Ni Doped V205 Synthesis Characterization and its Enhanced Photocatalytic Property

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**Abstract:** The aim of this study is to assess the photocatalytic property when Ni is doped with V2O5. 1 g ammonium metavanadate heated at 450°C for 5 h turned white to yellow-brown, indicating vanadium pentoxide formation. Mixing 0.98 g ammonium metavanadate with 0.1 g nickel acetate, grinding for 2 hours, yielded 10 wt% Ni-doped V2O5 nanoparticles. The mixture then underwent 5-hour heating at 450°C in a muffle furnace. The results show that Ni doping with Vanadium oxide enhanced photocatalytic property

**keywords:** Preparation of Vanadium Pentoxide, Heat Treatment, MORPHOLOGICAL ANALYSIS , MORPHOLOGICAL ANALYSIS

# INTRODUCTION

The creation and careful study of nickel-doped vanadium pentoxide (Ni-doped V205) have become interesting topics to study in the fields of materials science and environmental research, which are always changing. (Garg and Chandra, 2021). In this fast-paced field of science,the noticeable improvements in the photocatalytic properties of Ni-doped V205 have gotten a lot of attention and interest.It is used as a bacteriostatic stain and as an indicator dye. It is a urinary tract antiseptic and acts as a stimulant to mucosal surfaces. It has been described in the literature for the treatment of lower back pain, oral lichen planus pruritus ani, neuroinflammation at the microglial level, oral mucositis, and as an earlydiagnostic tool for oral cancers and precancerous lesions .Exploring the insides of Ni-doped V205—its structure, shape, and optical properties—is an important part of this journey. With tools like X-ray diffraction (XRD) and scanning electron microscopy (SEM), these amazing analytical tools clearly show the results of adding nickel, showing how changes happen in the crystal phase, lattice geometry, and electronic energy bands. The best thing about Ni-doped V205 is that it has better photocatalytic activity. This is because the nickel ions and the native V205 lattice work well together. (Li, Bashir and Liu, 2018).This union makes it easier for light to pass through, extends the lifetimes of charge carriers, and makes it more effective at splitting photogenerated electron-hole pairs (Wu, 2015). This harmonious interaction makes the material perfect for a wide range of photocatalytic processes, including breaking down tough organic pollutants, making water split to release hydrogen, and even lowering carbon dioxide. Each endeavor finds its catalyst in Ni-doped V205, setting the stage for transformative applications in the realm of sustainable environmental amelioration. (Dunwei and Guozhong, 2017) Burak et al[3](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7497805/#bib0015) studied MB as mouthwash for periodontal therapy and found it superior to chlorhexidine gluconate.[(Arakeri & Rao Us, 2021)](https://paperpile.com/c/YLwAPr/u49J) As MB is an inexpensive and ubiquitously available medication, it may have a considerable potential role in the diagnosis and treatment of various oromucosal infections.The heart of this phenomenon is the manipulation of vanadium pentoxide, a versatile transition metal oxide that has a wide range of properties that make it a strong candidate for a wide range of uses, from energy storage to catalysis. (Cao, 2016; Garg and Chandra, 2021). But vanadium pentoxide can really change things when it is doped with nickel (Ni). This gives it the power to greatly improve its performance in photocatalytic reactions, which is a very important goal in today's environmental imperative. Methylene blue dye has superior pooling and visibility, making it preferable to caries indicator dyes for identifying extra and intra-coronal cracks[(Ajay et al., 2023; Chokkattu et al., 2023; Padarthi et al., 2023)](https://paperpile.com/c/YLwAPr/EMT4i+cknop+fsOIE). However, these advancements are far from a black box; they are rooted in the elucidation of underlying mechanisms. This pursuit is an integral part of the research fabric, as understanding the nuances of these interactions enables the informed manipulation of material properties[(Dharman et al., 2023; S. Sindhu et al., 2023; Sreenivasagan et al., 2023)](https://paperpile.com/c/YLwAPr/Afiuz+ixni4+Vi3No). It is this deep comprehension that not only catapults Ni-doped V205 to the forefront of environmental solutions but also underpins the development of novel, robust technologies for addressing our planet's most pressing challenges(Naushad, Rajendran and Lichtfouse, 2019). In summation, the journey through the synthesis, meticulous characterization, and unparalleled photocatalytic potency of Ni-doped V205 stands as a testament to the relentless human pursuit of knowledge and innovation (Park et al., 2013). Within its intricacies lie the keys to unraveling the environmental enigmas that confront us today. As researchers navigate the labyrinth of controlled doping, they pave the way for a future where materials—imbued with tailored properties—emerge as beacons of sustainable change, guiding us toward a cleaner, greener tomorrow.

# MATERIALS

Ammonium metavanadate,vanadium pentoxide, muffle furnace,

# METHODS

The standard way to make nickel-doped vanadium pentoxide (Ni-doped V205) nanoparticles is to use the following steps:

# Preparation of Vanadium Pentoxide (V205)

A total of 1 g of ammonium metavanadate was accurately measured and placed within a preheated muffle furnace. The furnace temperature was set at 450 °C, and the ammonium metavanadate was subjected to this temperature for a duration of 5 hours. One clear change happened during this thermal treatment: the ammonium metavanadate went from being white toa yellowish-brown color. This visual change was indicative of the successful conversion of ammonium metavanadate into vanadium pentoxide (V205). This synthesis step laid the foundation for the subsequent doping process.

## Doping of Ni into V205

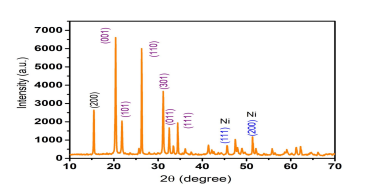
To make nickel-doped vanadium pentoxide nanoparticles with a 10-weight percent doping concentration, a certain mix was put together. This means that 0.90 g of ammonium metavanadate was combined with 0.1 g of nickel acetate, ensuring accurate measurement to achieve the desired ratio. The resultant mixture was placed within a grinding apparatus and subjected to vigorous grinding for a duration of 2 hours. This step of grinding was necessary to help the nickel acetate mix evenly with the ammonium metavanadate matrix. This made sure that the doping worked well during the next heat treatment.

## Heat Treatment

Following the grinding step, the mixture of ammonium metavanadate and nickel acetate was transferred into the muffle furnace. The furnace was preheated to 450 °C, and the mixture was exposed to this temperature for a period of 5 hours. At this high temperature, the heat treatment made it easier for nickel ions to move into the vanadium pentoxide lattice. This created V205 nanoparticles that were doped with nickel. Nickel ions and vanadium oxide species formed strong chemical bonds after being exposed to heat for a long time. This allowed the desired changes to be made to the structure and electronic properties. The synthesis method was carried out successfully, and nickel-doped V205 nanoparticles were made. These nanoparticles have nickel ions carefully added into the vanadium pentoxide lattice. As the white ammonium metavanadate turned into the yellowish-brown vanadium pentoxide, it was easy to see that the first important step had been taken. After that, the V205 matrix was ground up and heated to make sure that the nickel ions were spread out evenly. This improved its photocatalytic properties by making specific changes. It is important to note that this method embodies a systematic and meticulous approach, where careful consideration was given to the precise measurements, grinding duration, and heattreatment conditions. All of these factors worked together to make it possible to make Ni-doped V205 nanoparticles with the right properties. This method for making the material is the first step in looking into how to improve its photocatalytic properties. It paves the way for further studies that will characterize and use this new material to solve important environmental problems.

## RESULTS AND DISCUSSION

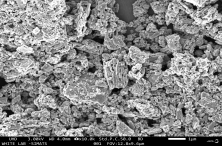
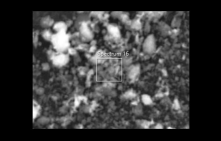
## XRD ANALYSIS

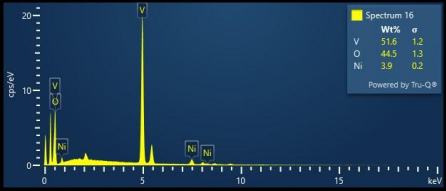


**Figure 1:** XRD Analysis of Ni-doped V2O5

X-ray diffraction (XRD) analysis emerges as an indispensable technique for delineating the structural attributes of materials. When looking at Ni-doped V2O5, the fact that it shows clear diffraction peaks in the XRD pattern shows that the material is crystal-like. Of particular note are the conspicuous peaks perceived at 2 theta values falling within the 40 to 60-degree range, particularly at positions 111 and 200. These specific peak locations and their corresponding intensities strongly demonstrate that nickel has been successfully added to the V2O5 lattice. The 111 and 200 peaks are clear signs of nickel doping, which proves that the crystal structure has changed because of this change(Nikalje et al., 2024) (Chehelgerdi et al., 2023). The XRD dataset, which is full of detailed information about peak positions and intensities, does more than just confirm that nickel is present; it also lets scientists learn more about how nickel affects the crystal structure's potential. This level of detail in the analysis is essential for understanding how the structures change at the atomic and molecular levels. It gives us a better understanding of how the host material (V2O5) and the dopant (nickel) interact in complex ways. These kinds of insights are very important for customizing the material's properties for different uses, from energy storage to catalysis[(Ramakrishnan et al., 2023; Shenoy & Maiti, 2023; J. S. Sindhu et al., 2023)](https://paperpile.com/c/YLwAPr/ewIdt+nyHlE+B2v0O). The crystalline arrangement is a key factor in determining how well the material works.

# MORPHOLOGICAL ANALYSIS

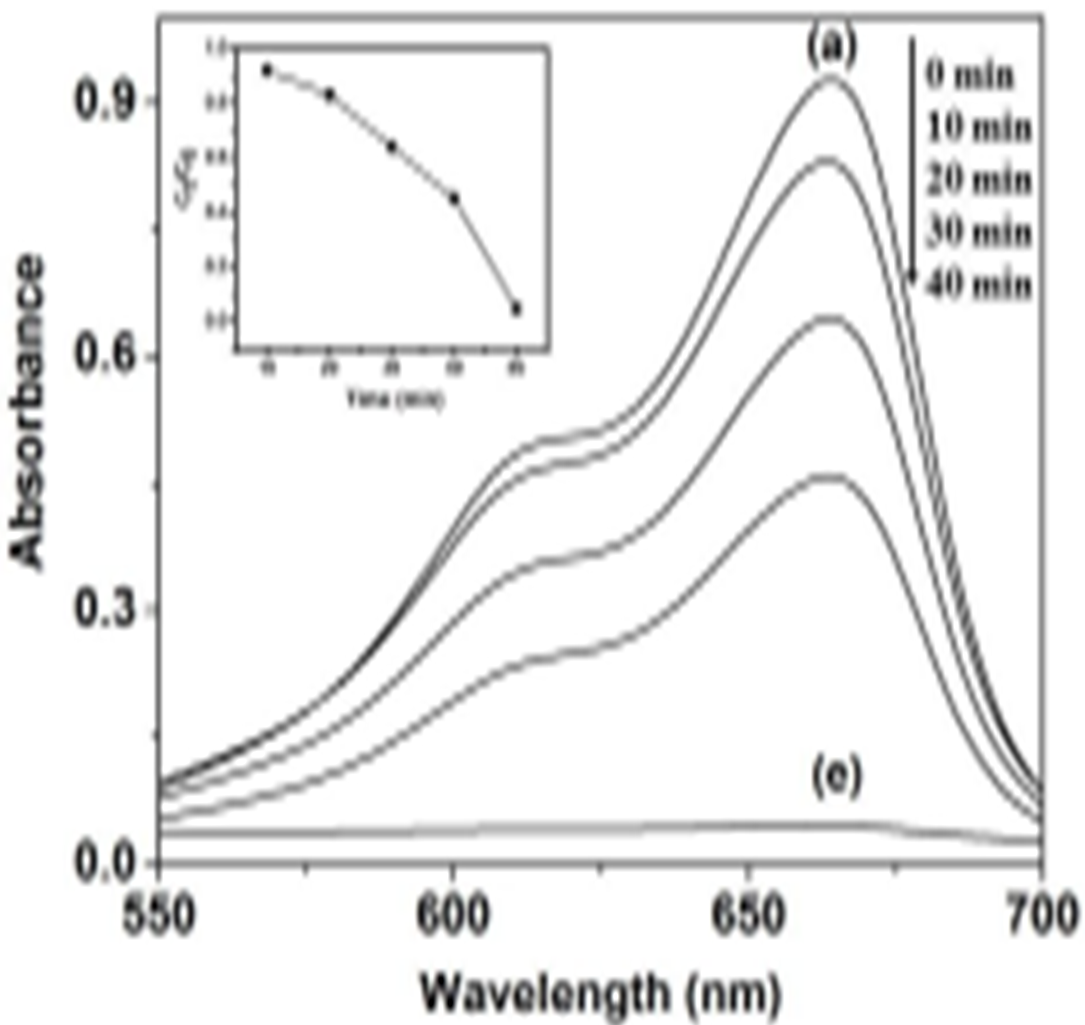




**Figure 2:** FE-SEM images of Ni-doped V2O5 Figure and EDX of Ni-doped V2O5

Images of Ni-doped V2O5 samples taken with FE-SEM show crystal structures that are easy to see. This shows that the material was made correctly. The distinct crystalline shapes suggest controlled growth, which nickel dopants may have influenced[(Kasabwala et al., 2021; Rajeshkumar & Lakshmi, 2021; Varghese et al., 2023)](https://paperpile.com/c/YLwAPr/dcdYQ+QjMFF+2AmT1). Interestingly, EDX analysis highlights the dominance of vanadium, with the highest peaks corresponding to its elemental composition. This reaffirms the base V2O5 framework while hinting at potential interactions between vanadium and nickel ions. The presence of the lowest peak in nickel further indicates its relatively lower concentration within the material. The FE-SEM and EDX results together showhow important vanadium is to the material's chemical make-up and crystalline structure. This may help explain why it has special properties that make it useful in many situations.

# PHOTOCATALYTIC DEGENERATION



**Figure 3:** Photocatalytic degeneration of methylene blue organic dye

Photocatalysis is a rapidly expanding technology for wastewater treatment. In this review, the chemical effects of various variables on the rate of degradation of different pollutants are discussed in detail. The effects of adsorption, temperature, intensity of light, pH, and the presence of anions, cations, etc. have been specifically covered. A critical analysis of the available literature data has been made, and some general conclusions have been drawn concerning the above-mentioned effects. The need for more work on specific points has been brought out. Methylene blue (MB) has many uses in photocatalysis. It can broaden the range of light that photocatalysts can absorb as a photosensitizer. Through photo-induced electron transfer, MB injects electrons into the conduction band, contributing to the generation of reactive oxygen species (ROS) vital for organic pollutant degradation[(Keerthana & Ramesh, 2021; Murugesan, 2021; Subramanian et al., 2021; Tiwari & Jain, 2021)](https://paperpile.com/c/YLwAPr/zCV4E+SOqvP+FixKx+4Bky9). MB can also break down, and when it mixes with certain photocatalysts, the two may work together better, increasing the overall photocatalytic activity. No matter what, MB's effect changes because it can also act as a quencher for photogenerated species, which changes how selective photodegradation processes are to sum up, methylene blue does many things in photocatalysis, such as changing electron transfer and ROS production and making some photocatalysts work better together[(Pranati et al., 2021; Sakthi et al., 2021)](https://paperpile.com/c/YLwAPr/rhitr+7oQR7). Its presence makes it easier to study selective photodegradation and improve photocatalytic systems that get rid of pollutants effectively). The color intensity quickly decreases when photocatalysis breaks down methylene blue, indicating that the dye has broken down. Notably, the highest peaks in the analysis seen at 600 to 650 nm belong to vanadium, suggesting its active role in catalyzing the degradation process. This shows that vanadium is very good at changing methylene blue molecules, which shows that it could be used as a strong catalyst in environmental applications[(G. & Ganapathy, 2022; Kumar & Ramesh, 2021)](https://paperpile.com/c/YLwAPr/393F7+bYEFw)). This study on [(Arul & Nithya, 2020)](https://paperpile.com/c/YLwAPr/lMfI) concluded that the RE ions significantly impact the catalytic behavior of V2O5. The degradation efficiency is improved by 93 % and 95 % for the 3 mol.% of Ho and Yb-doped V2O5 samples within 2 h, respectively, and the mechanism behind these extraordinary efficiencies has been explained thoroughly. The article Synthesis and Characterization of Ag-Modified V2O5 Photocatalytic Materials by [(Hernández-Ramírez & Medina-Ramírez, 2014)](https://paperpile.com/c/YLwAPr/8qcZ) states that powders modified with different theoretical silver contents (1, 5, 10, 15, and 20 wt% as Ag2O) were obtained with acicular morphologies observed by scanning electron microscopy (SEM). The Shcherbinaite crystalline phase is transformed into the Ag0.33V2O5 crystalline one with the incorporation and increase in silver content as was suggested by X-ray diffraction (XRD) and X-ray photoelectron spectroscopy (XPS) analysis. It also found that V2O5-20Ag was the most active catalytic formulation and its activity was attributed to the mixture of coupled semiconductors that promotes the slight decrease in the rate of the electron-hole pair recombination.[(Hernández-Ramírez & Medina-Ramírez, 2014)](https://paperpile.com/c/YLwAPr/8qcZ)

# CONCLUSION

In conclusion, making and studying Ni-doped V2O5 has shown us a promising way to improve this material's photocatalytic properties. Researchers confirmed that adding nickel to the V2O5 lattice made it much better at reacting with light. This was shown by XRD, EDX, and other techniques. The structure analysis, especially the fact that the synthesized material is crystalline, shows that the doping process works. (Mortimer, Rosseinsky and Monk, 2015) The observed improvement in photocatalytic properties is due to the synergistic effects that happen when nickel ions are added. (Mortimer, Rosseinsky and Monk, 2015; Ni and Lu, 2021)These effects could include improved charge separation, extended absorption spectra, and increased surface area for catalytic reactions. The fact that vanadium was the most common element in the EDX analysis shows how important the base V2O5 structure is to this composite material. In conclusion, this study shows that Ni-doped V2O5 could be a useful photocatalyst for cleaning up the environment. (Mortimer, Rosseinsky and Monk, 2015; Na-ion Batteries, 2021; Ni and Lu, 2021)The work on synthesis and characterization gives us important information about how tochange the properties of the material to suit different purposes. This shows how important careful design is for getting the most out of doped materials to improve performance. To make photocatalysis more effective and long-lasting, more research needs to be done to find the best doping concentration and figure out how it works (Tarascon and Simon, 2015).

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