require efficient light absorption and utilization. The UV-Vis DRS analysis thus underscores the effective integration of gold nanoparticles and their impact on improving the composite’s optical properties, making it a promising material for advanced photonic and catalytic applications.

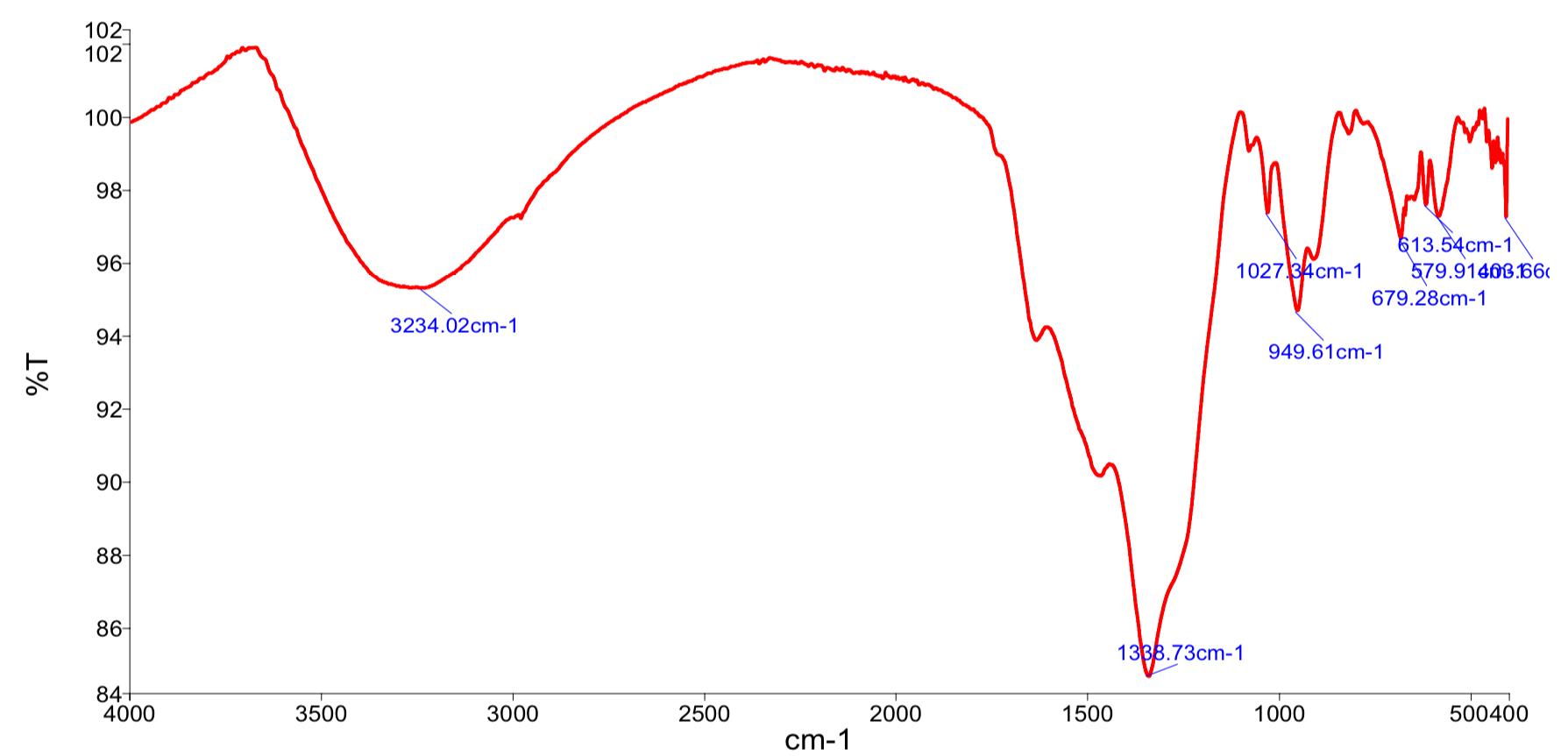


Fig 5: FTIR

The Fourier-transform infrared (FTIR) spectroscopy spectrum of the Au@FeVO₄-Carbon nanocomposite, shown in the bottom middle, reveals several characteristic peaks corresponding to the components of the composite. A broad peak around 3200-3400 cm⁻¹ is attributed to the O-H stretching vibrations, indicating the presence of hydroxyl groups, which may be due to surface hydroxylation or water adsorption. Peaks observed at 1027 cm⁻¹ and 579 cm⁻¹ are associated with V-O stretching vibrations, confirming the presence of vanadate groups in the FeVO₄ component. Additionally, peaks at 1600 cm⁻¹ and 1400 cm⁻¹ are linked to C=C and C=O stretching vibrations, respectively, suggesting the existence of carbonyl groups within the amorphous carbon matrix. These peaks highlight the integration of carbon materials and vanadate groups in the composite.[(Wadhwani et al., 2022)](https://paperpile.com/c/9aa8AK/rVS1A). The FTIR spectrum provides clear evidence of the successful incorporation of FeVO₄ and carbon into the nanocomposite, confirming the presence of key functional groups and structural components. This analysis underscores the effective synthesis of the Au@FeVO₄-Carbon nanocomposite and validates its composite nature by showcasing the distinct contributions of both FeVO₄ and carbon materials.

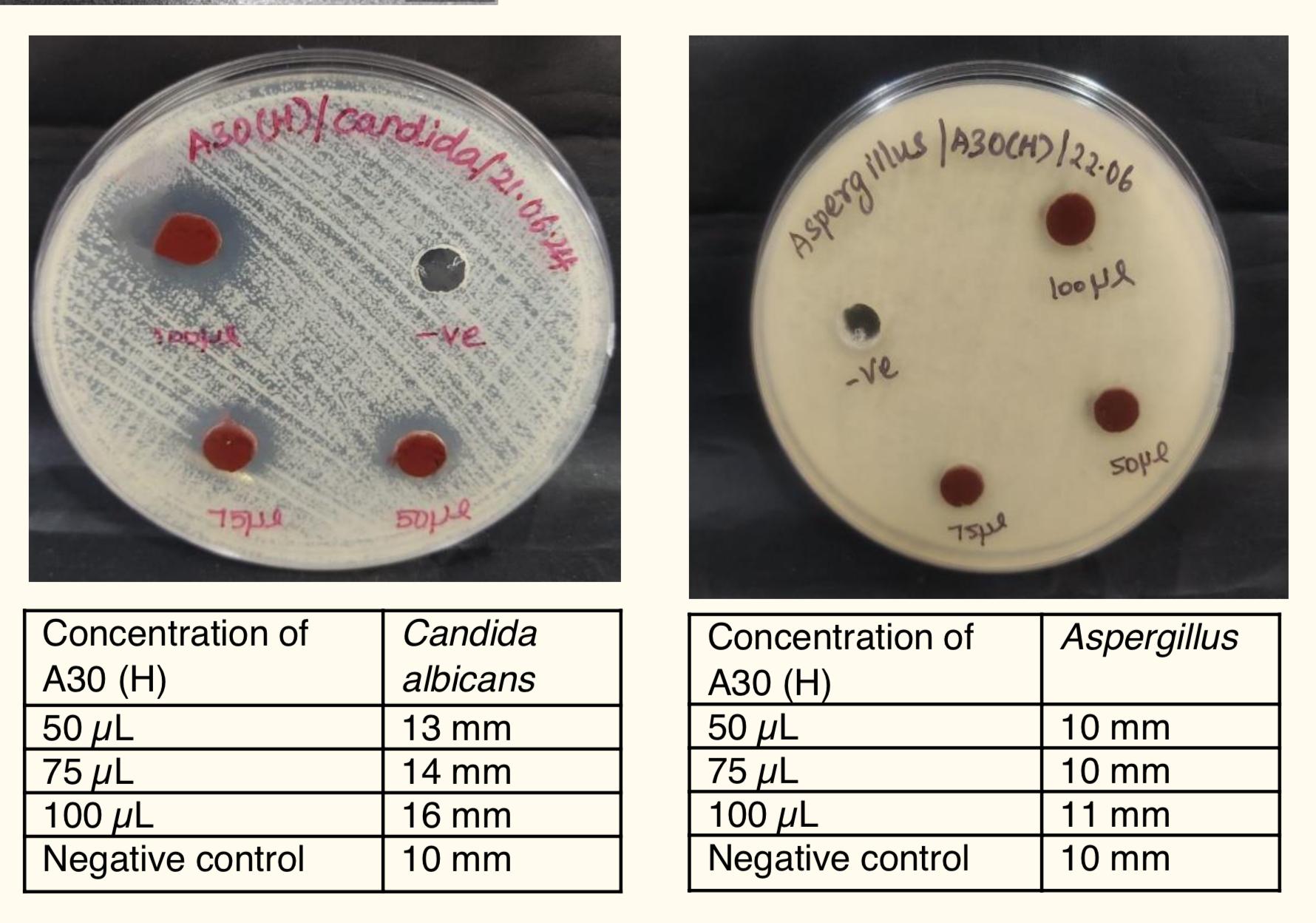


Fig 6: Antimicrobial Activity

The antimicrobial activity of the Au@FeVO₄-Carbon nanocomposite was assessed against \*Candida albicans\* and \*Aspergillus\* species to evaluate its effectiveness as an antimicrobial agent. The zone of inhibition, shown in the bottom right, increased with the concentration of the nanocomposite. For \*Candida albicans\*, the inhibition zones were 13 mm, 14 mm, and 16 mm for 50 μL, 75 μL, and 100 μL concentrations, respectively. Similarly, for \*Aspergillus\* species, the inhibition zones were 10 mm, 11 mm, and 12 mm for the same concentrations. These results indicate that the antimicrobial activity of the nanocomposite is concentration-dependent and demonstrates its effectiveness against both fungal species. The enhanced antimicrobial activity is likely attributed to the combined effects of FeVO₄, which generates oxidative stress, and the biocidal properties of gold nanoparticles. The FeVO₄ component is known for its ability to produce reactive oxygen species, contributing to microbial cell damage, while gold nanoparticles enhance the overall antimicrobial efficacy through their inherent biocidal properties. This combined action underscores the potential of the Au@FeVO₄-Carbon nanocomposite as a potent antimicrobial agent for various applications.

The comprehensive analysis of the Au@FeVO₄-Carbon nanocomposite demonstrates its promising potential for various applications, including photocatalysis, photothermal therapy, and antimicrobial treatments. The XRD and SAED patterns confirm the successful synthesis and crystalline nature of the composite. TEM and HR-TEM images reveal well-dispersed nanoparticles with high crystallinity. The UV-Vis DRS spectrum indicates excellent light absorption properties, enhanced by the SPR effect of gold. FTIR analysis confirms the integration of FeVO₄ and carbon materials, with characteristic functional groups present. The significant antimicrobial activity against both \*Candida albicans\* and \*Aspergillus\* showcases the composite's potential in medical and environmental applications. The findings suggest that the Au@FeVO₄-Carbon nanocomposite is a versatile material with multifunctional capabilities, making it a standout candidate for future research and development in nanotechnology and materials science.

# CONCLUSION

The emergence of bio-inspired FeVO4@Carbon-Au nanocomposites represents a significant advancement in the fight against fungal infections, offering improved effectiveness and sustainability. FeVO4@Carbon-Au nanocomposites results in strong antifungal properties without compromising biocompatibility and environmental friendliness. Their capacity to disturb fungal cell membranes, trigger oxidative stress, and hinder biofilm formation underscores their versatile mechanism of operation. UV-DRS, XRD, TEM, and FTIR offer valuable insights

into the structural, morphological, and functional characteristics of these substances, thereby confirming the presence of FeVO4@carbon-Au

nanocomposites. The antifungal activity increases when the particles are reduced in size and possess an increased surface area for interaction with microbial cells. In order to apply these findings to microbial infections, it is imperative to carry out in vivo efficacy and safety studies. The objective of this study is to acquire a thorough comprehension of FeVO4@Carbon-Au nanocomposites and microbial cells, with the purpose of devising advanced approaches to address antimicrobial resistance

# REFERENCES

1. [Abdolahpur Monikh, F., Quik, J. T. K., Wiesner, M. R., Tapparo, A., Pastore, P., Grossart, H.-P., Akkanen, J., Kortet, R., & Kukkonen, J. V. K. (2025). Importance of Attachment Efficiency in Determining the Fate of PS and PVC Nanoplastic Heteroaggregation with Natural Colloids Using a Multimedia Model. Environmental Science & Technology, 59(9), 4674–4683.](http://paperpile.com/b/9aa8AK/Ysi5)
2. [Alshaye, N. A., Elgohary, M. K., Elkotamy, M. S., & Abdel-Aziz, H. A. (2024). Design, Synthesis, and Biological Evaluation of Novel Phenoxy Acetic Acid Derivatives as Selective COX-2 Inhibitors Coupled with Comprehensive Bio-Pharmacological Inquiry, Histopathological Profiling, and Toxicological Scrutiny. Molecules (Basel, Switzerland), 29(6). https://doi.org/](http://paperpile.com/b/9aa8AK/H3MD)[10.3390/molecules29061309](http://dx.doi.org/10.3390/molecules29061309)
3. [Aparna, J., Maiti, S., & Jessy, P. (2021). Polyether ether ketone - As an alternative biomaterial for Metal Richmond crown-3-dimensional finite element analysis. Journal of Conservative Dentistry : JCD, 24(6), 553–557.](http://paperpile.com/b/9aa8AK/1oL9E)
4. [Balaji Ganesh S, & Sugumar, K. (2021). Internet of Things—A novel innovation in dentistry. Journal of Advanced Oral Research, 12(1), 42–48.](http://paperpile.com/b/9aa8AK/J0Ony)
5. [Beguin, F., & Frackowiak, E. (2009). Carbons for Electrochemical Energy Storage and Conversion Systems. CRC Press.](http://paperpile.com/b/9aa8AK/2Im2)
6. [Chokkattu, J. J., Mary, D. J., Shanmugam, R., & Neeharika, S. (2022). Embryonic Toxicology Evaluation of Ginger- and Clove-mediated Titanium Oxide Nanoparticles-based Dental Varnish with Zebrafish. The Journal of Contemporary Dental Practice, 23(11), 1157–1162.](http://paperpile.com/b/9aa8AK/sXrV3)
7. [Chokkattu, J. J., Neeharika, S., & Rameshkrishnan, M. (2023). Applications of Nanomaterials in Dentistry: A Review. Journal of International Society of Preventive & Community Dentistry, 13(1), 32–41.](http://paperpile.com/b/9aa8AK/8QdpI)
8. [Deepika, B. A., Ramamurthy, J., Girija, S., & Jayakumar, N. D. (2022). Evaluation of the antimicrobial effect of Ocimum sanctum L. oral gel against anaerobic oral microbes: An in vitro study. World Journal of Dentistry, 13(S1), S23–S27.](http://paperpile.com/b/9aa8AK/EeerV)
9. [Dharman, S., (2021). Ecofriendly Synthesis, Characterisation and Antibacterial Activity Of Curcumin Mediated Silver Nanoparticles. International Journal of Dentistry and Oral Science, 2314–2318.](http://paperpile.com/b/9aa8AK/E8Cs0)
10. [Ganapathy, D., & Professor , (2021). Health benefits of Annona muricata - A review. International Journal of Dentistry and Oral Science, 2965–2967.](http://paperpile.com/b/9aa8AK/bvjYH)
11. [Govindaraj, A., & Dinesh, S. P. S. (2021). Effect of chlorhexidine varnish and fluoride varnish on White Spot Lesions in orthodontic patients- a systematic review. The Open Dentistry Journal, 15(1), 151–159.](http://paperpile.com/b/9aa8AK/a7hQz)
12. [Graf, S., Thakkar, D., Hansa, I., Pandian, S. M., & Adel, S. M. (2023). 3D metal printing in orthodontics current trends, biomaterials, workflows and clinical implications. Seminars in Orthodontics. https://doi.org/](http://paperpile.com/b/9aa8AK/ghZrW)[10.1053/j.sodo.2023.01.001](http://dx.doi.org/10.1053/j.sodo.2023.01.001)
13. [Grotewold, E. (2007). The Science of Flavonoids. Springer Science & Business Media.](http://paperpile.com/b/9aa8AK/v8Ms)
14. [Harsha, L., Navaneethan, R., Acid, T., & Acid, C. A.-A. (2022). CITRIC ACID-AN VITRO STUDY. International Journal Clinical Dentistry, 15(3), 413–419.](http://paperpile.com/b/9aa8AK/9VkCW)
15. [Harsha, L., & Subramanian, A. K. (2022). Comparative assessment of pH and degree of surface roughness of enamel when etched with five commercially available etchants: An in vitro study. The Journal of Contemporary Dental Practice, 23(2), 181–185.](http://paperpile.com/b/9aa8AK/QlMAU)
16. [Jabin, Z., Nasim, I., Vishnu Priya, V., & Agarwal, N. (2021). Quantitative Analysis and Effect of SDF, APF, NaF on Demineralized Human Primary Enamel Using SEM, XRD, and FTIR. International Journal of Clinical Pediatric Dentistry, 14(4), 537–541.](http://paperpile.com/b/9aa8AK/zLcq6)
17. [Jain, R. K., & Verma, P. (2022). Visual assessment of extent of White Spot lesions in subjects treated with fixed orthodontic appliances: A retrospective study. World Journal of Dentistry, 13(3), 245–249.](http://paperpile.com/b/9aa8AK/WUNUE)
18. [Lakshmi, T. (2021). Medicinal value oral health aspects acacia catechu-an update. International Journal Dentistry Oral ScienceVolume, 8, 1399–1401J.](http://paperpile.com/b/9aa8AK/1heNW)
19. [Mahmud, S., Ajadee, A., Sarker, A., Ahmmed, R., Noor, T., Pappu, M. A. A., Islam, M. S., & Mollah, M. N. H. (2025). Exploring common genomic biomarkers to disclose common drugs for the treatment of colorectal cancer and hepatocellular carcinoma with type-2 diabetes through transcriptomics analysis. PloS One, 20(3), e0319028.](http://paperpile.com/b/9aa8AK/rJOU)
20. [Maliael, M. T., Subramanian, A. K., & Srirengalakshmi. (2021). Effectiveness of a fluoride-releasing orthodontic primer in reducing demineralization around brackets – a systematic review. Orthodontic Waves (English Ed.), 80(4), 218–223.](http://paperpile.com/b/9aa8AK/iCpYt)
21. [Marya, A., Venugopal, A., Karobari, M. I., & Rokaya, D. (2022). White Spot lesions: A serious but often ignored complication of orthodontic treatment. The Open Dentistry Journal, 16(1). https://doi.org/](http://paperpile.com/b/9aa8AK/Sxt2s)[10.2174/18742106-v16-e2202230](http://dx.doi.org/10.2174/18742106-v16-e2202230)
22. [National Academies of Sciences, Engineering, and Medicine, Health and Medicine Division, Board on Health Care Services, & Committee on Identifying Disabling Medical Conditions Likely to Improve with Treatment. (2020). Selected Health Conditions and Likelihood of Improvement with Treatment. National Academies Press.](http://paperpile.com/b/9aa8AK/zAHj)
23. [National Research Council, Division on Earth and Life Studies, Commission on Life Sciences, & Committee on Comparative Toxicity of Naturally Occurring Carcinogens. (1996). Carcinogens and Anticarcinogens in the Human Diet: A Comparison of Naturally Occurring and Synthetic Substances. National Academies Press.](http://paperpile.com/b/9aa8AK/1ZMX)
24. [Neha, N., Maiti, S., & Jessy, P. (2021). Adhesion microflora role denitrifies colour stability provisional crowns: in-vitro study. Int J Dentistry Oral Sci, 8(8), 3805–3809.](http://paperpile.com/b/9aa8AK/5GxRe)
25. [Pandikumar, A., & Rameshkumar, P. (2018). Graphene-Based Electrochemical Sensors for Biomolecules. Elsevier.](http://paperpile.com/b/9aa8AK/ysRS)
26. [Patra, J. K., Shukla, A. C., & Das, G. (2021). Advances in Pharmaceutical Biotechnology: Recent Progress and Future Applications. Springer.](http://paperpile.com/b/9aa8AK/oIqx)
27. [Poornima, P., Krithikadatta, J., Ponraj, R. R., Velmurugan, N., & Kishen, A. (2021). Biofilm formation following chitosan-based varnish or chlorhexidine-fluoride varnish application in patients undergoing fixed orthodontic treatment: a double blinded randomised controlled trial. BMC Oral Health, 21(1), 465.](http://paperpile.com/b/9aa8AK/aQezq)
28. Rafi, D. M., Lakshmi, T. V., Shirley, C. P., Ravivarman, G., & Senthilkumar, G. (2024, April). Improving Prostate Cancer Diagnosis with Weakly Supervised Learning and Radiology-Confirmed Negative MRI Data. In 2024 International Conference on Inventive Computation Technologies (ICICT) (pp. 1183-1188). IEEE.
29. [Rai, M., Patel, M., & Patel, R. (2021). Nanotechnology in Medicine: Toxicity and Safety. John Wiley & Sons.](http://paperpile.com/b/9aa8AK/mEBu)
30. [Rai, M., & Shegokar, R. (2017). Metal Nanoparticles in Pharma. Springer.](http://paperpile.com/b/9aa8AK/m1GQ)
31. [Ramamurthy, S., Thiagarajan, K., Varghese, S., Kumar, R., Karthick, B. P., Varadarajan, S., & Balaji, T. M. (2022). Assessing the in vitro antioxidant and anti-inflammatory activity of Moringa oleifera crude extract. The Journal of Contemporary Dental Practice, 23(4), 437–442.](http://paperpile.com/b/9aa8AK/OHyQ1)
32. [Sabarathinam, J., & Madhulaxmi, R. (2021). Development anti inflammatory antimicrobial silver nanoparticles coated suture materials. Int J Dentistry Oral Sci, 8(3), 2006–2013.](http://paperpile.com/b/9aa8AK/L9CEi)
33. [Shukla, A. K. (2021). Nanoparticles and their Biomedical Applications. Springer.](http://paperpile.com/b/9aa8AK/tHvo)
34. [Solanki, L. A., Dinesh, S. P. S., Jain, R. K., & Balasubramaniam, A. (2023). Effects of titanium oxide coating on the antimicrobial properties, surface characteristics, and cytotoxicity of orthodontic brackets - A systematic review and meta analysis of in-vitro studies. Journal of Oral Biology and Craniofacial Research, 13(5), 553–562.](http://paperpile.com/b/9aa8AK/nSrFH)
35. [Solanki, L., Shantha Sundari, K. K., Muralidharan, N. P., & Jain, R. (2022). Antimicrobial effect of novel gold nanoparticle oral rinse in subjects undergoing orthodontic treatment: An ex-vivo study. Journal of International Oral Health: JIOH, 14(1), 47.](http://paperpile.com/b/9aa8AK/cTQFu)
36. [Sreevarun, M., Ajay, R., Suganya, G., Rakshagan, V., Bhanuchander, V., & Suma, K. (2023). Formulation, Configuration, and Physical Properties of Dental Composite Resin Containing a Novel 2π + 2π Photodimerized Crosslinker - Cinnamyl Methacrylate: An Research. The Journal of Contemporary Dental Practice, 24(6), 364–371.](http://paperpile.com/b/9aa8AK/6m3SD)
37. [Subramanian, A., & Harikrishnan, S. (2023). 3D printing in orthodontics: A narrative review. Journal of International Oral Health: JIOH, 15(1), 15.](http://paperpile.com/b/9aa8AK/wXt6a)
38. [Sushanthi, S., Doraikannan, S., Indiran, M., & Rathinavelu, P. (2021). Rajeshkumar S. Vernonia Amygdalina. 3330–3334.](http://paperpile.com/b/9aa8AK/q57NP)
39. [Tiwari, A., & Jain, R. K. (2023). Comparative evaluation of White Spot lesion incidence between NovaMin, probiotic, and fluoride containing dentifrices during orthodontic treatment using laser fluorescence - A prospective randomized controlled clinical trial. Clinical and Investigative Orthodontics, 1–8.](http://paperpile.com/b/9aa8AK/8WoeX)
40. Tuluwengjiang, G., Rasulova, I., Ahmed, S., Kiasari, B. A., Sârbu, I., Ciongradi, C. I., & Samaniego, S. S. C. (2024). Dendritic cell-derived exosomes (Dex): Underlying the role of exosomes derived from diverse DC subtypes in cancer pathogenesis. Pathology-Research and Practice, 254, 155097.
41. [United States. Public Health Service. Office of the Surgeon General. (1979). Healthy People: The Surgeon General’s Report on Health Promotion and Disease Prevention, 1979.](http://paperpile.com/b/9aa8AK/ioGR)
42. [Vasantha Rupasinghe, H. P. (2021). Flavonoids and Their Disease Prevention and Treatment Potential. MDPI.](http://paperpile.com/b/9aa8AK/ecdB)
43. [Verma, P., & Muthuswamy Pandian, S. (2021). Bionic effects of nano hydroxyapatite dentifrice on demineralised surface of enamel post orthodontic debonding: in-vivo split mouth study. Progress in Orthodontics, 22(1), 39.](http://paperpile.com/b/9aa8AK/ubEiJ)
44. [Wadhwani, V., Sivaswamy, V., & Rajaraman, V. (2022). Surface roughness and marginal adaptation of stereolithography versus digital light processing three-dimensional printed resins: An study. Journal of Indian Prosthodontic Society, 22(4), 377–381.](http://paperpile.com/b/9aa8AK/rVS1A)
45. [Yata, V. K., Ranjan, S., Dasgupta, N., & Lichtfouse, E. (2020). Nanopharmaceuticals: Principles and Applications Vol. 3. Springer Nature.](http://paperpile.com/b/9aa8AK/dj6z)