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Antibacterial Activity of V_2O_5 Nanoparticles

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Short Research Article

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ABSTRACT

The chemical synthesis of vanadium pentoxide nanoparticles (V_2O_5 NPs) is presented in this article. The formation of V_2O_5 NPs is confirmed by the 508 cm^{-1} band visible in the Fourier-transform infrared spectrum. According to the scanning electron microscopy analysis, the 40–50 nm-sized V_2O_5 NPs resemble sponges. The size of V_2O_5 NPs is in between 33.72 and 52.78 nm, as shown by XRD. The antibacterial capabilities of V_2O_5 NPs were evaluated against *Staphylococcus aureus* and *Bacillus cereus.* Moderate antibacterial activity is exhibited by the synthesized V_2O_5 NPs.

Keywords: V2O5 NPs; chemical synthesis; XRD; antibacterial activity.

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1. INTRODUCTION

Metal nanoparticles have a large fraction of surface atoms and a high specific surface area. Scientists are becoming more interested in nanoparticles because of their distinctive physicochemical qualities, which include catalytic activity, optical, electrical, antimicrobial, and magnetic qualities. They are also being synthesized using revolutionary technologies (Abd-Alghafour 2016, Mu et al. 2015, Alwin David and Vedhi 2017, Alwin David and Vedhi 2022, Alwin David et al. 2017, Alwin David and Vedhi 2017, Alwin David and Subramanian 2021, Alwin David et al. 2017, Alwin David and Revathi 2018, Alwin David and Subramanian 2021, Alwin David and Ram Kumar 2022, Subramanian and Alwin David 2024, Subramanian and Alwin David 2024, Subramanian and Alwin David 2024).

Vanadium pentoxide is a brownish-yellow solid, although it has a bright orange color when it is first precipitated from an aqueous solution. It is both an oxidizing agent and an amphoteric oxide due to its high oxidation state. Vanadium pentoxide (V_2O_5) is an electro-chromic form that is thermodynamically stable.

The nanoparticles of vanadium pentoxide display a noteworthy thermochromic characteristic. Vanadium pentoxide finds widespread application in industrial chemical reactions as a catalyst. Additionally, V_2O_5 thin films can be utilized in smart windows, reflectance mirrors, optical filters, and surfaces with adjustable emittance to regulate the temperature in spacecraft.

2. MATERIALS AND METHODS

2.1 Chemicals Used

Vanadium pentoxide, ammonium sulfate and ammonium hydroxide used for the synthesis of V_2O_5 NPs were purchased from nice chemicals.

2.2 Synthesis of V_2O_5 Nanoparticles

For the synthesis of V_2O_5 NPs, a solution of 1.5 M ammonium sulfate which consisted of 0.75 M vanadium pentoxide was used. 50 mL of aqueous solution in total was heated to 75 degrees Celsius and kept there for ninety minutes. Subsequently, a 2.5 M ammonium hydroxide solution was added dropwise while being stirred rapidly. After gathering the precipitate, it was periodically cleaned with ethanol and distilled water before being dried at 50 to 55°C. The sample was calcined at 400°C for four hours before being gradually cooled to room temperature.

2.3 Characterization

FTIR measurements were performed on the nanoparticles using KBr pellets by a SHIMADZU FTIR 8400S spectrometer. The average grain size was determined by XRD performed using X-ray diffractometer. The polymer film surface morphology was studied by computer controlled Hitachi S300 H SEM. Thermal analysis of nano composites were carried out using Perkin Elmer Diamond TG/DTA.

3. RESULTS AND DISCUSSION

Characterizations and applications of V_2O_5 NPs are described below by various techniques. The results obtained are discussed in detail as follows:

3.1 FTIR Analysis

FTIR spectrum of V_2O_5 nanoparticles exhibited three characteristic vibration modes: V=O vibrations at 1030 cm^{-1}, the V-O-V symmetric stretch around 508 cm^{-1} and the V-O-V asymmetric stretch at 770 cm^{-1}.

3.2 X-ray Diffraction Analysis

The crystallite size can be evaluated using Debye-Scherer equation:

$$D = \frac{k \times \lambda}{\beta \cos\theta}$$

where D is the thickness (diameter) of the particle, λ is the wavelength of the X-ray beam, β is the full width at half maximum (FWHM) of the peak position in radians, k is the shape factor (0.94) and θ is the Bragg diffraction angle at peak position.

An average crystallite size of 40.32 nm is obtained from the Debye-Scherer formula analysis of the XRD data. According to the Scherrer formula, the crystallite size of the V_2O_5 NPs is expected to be between 33.72 and 52.78 nm.

3.3 Scanning Electron Microscopy (SEM)

The surface morphology and approximate size of the V_2O_5 NPs are revealed by the SEM. The

SEM picture demonstrates the sponge-like morphology of the V_2O_5 NPs. The V_2O_5 NPs measured by SEM had a size between 40 and 50 nm.

3.4 Thermal Behavior of -V_2O_5 NPs

According to the exothermic peak in the DTA curve of V_2O_5 NPs, the weight loss up to 500ºC indicates the full combustion of the V_2O_5 NPs, while the weight loss at 100ºC indicates the elimination of the reversibly bound water. The DTA curve indicates the crystallization of this phase, with a somewhat abrupt endothermic peak at 460ºC.

3.5 Anti-Bacterial Activity of V_2O_5 NPs

The bacteria *Bacillus cereus* and *Staphylococcus aureus* were the targets of antibacterial action. The findings of the antibacterial activity showed that all of the V_2O_5 NPs moderately inhibited the *Staphylococcus aureus* and *Bacillus cereus* bacterial strains.

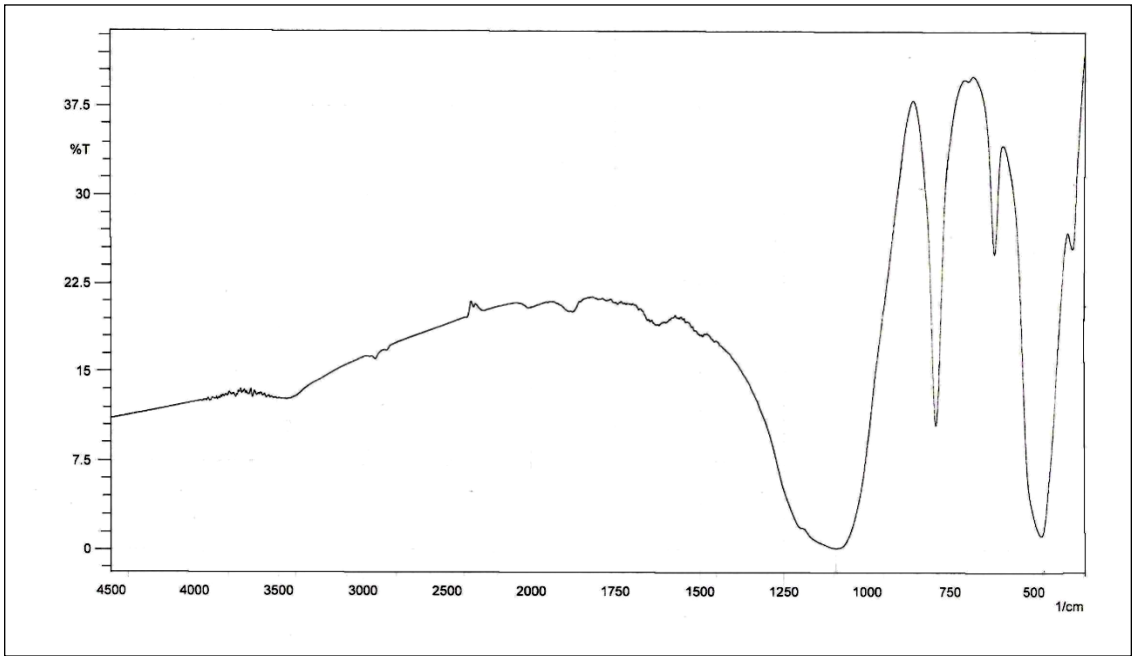

Fig. 1. FTIR spectrum of V_2O_5 NPs

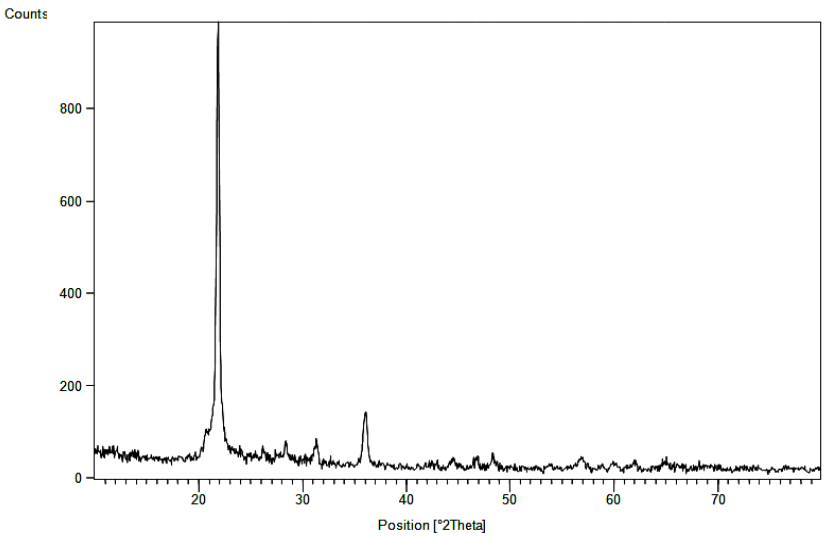

Fig. 2. XRD behavior of V_2O_5 NPs

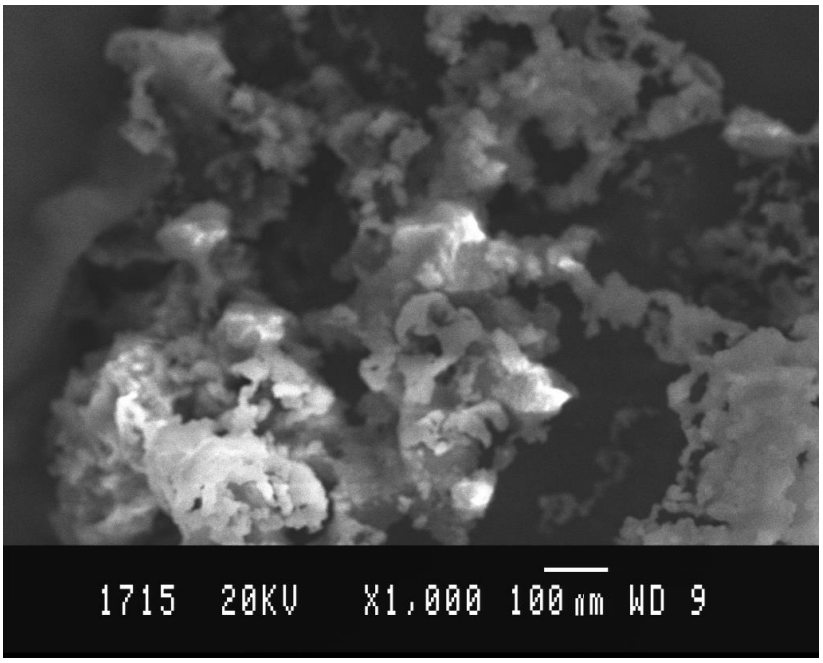

Fig. 3. SEM behavior of V_2O_5 NPs

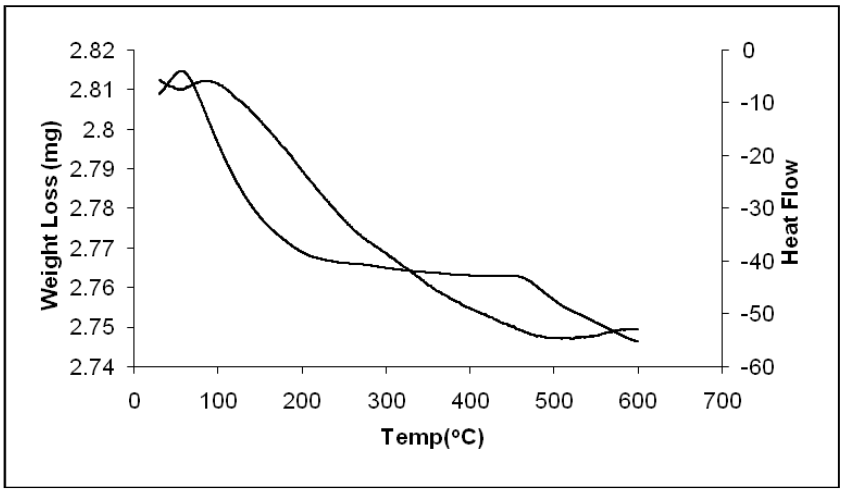

Fig. 4. TG/DTA curve of V_2O_5 nanoparticle

Table 1. Anti-bacterial Activity of V_2O_5 NPs

Test Pathogens	Zone of Inhibition (ZOI) in mm	
	Sample	Standard
Bacillus Cereus	6	8
Staphylococcus aureus	13	17

4. CONCLUSION

Chemical synthesis of V_2O_5 NPs is demonstrated. Band at 508 cm^{-1} in FT-IR spectra confirm the presence of V_2O_5 NPs. The V_2O_5 NPs have average particle size of 40.32 nm, as evedent by XRD pattern. V_2O_5 NPs are found to be sponge like shape with variable size ranging from 40 to 50 nm, as evident by SEM. The V_2O_5 NPs exhibit moderate antimicrobial activity against *Bacillus Cereus* and *Staphylococcus aureus*.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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