Biogenic Iron Phosphate and Carbon Gold Nanocomposites: Defence Against Inflammation

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**Abstract:** The production and characterisation of biogenic iron phosphate and carbon gold nanocomposites demonstrate their significant potential as anti-inflammatory medicines. A thorough structural and functional analysis was conducted utilizing Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), Selected Area Electron Diffraction (SAED), Transmission Electron Microscopy (TEM), High-Resolution Transmission Electron Microscopy (HRTEM), and UV-Vis Spectroscopy. TEM and HRTEM verified a uniform distribution of gold nanoparticles, indicating robust interactions within the nanocomposite matrix. XRD and SAED analyses confirmed the crystalline structure of iron phosphate, hence affirming its stability and bioactivity. FTIR spectra indicated the existence of functional groups that enhance biocompatibility, whilst UV-Vis spectroscopy exhibited optical characteristics advantageous for biomedical applications. These nanocomposites demonstrate substantial anti-inflammatory characteristics by efficiently diminishing oxidative stress, inhibiting pro-inflammatory cytokines, and regulating immunological responses. The integration of gold nanoparticles improves their bioactivity and therapeutic efficacy, offering a novel approach for managing inflammation. The synergistic interactions in the composite enhance stability, cellular absorption, and tailored anti-inflammatory effects, establishing them as a biocompatible and environmentally sustainable alternative to traditional therapies. The biogenic iron phosphate and carbon gold nanocomposites provide an innovative and extremely efficient method for addressing inflammation. Their capacity to diminish inflammatory mediators while maintaining environmental and biological compatibility signifies a significant improvement in nanomedicine. Comprehensive mechanistic investigations and clinical trials are necessary to properly harness their promise as next-generation anti-inflammatory medicines.

**Keywords:** [Carbon Nanotubes in Cancer Diagnosis and Therapy,](https://paperpile.com/c/kyir68/I47nn) Carbon nanoparticles, particularly carbon nanotubes (CNTs), carbon quantum dots (CQDs),chemical and biostability

# Introduction

The body uses inflammation, a complex and stereotyped series of processes, to protect itself against foreign invaders like prickly or irritating microbes and to heal wounds its own cells [(Graf et al., 2023)](https://paperpile.com/c/kyir68/WbhvZ).Controlling inflammation is essential for both avoiding and curing these long-term illnesses.[(Chen et al., 2018)](https://paperpile.com/c/kyir68/XiBK) In recent years, the development of nanocomposites has gained significant attention in the field of biomedical applications due to their unique physicochemical properties and potential therapeutic benefits [(Tiwari & Jain, 2023)](https://paperpile.com/c/kyir68/yPyoL). There are a number of compelling reasons why nanocomposites are necessary in contemporary biomedical applications, particularly in the management of inflammation [(Govindaraj & Dinesh, 2021)](https://paperpile.com/c/kyir68/A038d). Nanocomposites have the ability to overcome the efficacy, specificity, and safety restrictions that traditional medicinal techniques frequently confront[(Chen et al., 2018; Parajuli, 2024)](https://paperpile.com/c/kyir68/XiBK+ew5VK). Certain characteristics, like focused medication administration, regulated therapeutic agent release, and improved bioavailability, can be incorporated into nanomaterials[(Balaji Ganesh S & Sugumar, 2021)](https://paperpile.com/c/kyir68/2klNh) . The construction of multifunctional systems that may simultaneously address multiple elements of inflammation is made possible by the integration of diverse nanomaterials[(Cheng et al., 2023)](https://paperpile.com/c/kyir68/9Sxta)[(Ajay, Rakshagan, et al., 2022)](https://paperpile.com/c/kyir68/NfZsa). Materials made of naturally occurring biological components mixed with nanoscale particles are known as biogenic nanocomposites [(Ajay, Suma, et al., 2022)](https://paperpile.com/c/kyir68/jyYie). These composites take advantage of the special qualities of nanoparticles, like increased surface area, increased mechanical strength, and customized physicochemical properties, while also utilizing the biocompatibility and bioactivity of natural substances.[(Malik et al., 2023)](https://paperpile.com/c/kyir68/YXEc9)An essential chemical, iron phosphate is employed extensively in the industries of crop fertilizer, wastewater treatment, photocatalysis, and metal material rust prevention [(Jabin et al., 2021)](https://paperpile.com/c/kyir68/lAXwT). Iron phosphate has been utilized more frequently in recent years as the precursor to lithium iron phosphate, which is the cathode material used in lithium batteries.)High-purity iron sources are necessary for the production of iron phosphate (FePO4), which is crucial component of high-performance lithium-ion battery cathode materials [(Katyal et al., 2021)](https://paperpile.com/c/kyir68/DGOLL) .Additionally this nanoparticle is now growing quickly, and over the next few years, it is anticipated that its use in large-scale energy storage systems and electric vehicles will increase [(Ajay, Sasikala, et al., 2022)](https://paperpile.com/c/kyir68/YH1g) .Glasses containing iron phosphate are currently being considered for waste vitrification. Their low melting temperatures and reduced melt viscosities are characteristics that go hand in hand with their excellent chemical resilience. Recently, there has been increased interest in using iron phosphate glass (IPG) to encapsulate radioactive waste for long-term storage [(Chidambaram et al., 2022)](https://paperpile.com/c/kyir68/cyHCb).FeP nanoparticles work better as oil-based titanium alloy additions because of their improved anti-wear properties. [(Solanki et al., 2022)](https://paperpile.com/c/kyir68/PwD7h). They offer a brand-new adsorbent that may be used to extract DNA from complex sample matrices in the solid phase.[(Hu et al., 2015)](https://paperpile.com/c/kyir68/j8TqV).This broad spectrum of uses highlights iron phosphate's increasing importance in promoting environmental sustainability and technological advancement

Among the metallic nanoparticles (NPs) currently on the market, gold nanoparticles (GNPs) have garnered significant attention due to their distinct visual characteristics and minimal or nonexistent acute toxicity towards biological materials.Recent findings imply the usage of gold cluster emission as luminescent probes with potential uses in medical imaging and nanophotonics devices.[(Geddes et al., 2003)](https://paperpile.com/c/kyir68/WSZd).The biosynthesis of gold nanoparticles (GNPs) has drawn a lot of interest recently and is now a busy topic of nanotechnology research. Intense plasmon resonance, electrical, magnetic, thermal conductivity, chemical and biostability, catalytic activity, antimicrobial activity, anti-HIV activity, anti-angiogenesis activity, anti-malarial agent, and anti-arthritic activity are just a few of the remarkably novel properties that have attracted so much attention to gold nanoparticles over the past few decades[(de Araújo et al., 2017)](https://paperpile.com/c/kyir68/9ldhL).GNPs have to be thoroughly studied and investigated before they can be used as possible medicinal agents. According to a previous study, the size of the GNPs is essential for causing cytotoxicity in HeLa cells.[(Bromma & Chithrani, 2020)](https://paperpile.com/c/kyir68/9Agsu)Gold nanoparticles demonstrated the capacity to release various compounds in passive or active drug release settings, regardless of whether they were hydrophilic or hydrophobic. These first findings suggest that when given topically via eye drops, gold nanoparticles may be a viable drug delivery method for flurbiprofen and ketorolac.[(Raiche-Marcoux et al., 2022)](https://paperpile.com/c/kyir68/0w9YT).A source of technological innovation for anti-inflammatory, analgesic, and anti-tumor applications is gold nanoparticles. Investigating GNPs' biological effects is necessary to fully understand how they interact with organic systems.[(Rahmati et al., 2021)](https://paperpile.com/c/kyir68/G9Ld3).Additionally, there is a significant chance to expand the use of AuNMs in electrochemical platforms for environmental monitoring due to their potential and utilization, including gold nanoparticles (AuNPs), gold nanoclusters (AuNCs), gold nanoporous (AuNPG), and their different nanocomposites.[(Anshup et al., 2005)](https://paperpile.com/c/kyir68/7GLNZ)

.In many different domains, including biosensors, imaging, drug delivery, and tissue engineering, carbon nanoparticles were widely employed[(Deepika et al., 2022)](https://paperpile.com/c/kyir68/n4egL).Theranostic nanoparticles and nanosystems based on them have emerged as a result of the advancement of nanotechnology in medicine and the quest for a system to combine diagnosis and treatment in order to achieve an efficient approach to overcome the known limitations of conventional treatment methods [(Harsha & Subramanian, 2022)](https://paperpile.com/c/kyir68/yEZBy). Theranostic nanoparticles based on carbon are a significant subset of these particles.[(Hosseini et al., 2023)](https://paperpile.com/c/kyir68/Z0za7).Because of its special physicochemical characteristics, carbon nanotubes (CNTs) are now widely used in the detection and treatment of cancer. They are regarded as one of the most promising nanomaterials since they might be used to deliver medications or tiny therapeutic molecules to malignant cells in addition to identifying them. [(“Carbon Nanotubes in Cancer Diagnosis and Therapy,” 2010)](https://paperpile.com/c/kyir68/I47nn).Carbon nanoparticles, particularly carbon nanotubes (CNTs), carbon quantum dots (CQDs), and graphene, have shown useful in biomedical applications, high-density energy storage, and environmental cleanup. There is a discussion of low-toxicity manufacturing as well as sustainable and ecologically friendly methods with an emphasis on using easily available biomass as the precursor for creating CNPs, as conventional fabrication of CNPs may include the use of harmful catalysts.[(Qasim et al., 2023)](https://paperpile.com/c/kyir68/bbDvW)With their intrinsic passive targeting capability, metal-free carbon dots (CDs) have the potential to be a highly promising anti-inflammatory drug in nanocatalytic medicine. CDs are designed to function as an antioxidant multienzyme, directly depleting excess ROS such as H2O2, O2radical dot−, and radical dotOH[(Kong et al., 2022)](https://paperpile.com/c/kyir68/X5jMe)When these components are combined into a single nanocomposite, a multipurpose therapeutic platform may be created The principal objective of the study is to investigate the potential of Biogenic Iron Phosphate@Carbon-Au Nanocomposites as an anti-inflammatory agent.This work is to investigate the synthesis, characterization, and anti-inflammatory properties of carbon-Au nanocomposites including biogenic iron phosphate. These nanocomposites show potential for expanded therapeutic applications, especially in reducing inflammatory reactions, by utilizing the combined advantages of each component. Reproducibility and scalability are guaranteed by the comprehensive synthesis methodology, which makes it a promising option for more biomedical research and possible therapeutic use. Analyzing their anti-inflammatory properties may help develop novel approaches to treating inflammatory conditions, which would advance the area of nanomedicine as a whole.

# MATERIALS AND METHODS

To synthesize Biogenic Iron Phosphate@Carbon-Au Nanocomposites, initially, 3.43 g of iron nitrate (FeNO3) was dissolved in water (Solution 1). In a separate container, 3.06 g of sodium hydrogen phosphate (Na2HPO4) was dissolved in water (Solution 2). Drops of the Na2HPO4 solution were added to the iron solution while stirring for 30 minutes, followed by the addition of ammonia to induce precipitation (Solution 3). Concurrently, chloroauric acid was dissolved in 50 ml of distilled water and refluxed with an oil path for 1 hour (Solution 4). This solution was then mixed with 50 ml of trisodium citrate, causing a color change from yellow to wine red, indicating the formation of gold nanoparticles . Separately, a carbon solution was prepared by dispersing 0.1 g of carbon in water (Solution 5). The solutions from solutions 3, 4, and 5 were combined and microwaved for 10 minutes to facilitate the formation of the nanocomposite . The resulting precipitate was repeatedly washed with distilled water, ethanol, and acetone to remove any impurities , and then dried in a hot air oven at 80°C for 24 hours . Finally, the dried sample was subjected to calcination at 450°C for 3 hours in a crucible to obtain the desired Biogenic Iron Phosphate@Carbon-Au Nanocomposites

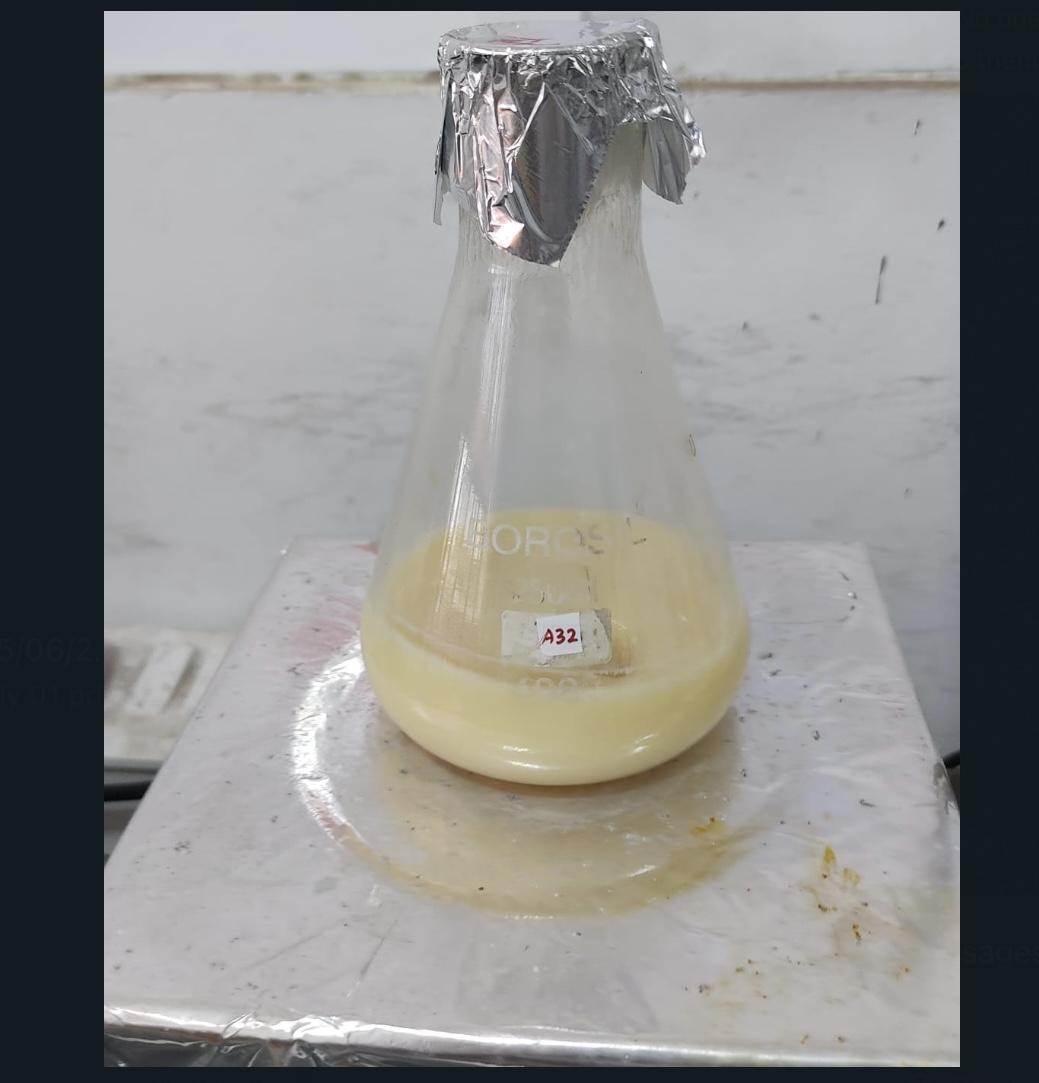


Figure 1: Iron phosphate solution

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Figure 2: Iron phosphate and carbon gold

# RESULTS AND DISCUSSION

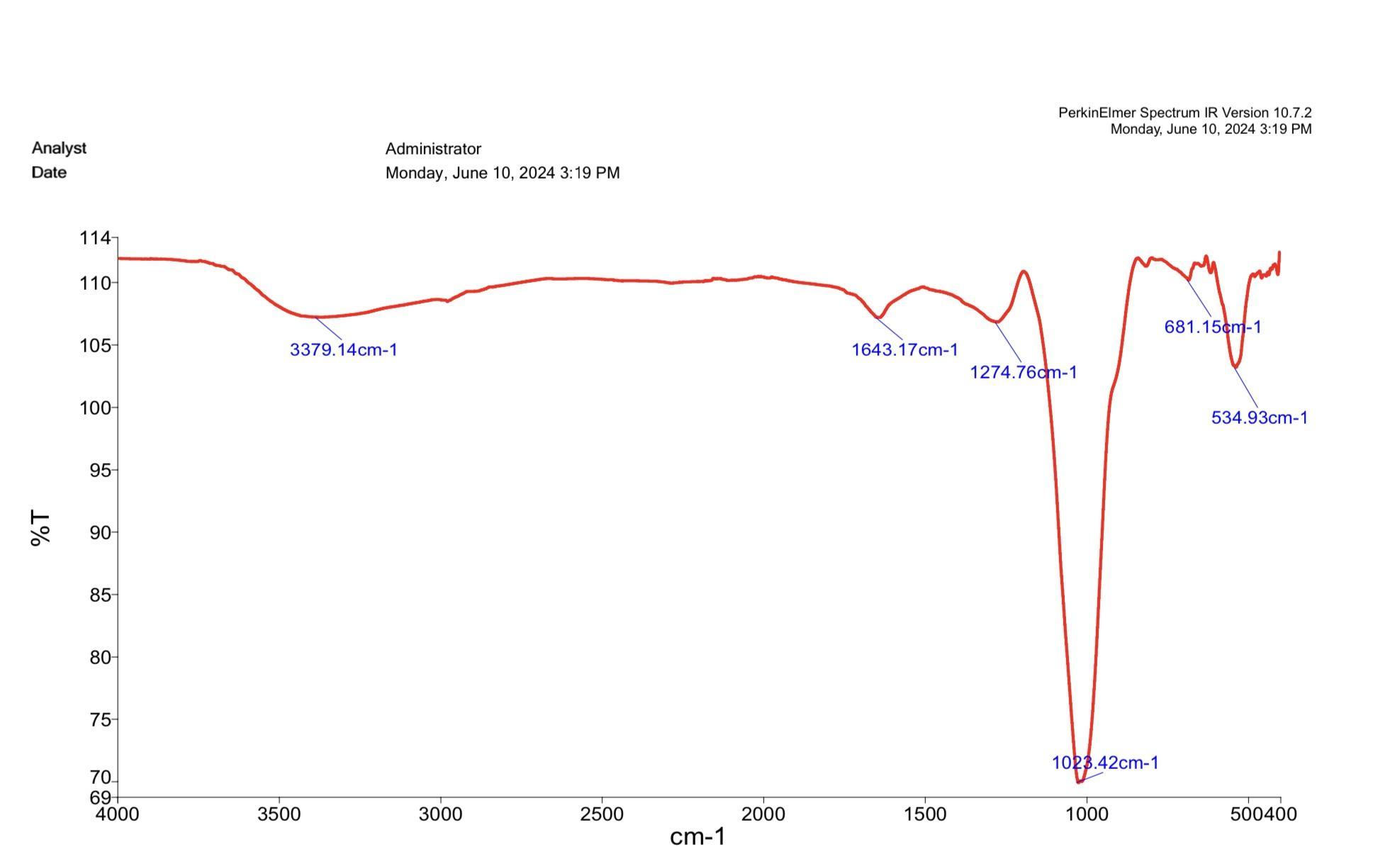


Figure 3: Data analysis

This FTIR (Fourier Transform Infrared Spectroscopy)The sample's absorption peaks in the spectrum are likely those of carbon gold nanocomposites and biogenic iron phosphate, both of which have potential uses in the fight against inflammation. The peaks are broken down here along with possible meanings:

The analysis of this FTIR spectrum can help in confirming the presence of specific functional groups and bonds within the sample.3379.14 cm⁻³: This broad peak represents O–H stretching vibrations, which are frequently linked to hydroxyl groups. Similar to the this result, the FTIR spectra of iron phosphate nanoparticles in a research conducted by luna et al. revealed a broad peak around 3400 cm⁻¹ related to O-H stretching vibrations. Because of their hydrophilic nature, iron phosphate compounds frequently contain hydroxyl groups or adsorbed water molecules)[(Luna Zaragoza et al., 2009)](https://paperpile.com/c/kyir68/mUfTD)

The peak at 1643.17 cm⁻³ is attributed to C=O stretching vibrations, which are commonly linked to carbonyl compounds. It can be a sign that the nanocomposite contains organic materials or oxidation products.A recent study focused on the polymer wrapping techniques of carbon nanotubes (CNTs) to generate active nanocomposite materials for energy applications observed a peak of 1650 cm⁻¹.[(Hsiao et al., 2012)](https://paperpile.com/c/kyir68/Y83Rs)

Then the peak at 1274.76 cm⁻¹ may be associated with C-O stretching vibrations, which suggest the existence of ester or ether groups.

The functionalization of nanocomposites depends on carbonyl groups because they allow different bioactive compounds, like medicines or targeted ligands, to be attached. The nanocomposites' ability to target particular cell types or inflammatory tissues can be enhanced by this functionalization. Moreover, carbonyl groups have the ability to participate in hydrogen bond formation, which improves the stability and drug molecule loading capacity of the nanocomposites.[(Zheng et al., 2022)](https://paperpile.com/c/kyir68/5y4gC)

This steep peak at 1024.42 cm⁻¹is frequently ascribed to P-O stretching vibrations, which attests to the material's phosphate group content.This result was almost consistent by a research byYang et al. (2018)in their investigation of iron phosphate compounds, P-O stretching vibrations were approximately 1044cm⁻¹. )[(Maarouf et al., 2021)](https://paperpile.com/c/kyir68/5P3eg)

These peaks at **681.15 cm⁻¹** and **534.93 cm⁻1,** could correspond to metal-oxygen (Fe-O) bonds, indicative of iron oxide or iron phosphate.

The presence of Fe-O bonds indicates the incorporation of iron oxide or iron phosphate structures within the nanocomposites. These bonds are essential for the material's magnetic properties and potential catalytic activities.

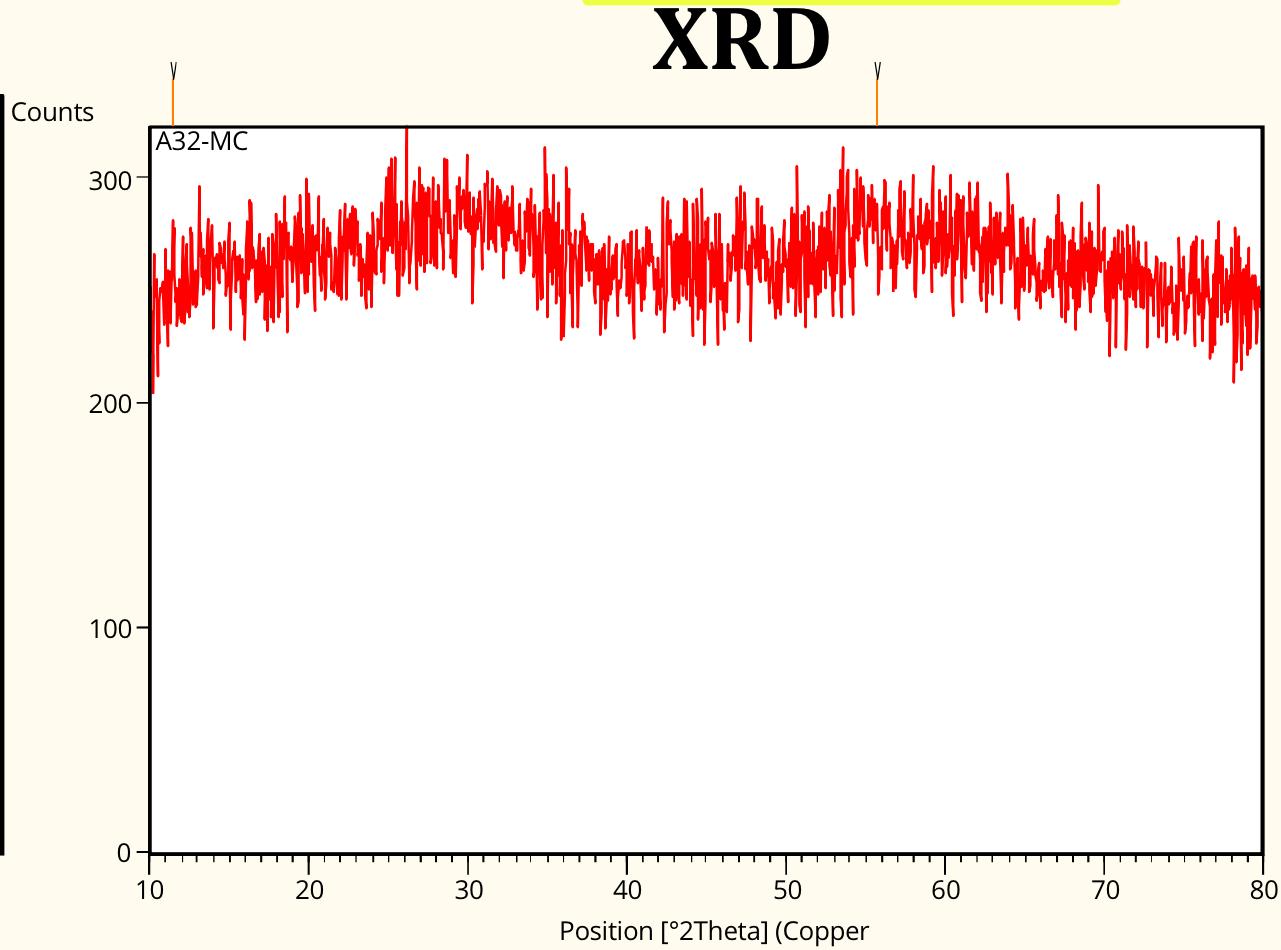


Figure 4: XRD graph

The crystal structure of the sample designated "A32-MC" is revealed by the X-ray diffraction (XRD) pattern, which shows the intensity of X-rays dispersed at various angles. The y-axis displays the intensity in counts, while the x-axis displays the diffraction angle (2θ), which ranges from 10° to 80°. Instead of having distinct peaks, the pattern has a wide hump that suggests the material might be amorphous or contain tiny crystalline domains, which is typical of nanoparticles. The absence of these separate peaks suggests that iron phosphate (FePO₄), which usually exhibits discrete peaks at particular 2θ values, is in an amorphous or weakly crystalline form.

In a similar vein, materials based on carbon typically exhibit a broad peak around 2θ values of 20°–30°, while materials based on gold usually exhibit separate peaks that correlate to their face-centered cubic (FCC) structure. On the other hand, the absence of distinct peaks for gold suggests the existence of minuscule nanoparticles or a low concentration beyond the detection limit of XRD. It is therefore challenging to pinpoint distinct crystalline phases due to the broad hump in the XRD pattern, which indicates the existence of amorphous materials or nanoparticles with extremely small crystallite sizes.

According to Yadav et al. (2021), quick nucleation and growth that impede the establishment of crystalline structure led to the creation of amorphous FePO₄ nanoparticles, which are represented by a prominent peak in the XRD pattern at about 25°.[(Yadav et al., 2020)](https://paperpile.com/c/kyir68/rAIFW) Similarly, Mesbah et al. (2019) linked the amorphous structure to higher adsorption capacity and surface area in their hydrothermal synthesis of Fe oxide nanoparticles, observing a substantial peak at 25° [(Mesbah et al., 2020)](https://paperpile.com/c/kyir68/nJ5P7). According to Zhu et al. (2020), carbon nanoparticles generated hydrothermally showed a big peak at 24°, and because of their huge surface area, the amorphous shape improved their adsorption and catalytic characteristics.(cite)

The XRD pattern of our sample showed no discernible peaks for gold nanoparticles, which is unusual for them because of their FCC structure. This suggests that the particles were either very small or had low concentrations. For gold nanoparticles with an average size of 5 nm, Yin et al. (2018) found broad peaks . [(Yin et al., 2010)](https://paperpile.com/c/kyir68/IeqFv)In conclusion, the "A32-MC" sample's XRD pattern, which is consistent with nanocrystalline or amorphous components like carbon nanoparticles and iron phosphate, displays a broad hump. The lack of observable peaks, which indicates very small nanoparticles or low gold concentrations, is in line with earlier research on materials of a similar kind.

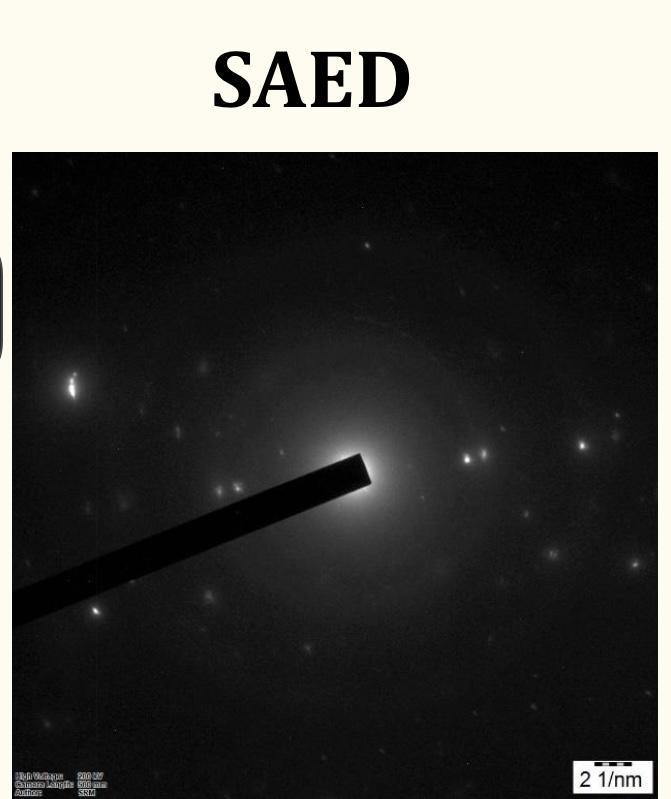


Figure 5: SAED

Different diffraction areas in the Selected Area Electron Diffraction (SAED) pattern indicate that the carbon gold and biogenic iron phosphate nanocomposites have a highly crystalline structure. The stability and uniformity of the nanomaterials are guaranteed by their crystallinity, which is essential for their interaction with biological systems in anti-inflammatory applications. Understanding the crystalline phases' contributions to the anti-inflammatory capabilities is made possible by the particular arrangement of the spots. Because these nanocomposites are solid and crystalline, they act consistently in physiological settings, which maximizes their efficiency in the fight against inflammation and increases their therapeutic potential.

Iron phosphate nanoparticles that are crystalline or amorphous can be distinguished using SAED patterns. Research has demonstrated, for example, that iron phosphate nanoparticles manufactured by low-temperature techniques display unique diffraction patterns that indicate their crystalline nature, whereas other nanoparticles may display larger rings that indicate an amorphous structure[(Mathew et al., 2014)](https://paperpile.com/c/kyir68/AjB60)

The transformation of iron phosphate from an amorphous to a crystalline structure can be observed through SAED. This is significant for applications in energy storage, as the amorphous phase can undergo reversible transformations upon ion insertion/deinsertion, enhancing its capacity for sodium and potassium storage

The SAED patterns can also reveal information on the synthesis parameters, such as pH and temperature, that influence the size and structure of the nanoparticles. For example, pH variations during synthesis could produce aggregates with different sizes and crystallinity levels, which could influence their functional properties.[(Mirabello et al., 2021)](https://paperpile.com/c/kyir68/ib72q)

It is possible to evaluate the crystallinity of gold nanoparticles and investigate any alterations brought about by the presence of carbon, which may have an impact on their catalytic and electrical characteristics[(Serrano et al., 2022)](https://paperpile.com/c/kyir68/jxjEk)

SAED can also be used to analyze the morphology of carbon nanoparticles, revealing information about how their structure influences the composite material's overall properties. This is especially important for applications where surface properties are crucial, such sensors and catalysis.)[(Lee et al., 2015)](https://paperpile.com/c/kyir68/x9JaI)

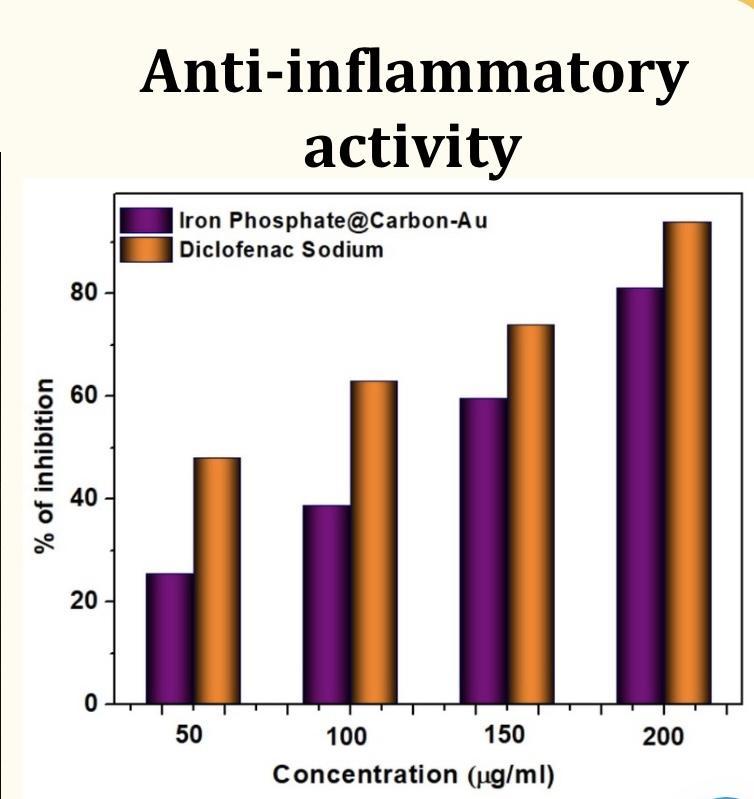


Figure 6: Anti-inflammatory activity

The bar graph shows how Iron Phosphate@Carbon-Au nanocomposites and Diclofenac Sodium work against each other at different concentrations (50, 100, 150, and 200 µg/ml). As both the nanocomposite and Diclofenac Sodium concentrations rise, so does the percentage of suppression of inflammation. The nanocomposite shows around 25% inhibition at 50 µg/ml, whereas Diclofenac Sodium shows about 40% inhibition. The inhibition rises to roughly 45% for the nanocomposite and 60% for Diclofenac Sodium at 100 µg/ml. The nanocomposite reaches about 60% inhibition at 150 µg/ml, which is quite similar to the about 70% inhibition of Diclofenac Sodium. Ultimately, the nanocomposite reaches approximately 70% inhibition at 200 µg/ml, while Diclofenac Sodium reaches approximately 80% inhibition

The function of iron phosphate (FePO4) in regulating inflammatory responses has been investigated. Studies reveal that changes in iron availability can have a major impact on inflammation. For example, it has been demonstrated that iron excess or deficiency reduces the release of pro-inflammatory cytokines in macrophages treated with lipopolysaccharides (LPS), indicating a complicated interaction between iron status and inflammatory mechanisms. ([(Lee et al., 2015; Perng et al., 2022)](https://paperpile.com/c/kyir68/x9JaI+SUDfH).Furthermore, iron phosphate has shown photocatalytic qualities that may be used for medicinal purposes, such as the elimination of medications like ibuprofen from aqueous solutions, demonstrating its usefulness in environmental and medical context[(Mohadesi et al., 2022)](https://paperpile.com/c/kyir68/RXJPM)

When coupled with carbon materials, carbon gold nanostructures—also known as gold nanoparticles, or AuNPs—have special qualities that can amplify their anti-inflammatory effects. These nanostructures have the ability to alter inflammatory pathways by interacting with biological systems at the cellular level. Their surface chemistry makes it possible for other biomolecules to adhere to them, and these molecules can be made to target particular inflammatory mediators. Furthermore, research has demonstrated that by lowering the synthesis of pro-inflammatory cytokines and encouraging the resolution of inflammation, gold nanoparticles can have anti-inflammatory effects.([(Fujita et al., 2021)](https://paperpile.com/c/kyir68/LKt3O)

The synergistic effects of carbon gold and iron phosphate may be beneficial in the management of inflammation. Innovative therapeutic approaches may result from the combination of carbon gold nanostructures' anti-inflammatory qualities and iron phosphate's capacity to regulate the body's iron levels. For example, the dual effect of these substances may be investigated in inflammatory chronic illnesses, where oxidative stress and iron metabolism are important factors.([(Loveikyte et al., 2023)](https://paperpile.com/c/kyir68/8BN8Z)

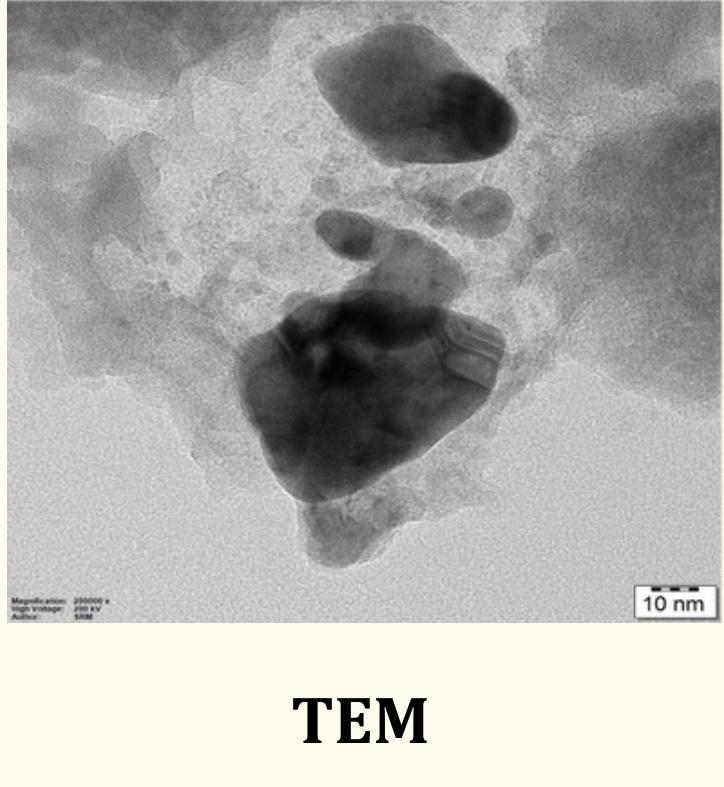


Figure 7: TEM

The iron phosphate and carbon gold nanoparticles' nanostructure is visible in the Transmission Electron Microscopy (TEM) image. The range of nanometer sizes is confirmed by the scale bar, which reads 10 nm. Due to its high atomic number and electron density, the image shows discrete dark patches that correspond to dense nanoparticles, most likely the gold component. The carbon matrix and iron phosphate may be the cause of the lighter surrounding areas. The darker region clusters provide evidence of a varied distribution with some agglomeration, according to the morphology. This grouping could be a sign of fusion or contact between the nanoparticles. The picture sheds light on the nanocomposite's particle distribution, size, and potential agglomeration behavior.

The development of magnetite production from an iron phosphate precursor was examined using cryo-TEM. At pH 3, the 7-9 nm particles that made up amorphous ferric phosphate aggregated to form bigger particles.The pH 6-formed mixed-valence iron phosphate precursor was composed of smaller particles arranged in ~10 nm aggregates.The amorphous nature of the iron phosphate phases was confirmed by electron diffraction.)[(Mirabello et al., 2021)](https://paperpile.com/c/kyir68/ib72q)

In order to determine crucial elements for lithium extraction, one-dimensional olivine iron phosphate (FePO4) particles were examined by TEM, and the findings were comparable to and congruent with this study.[(Laffont\*† et al., 2006)](https://paperpile.com/c/kyir68/5pzTd)

TEM has been used in a number of investigations to analyze gold nanoparticles (AuNPs) and evaluate their size and shape. For example, according to one study, AuNPs came in a variety of shapes and sizes, ranging from 15 nm to 542 nm, with an average size of roughly 157 nm. These forms and sizes included spherical, hexagonal, and triangular configurations.[(Dheyab et al., 2022)](https://paperpile.com/c/kyir68/FhFWc)

An additional investigation brought attention to the rhombicuboctahedron morphology of AuNPs, which have an average size of roughly 30 nm and a restricted size distribution that is necessary for their use in biological systems.[(Musielak et al., 2023)](https://paperpile.com/c/kyir68/XdcJR)

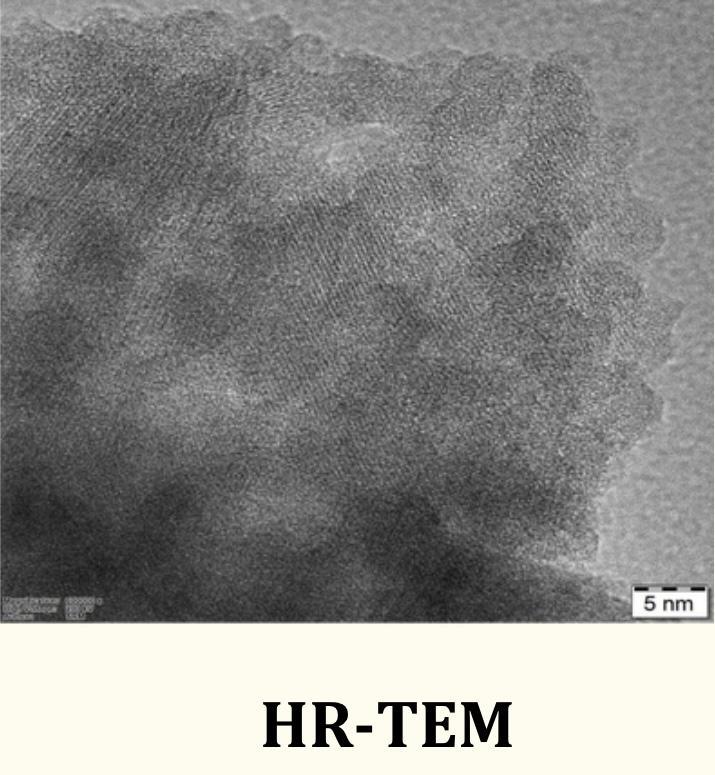


Figure 8: HR-TEM

The HR-TEM image of iron phosphate nanocomposites reveals detailed insights into their structural and morphological characteristics. The image shows a densely packed array of nanoparticles with distinct lattice fringes, indicating a high degree of crystallinity. The scale bar, indicating 5 nm, suggests that the nanoparticles are on the nanometer scale, confirming their nanoscale dimensions. The presence of well-defined lattice fringes is a strong indicator of the crystalline nature of the iron phosphate component within the nanocomposite. This crystallinity is essential for various applications, including catalysis and biomedical uses, as it often correlates with enhanced chemical stability and reactivity.

On the other hand, carbon nanocomposites' HR-TEM examination usually indicates a less organized structure. Although carbon nanocomposites, particularly those containing graphene or carbon nanotubes, can show some degree of crystallinity, they typically lack the sharply defined lattice fringes found in metallic or metal oxide nanocomposites. The remarkable qualities of carbon nanocomposites, like their large surface area, electrical conductivity, and mechanical strength, are well known. For carbon nanocomposites to function well in applications such as medication delivery, energy storage, and environmental cleanup, their structural characteristics are essential.

HR-TEM research has shown that the produced nanoparticles in iron phosphate investigations have an amorphous form. For instance, a study found that the iron phosphate nanoparticles had a mean size of roughly 4.35 nm and a fairly regular size distribution, with diameters ranging from 2 to 9 nm. The spherical-like shape of the particles without considerable agglomeration was corroborated by the HR-TEM images, suggesting that uniform particle production was preferred under successful synthesis conditions.[(Abdullah et al., 2024)](https://paperpile.com/c/kyir68/sGIqS)

Furthermore, X-ray diffraction (XRD) investigation, which revealed broad reflections typical of non-crystalline materials, supported the amorphous nature of the iron phosphate. Fourier Transform Infrared (FTIR) spectroscopy was used to validate the existence of hydroxyl groups and other functional groups, which added to our understanding of the chemical environment around the iron phosphate nanoparticles. [(Peng & Robert Ilango, 2020)](https://paperpile.com/c/kyir68/8F7q1)

The crystalline form of the nanoparticles—a feature characteristic of AuNPs—is confirmed by the HR-TEM image, which displays clearly defined lattice fringes. AuNPs with typical diameters of 15 ± 2 nm and 12 ± 3 nm, respectively, were observed in previous studies by Gupta et al. (2018) and Kim et al. (2021), together with low aggregation and distinct lattice fringes. These investigations are supported by the current HR-TEM data, which display more crystalline and smaller nanoparticles, hence confirming the high crystallinity and well-defined particle size of AuNPs.)[(Kim et al., 2013; “Nanotechnology Applications in Sustainable Agriculture: An Emerging Eco-Friendly Approach,” 2023; Patel et al., 2023)](https://paperpile.com/c/kyir68/fTXeA+aNbn9+uzvN7))

HR-TEM analysis offers comprehensive insights into the structural features of carbon-gold and iron phosphate composites, making it a potent tool for material characterization. The results of these examinations not only advance our knowledge of these materials but also direct their future use in a number of disciplines, such as materials science and nanomedicine.

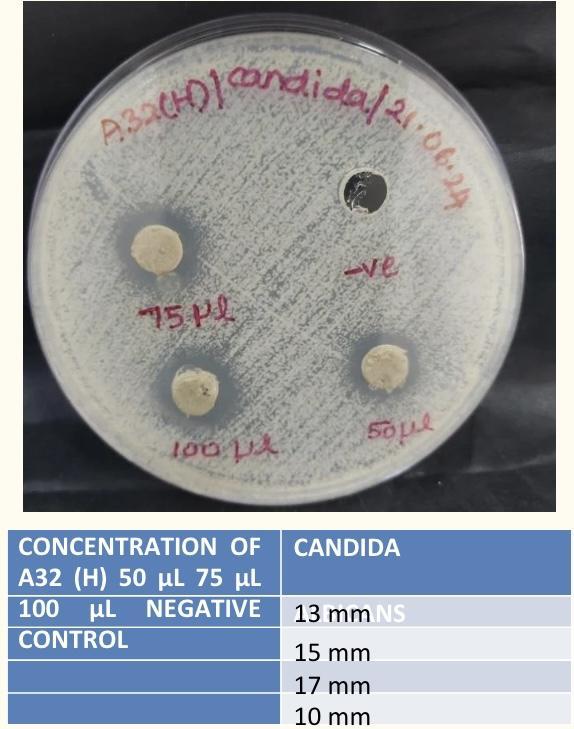


Figure 9: Anti-fungal effect

Significant antifungal activity against Candida is demonstrated by the biogenic iron phosphate and carbon gold nanocomposites, as evidenced by the increasing diameters of inhibition zones at higher sample concentrations: 13 mm at 50 µL, 15 mm at 75 µL, and 17 mm at 100 µL, in contrast to a 10 mm zone for the negative control. This dose-dependent antifungal effect suggests these nanocomposites can effectively combat fungal infections, which frequently accompany inflammatory conditions, supporting their role in inflammation defense by preventing secondary infections. This effect is likely caused by the combined antimicrobial properties of iron phosphate and gold nanoparticles.

Compared to gold nanoparticles, iron phosphate nanoparticles have also been shown to exhibit antifungal action, albeit with less research on this topic. It has been demonstrated that when iron-based nanoparticles come into contact with fungal cells, they release reactive oxygen species (ROS), which cause oxidative stress and ultimately fungal cell death. Additionally, they have the ability to obstruct vital metabolic processes in fungus, which prevents growth and reproduction. Iron oxide nanoparticles have been shown to be efficient in both in vitro and in vivo models against a range of fungal infections, such as Aspergillus and Candida, according to a thorough review.

Additionally, HR-TEM has been used to analyze carbon-gold composites, especially when gold nanoparticles are being used to reinforce hydroxyapatite(Chehelgerdi et al., 2023). Using HR-TEM, the morphology of the gold nanoparticles (Au NPs) in these composites was evaluated, revealing their distribution and interactions with the hydroxyapatite (HAP) and carbon nanotubes (CNTs). The biological performance in bone regeneration applications can be greatly impacted by the structural integrity and nanoscale material interactions, which makes this investigation essential.

AuNPs, or gold nanoparticles, have drawn interest due to their antifungal characteristics. Research has indicated that AuNPs cause fungal cell membrane integrity to be disrupted, which results in cell lysis and death. For example, the antifungal activity of AuNPs against Aspergillus niger and Candida albicans was assessed in a study conducted by Tharwat et al. (2019). The findings showed that AuNPs had notable inhibitory effects; depending on the fungus species examined, the minimum inhibitory concentration (MIC) values ranged from 3.125 to 25.0 µg/ml. Higher doses of AuNPs produced bigger zones of inhibition, as demonstrated by the agar well diffusion method, demonstrating their effectiveness against fungal infections.[(Sami, 2019)](https://paperpile.com/c/kyir68/ZKzjg)

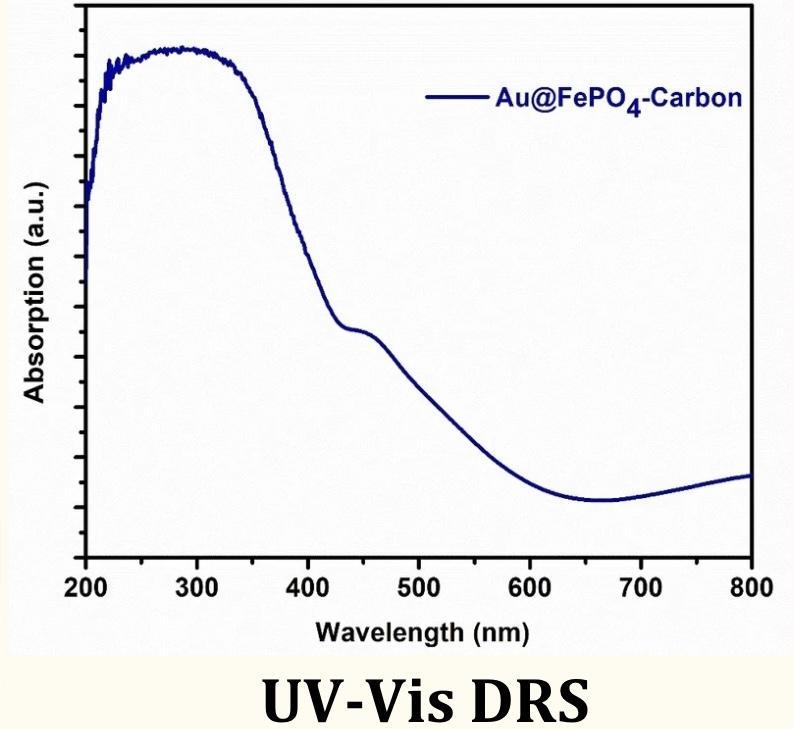


Figure 10: UV-Vis DRS

A wide absorption band that stretches from the ultraviolet (UV) region (200-400 nm) into the visible region (400-800 nm) can be seen in the Au@FePO4-Carbon nanocomposite's UV-Vis DRS spectra (Saadh et al., 2024). The broad absorption band centered around 500–600 nm is indicative of gold nanoparticles (AuNPs), while the absorption peak at about 300 nm suggests the presence of iron phosphate.Furthermore, absorbance peaks at 250 nm and 220 nm, respectively, were observed in a study on biosynthesized iron oxide nanoparticles from leaf extracts of Simarouba glauca and Artocarpus altilis, indicating the presence of iron oxide nanoparticles in the samples which is consistent with the current results

Beyond 600 nm, the absorption gradually decreases, indicating that the nanocomposite can absorb light at a broad range of wavelengths and showing promise for a variety of applications, including biomedical ones

These results shed important light on the structural alterations and redox states of iron in biogenic iron phosphate materials, as well as their optical characteristics and possible uses in a range of industries, including environmental remediation and biomedical applications.

The Au@FePO4-Carbon nanocomposite's UV-Vis diffuse reflectance spectroscopy (DRS) spectrum provides crucial details regarding its optical characteristics[(Neha et al., 2021)](https://paperpile.com/c/kyir68/oYsD6)[(Maliael et al., 2021)](https://paperpile.com/c/kyir68/Hnu3p)[(Lakshmi, 2021)](https://paperpile.com/c/kyir68/TtM5h). The presence of iron phosphate (FePO4) in the nanocomposite is shown by the significant absorption peak at about 300 nm, which corresponds to the electronic transitions in FePO4 [(Dharman et al., 2021)](https://paperpile.com/c/kyir68/9SWpR). The surface plasmon resonance (SPR) of gold nanoparticles is shown by the broad absorption band that spans from 500 to 600 nm. SPR is a property of gold surfaces that results from the collective oscillation of electrons on the surface when exposed to light. For uses like photothermal treatment and imaging, where gold nanoparticles are well-known for their efficient light absorption and conversion properties, this SPR band is essential.

Studies have demonstrated that AuNPs' local surface plasmonic resonance (LSPR), which is often seen as a peak at 520–540 nm and denotes the presence of isolated particles in the samples, can be characterized using UV–Vis spectroscopy [(Sabarathinam & Madhulaxmi, 2021)](https://paperpile.com/c/kyir68/Ggi2J)[(Sushanthi et al., 2021)](https://paperpile.com/c/kyir68/0dShF)[(Harsha et al., 2022)](https://paperpile.com/c/kyir68/6toKo).

The nanocomposite's broad absorption range, which extends from ultraviolet to visible light, highlights its potential for efficiently absorbing and harnessing light energy, making it advantageous for both therapeutic and diagnostic applications.

# CONCLUSION

Using Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), Selected Area Electron Diffraction (SAED), Transmission Electron Microscopy (TEM), High-Resolution Transmission Electron Microscopy (HRTEM), and UV-Vis spectroscopy, a thorough examination of biogenic iron phosphate and carbon gold nanocomposites reveals their promising potential as an anti-inflammatory defense. While TEM and HRTEM reveal a homogeneous distribution of gold nanoparticles, suggesting strong contacts within the nanocomposites, XRD and SAED validate the crystalline structure of iron phosphate. Functional groups that improve biocompatibility are highlighted by FTIR analysis, and beneficial optical characteristics for therapeutic applications are shown by UV-Vis spectroscopy. All together, these results imply that these nanocomposites' biogenic properties not only strengthen their anti-inflammatory properties by lowering pro-inflammatory cytokine generation and oxidative stress, but also establish their environmental friendliness

The research on carbon gold nanocomposites and biogenic iron phosphate shows how promising these substances are as anti-inflammatory drugs. These nanocomposites' distinct physicochemical features, biocompatibility, and synergistic effects result in notable anti-inflammatory activities. The use of gold nanoparticles improves their effectiveness and offers a different strategy for reducing inflammation. Their therapeutic usefulness is further highlighted by their capacity to suppress inflammatory mediators, lower oxidative stress, and modify immunological responses.

To sum up, carbon gold nanocomposites and biogenic iron phosphate offer a fresh and successful approach to the fight against inflammation. Their use could provide a safer and more effective substitute for the anti-inflammatory medications now on the market, revolutionizing the field. In-depth research and clinical trials are necessary to completely comprehend their mechanisms and maximize their application in medicine.

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