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Morphological and Compositional Study of Nitrogen-TiO_2 Anchored Composite with Azo Dyes in a DSSC

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ABSTRACT

The efficiency of Dye-Sensitized Solar Cells (DSSCs) heavily relies on the structural and morphological characteristics of the photoanode materials [1]. This study investigates the effects of Nitrogen on TiO2 and the subsequent anchoring with two different Azo dyes RP and VC, to evaluate their impact on DSSC performance [2]. A comprehensive analysis was conducted using Scanning Electron Microscopy (SEM) to study the surface morphology of pure TiO2, Nitrogen TiO2 (N-TiO2), and N-TiO2 composites with RP and VC Azo dyes [3]. Energy-Dispersive X-Ray Spectroscopy (EDS) provided insight into the elemental composition and confirmed the successful incorporation of nitrogen into the TiO2 structure. The SEM images reveal significant morphological differences between the pure and N-TiO2 samples, as well as changes induced by the azo dye anchoring [4]. The Nitrogen incorporation was found to increase surface roughness and enhance dye adsorption [5]. A comparative analysis of the N-TiO2 composite with RP and VC azo dyes highlights variations in dye distribution and surface coverage, which may influence light absorption and charge transfer efficiency. The findings provide valuable insights into the design of optimized photoanode materials, aiming to improve the photovoltaic performance of DSSCs [6].

Keywords : Dye-Sensitized Solar Cells, Nitrogen-TiO2, Azo dyes, SEM analysis, EDS

I. INTRODUCTION

The pursuit of efficient and sustainable energy solutions has intensified research into advanced solar cell technologies, with Dye-Sensitized Solar Cells (DSSCs)[7]. A crucial factor in the efficiency of DSSCs lies in the properties of the photoanode material, which directly influences light absorption and electron transport [8]. Titanium dioxide (TiO_2) is widely utilized due to its high stability and suitable band gap, but its limited light absorption range has led to various modification strategies, including the incorporation of nitrogen to enhance its optical properties [9]. This study focuses on the comparison of pure TiO_2, Nitrogen-modified TiO_2 (N-TiO_2), and N-TiO_2 composites anchored with two Azo dyes RP and VC. Scanning Electron Microscopy (SEM) was employed to investigate the surface morphology of the samples, revealing the impact of Nitrogen incorporation and dye anchoring on the microstructure of TiO_2 [10]. Changes in surface texture and distribution were observed, indicating enhanced surface area and dye adsorption potential. Additionally, Energy-Dispersive X-ray Spectroscopy (EDS) was used to examine the elemental composition, confirming the successful incorporation of nitrogen into the TiO_2 lattice and providing insights into the uniformity of the composite structures [11]. This comparative analysis aims to highlight the morphological and compositional influences of Nitrogen and Azo dyes on the performance of DSSCs.

II. MATERIALS AND METHODS

2.1 Sample Preparation

The TiO_2 samples were synthesized using a controlled sol-gel method to ensure uniform particle size and desired morphology. The samples were ground into fine powders for analysis. The TiO_2 samples, including pure TiO_2 and Nitrogen-modified TiO_2, were then stored in a desiccator to prevent contamination.

2.2. Characterization Techniques

SEM Analysis

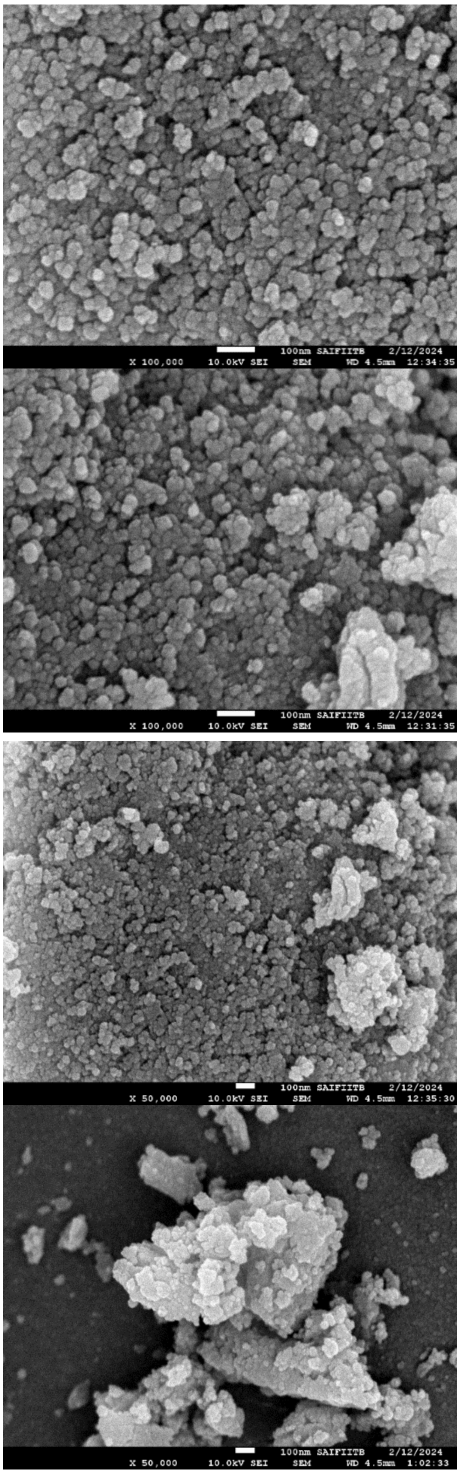
To investigate the surface morphology of the synthesized TiO_2 samples, Scanning Electron Microscopy (SEM) was performed at the SAIF Lab, IIT Bombay, using a high-resolution Field Emission Gun Scanning Electron Microscope (FEG-SEM). The SEM analysis was conducted using a JEOL JSM-7600F Field Emission Gun Scanning Electron Microscope (FEG-SEM), known for its ultrahigh resolution and versatile imaging capabilities. To ensure optimal image quality, TiO_2 samples, including pure and nitrogen-modified variants, were prepared as fine powders and evenly spread onto carbon adhesive tape mounted on aluminum stubs. A thin gold layer (~5 nm) was sputter-coated onto the samples to prevent charging, enhancing the SEI resolution, which reaches 1.0 nm at 15 kV. The JSM-7600F, with its wide magnification range (25x to 1,000,000x) and adaptable probe current, enabled detailed visualization of the samples' nanoscale features, crucial for accurate morphological and compositional analysis.

EDS Analysis

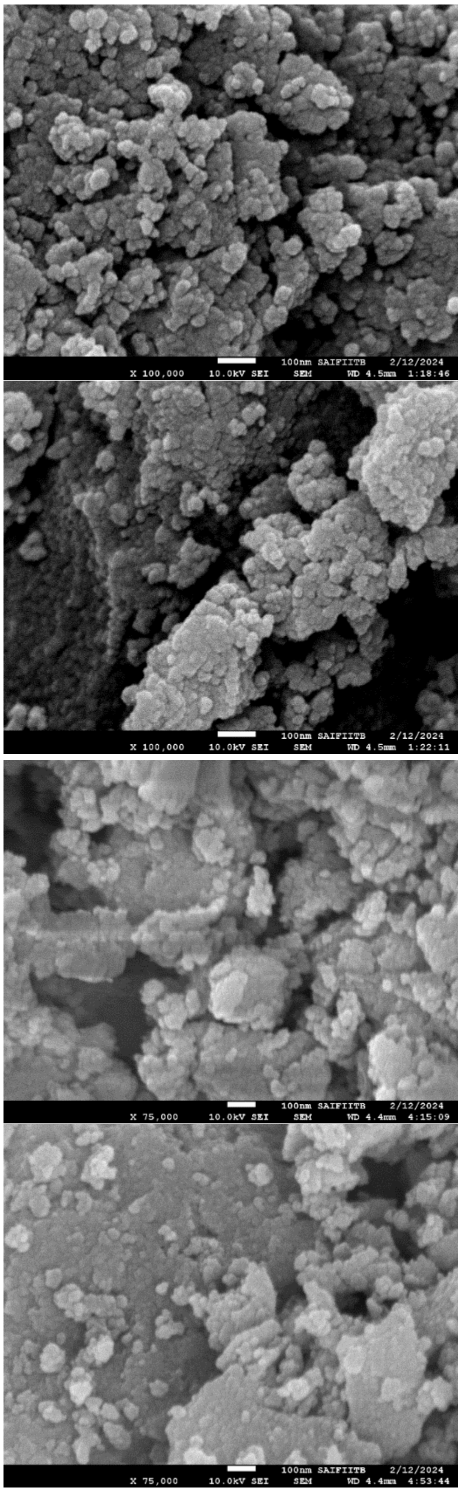
Energy-Dispersive X-ray Spectroscopy (EDS) was performed at the SAIF Lab, IIT Bombay, using an EDS detector integrated with the SEM system to analyze the elemental composition of the TiO_2 samples. The EDS spectra were collected at an accelerating voltage of 15 kV with a 60-120 second acquisition time, ensuring a high signal-to-noise ratio. Elemental maps were generated to visualize the distribution of titanium, oxygen, and nitrogen. Nitrogen incorporation was verified by detecting the nitrogen K-edge at 0.39 keV.

III. Results and Discussion

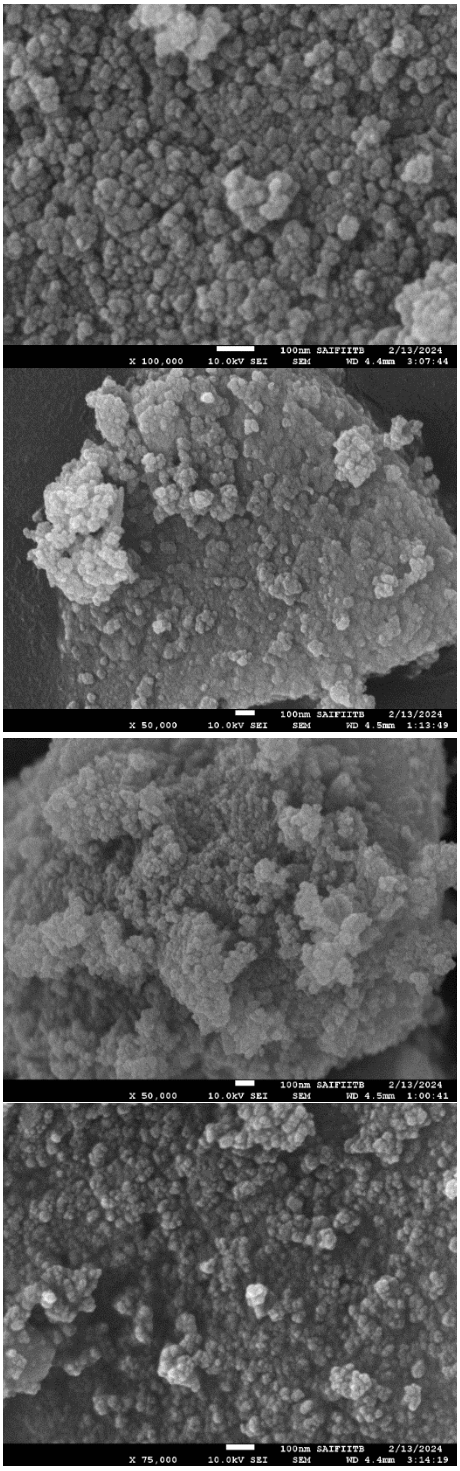
3.1 SEM Images of Pure TiO_2



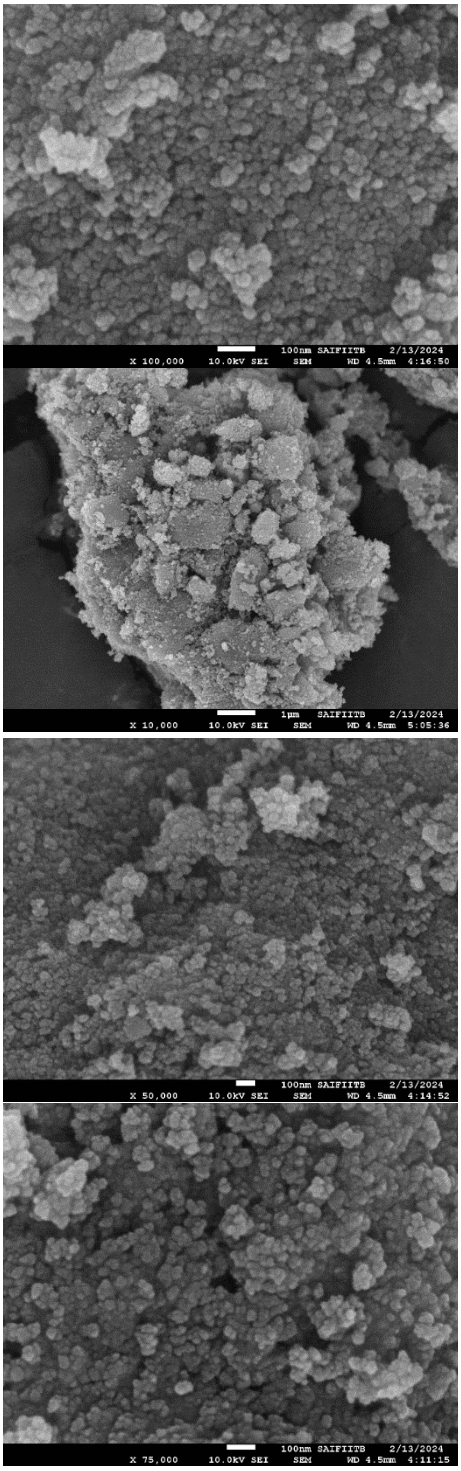
3.2 SEM Images of 8% N-TiO_2



3.3 SEM Images of 8% N-TiO_2 + VC



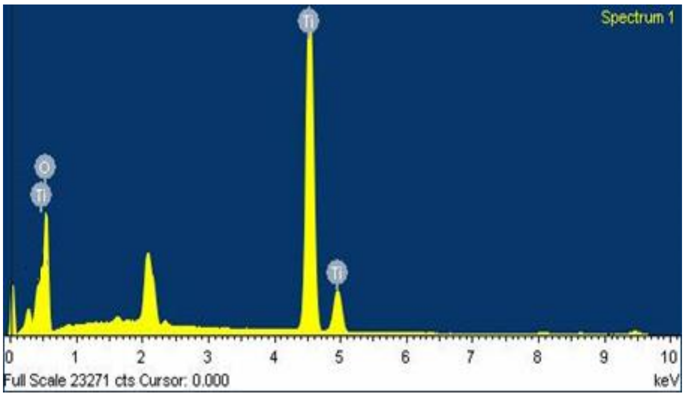
3.3 SEM Images of 8% N-TiO_2 + RP



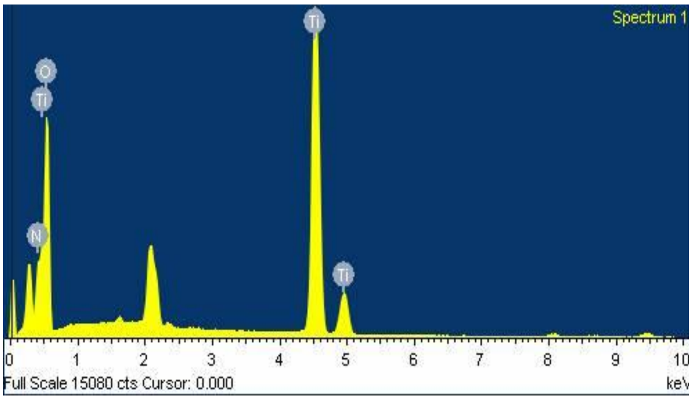
The SEM (Scanning Electron Microscopy) images of TiO_2, N-TiO_2, and their composites with azo dyes (VC and RP) reveal significant morphological differences that influence their performance in dye-sensitized solar cells

(DSSCs). The pure TiO_2 exhibits a distinct granular structure, while N-TiO_2 demonstrates a more porous morphology, which is beneficial for enhanced dye loading and electron transport. The composites with VC and RP show variations in surface texture and porosity, indicating effective integration of the dye molecules into the TiO_2 matrix. This morphological analysis underscores the importance of composite structure in optimizing the electronic properties and overall efficiency of DSSCs.

3.4 EDS Images of Pure TiO_2



3.5 EDS Images of 8% N doped TiO_2



The EDS (Energy Dispersive Spectroscopy) images of pure TiO_2 and N-TiO_2 composites provide critical insights into their elemental compositions. The EDS analysis confirms the successful incorporation of nitrogen into the TiO_2 lattice, as evidenced by the presence of nitrogen peaks in the N-TiO_2 spectrum. In contrast, the pure TiO_2 sample predominantly exhibits titanium and oxygen signals.

IV. CONCLUSION

The SEM and EDS analyses highlighted key differences among the TiO_2 samples. Pure TiO_2 showed a smooth surface, while nitrogen-modified TiO_2 (N-TiO_2) exhibited increased roughness and porosity. The addition of RP and VC azo dyes to N-TiO_2 altered the surface texture, with noticeable differences in dye distribution. EDS confirmed the successful nitrogen incorporation and provided elemental mapping, showing a uniform spread of nitrogen in N-TiO_2. These findings suggest that nitrogen incorporation and azo dye anchoring significantly impact the morphology and composition of TiO_2, with potential implications for enhancing solar cell performance.

V. s

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