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Development of Photoanode and Counter electrode materials for Cost effective DSSCs using Natural derived nanomaterials.

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Abstract

This study explores the synthesis of S-TiO2 and FeTiO3 nanoparticles using novel method and precursor sources. S-TiO2 nanoparticles are obtained from rutile sand through acid extraction and hydrolysis, while FeTiO3 nanoparticles are obtained from ilmenite sand through acid extraction and hydrolysis. A novel approach involves synthesizing S-TiO2 and FeTiO3 nanoparticles simultaneously using titanium iso-propoxide, sulfuric acid, and thiourea as chemical precursors. The optimization process involves forming titania paste for dye-sensitized solar cells (DSSCs), which are then fabricated using the optimized photoanode structure and widely studied electrolytes with a platinum counter electrode. The devices are tested and evaluated, yielding an impressive ~5% efficiency.

Keywords:

1. Introduction

The escalating energy crisis presents an unprecedented challenge that impacts the global energy. Sustainable and renewable energy sources have become vital as the demand for power keeps increasing. Within this framework, direct solar energy conversion to electricity presents a viable approach that offers an ecologically friendly and renewable alternatives. Innovative technologies have been developed as a result of the focus on harnessing solar power, and dye-sensitized solar cells (DSSCs) are attracting an abundance of research. Optimizing the efficiency of solar energy conversion processes is crucial for addressing modern renewable energy challenges. This requires improved light absorption, faster photon

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conversion, and enhanced charge transport systems within the solar cell. Throughout the context of current study, one noteworthy method is aimed at improving the efficiency of photocatalysis by doping transition metal oxides with metal and non-metal ions and engaging them via conjugated polymers and dyes. By permitting more effective charge separation and transport within the solar cell, this technique attempts to maximize the beneficial utilization of solar energy.

Doped titanium dioxide (TiO2) and iron titanate (FeTiO3) stand out among the materials investigated for these purposes. By reducing the environmental risks connected to conventional energy sources, these materials are essential to the creation of sustainable energy solutions. Dopants are added to TiO2 and FeTiO3 to enhance their photocatalytic properties and ensure compounds are going to be effective in addressing environmental challenges. A crucial gap in current research initiatives is the observation of a scarcity in the usage of natural minerals, particularly in the synthesis of TiO2 and FeTiO3 nanoparticles. Due to their inherent characteristics, natural minerals can serve as an accessible and environmentally friendly means of producing the nanoparticles needed for innovative solar cell technological advances. The fabrication of high surface area TiO2 and FeTiO3 nanoparticles is required to address this scarcity for the purpose of developing high-performance dye-sensitized solar cells.

Considering these factors considered, the objective of this research is to investigate a novel approach that employs hydrolysis and acid extraction techniques to synthesize S-TiO2 and FeTiO3 nanoparticles from natural rutile and ilmenite sands, respectively. The next research endeavors to enhance the efficiency and scalability of solar energy conversion technologies through analyzing materials for the counter electrode and optimizing titania paste for DSSC production. By adopting a multidisciplinary approach, the research intends to address the impending need for an environmentally conscious use of natural resources in energy alternatives.

2. Methodology

A key component of the research in this case is the deliberate addition of sulfur dopant, regardless of whether the dopant is accidentally included during the extraction process. The material's qualities are improved by this inadvertent doping process, thereby rendering it

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more appropriate for applications in water splitting and DSSCs. The synthesis of FeTiO3 nanoparticles is carried out using an affordable method that allows for the use of natural minerals. However, the nanoparticles grow around 450 degrees Celsius, which is a merely low temperature. The study also investigates the synthesis of FeTiO3 from chemical resources by adjusting the calcination temperature and the concentration of Fe content. Notably, higher temperatures over 800 degrees Celsius are required for the stable synthesis of FeTiO3 resembling naturally produced nanoparticles, emphasizing the formation process's temperature sensitivity.

Fig1: Synthesized Composite Materials Tio2, FeTio3, Sio2 etc,.

The optimization process indicates that a blend of PEG-600 and ethanol generates a more stable coating without affecting the structural integrity of the nanoparticles, which is important in trying for stable paste production for DSSCs. In comparison to other polymeric polymers such ethyl cellulose, this stability is favorable. The formulation process is enhanced through the design of a pot roller mill, ensuring the uniformity of the paste, a critical factor in achieving consistent and efficient DSSCs. The application of Pt sputtering at nanoscales is promoted as a significant technique that offers excellent performance during the synthesis process. The overall efficiency of the solar cell is enhanced by this nanoscale Pt deposition technique.

The work emphasizes the critical role of the atomic-level seed layer above the photoanode in the drive of developing an efficient photoanode. The diligent planning and application of this seed layer serves a significant part in preserving the stability and efficacy of the photoanode structure, which in return impacts the general performance of Dye-Sensitized Solar Cells (DSSCs) and water splitting processes. The importance focused on the precise atomic-level deposition of the seed layer emphasizes its critical function in achieving stability and

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efficiency in the photoanode, eventually leading to the improvement of solar energy conversion technology.

3. Results:

The findings presented offer strong evidence for the FeTiO3 structure of the minerals obtained from natural sources. In order to enable a thorough comparison, several Fe concentrations, ranging from 0M to 1M, were purposefully doped into TiO2. Among these concentrations, the 0.25M Fe-doped material is notably relevant to natural FeTiO3, as verified by XRD, EDX, and optical evaluations (UV and PL) in Fig2, Fig3.

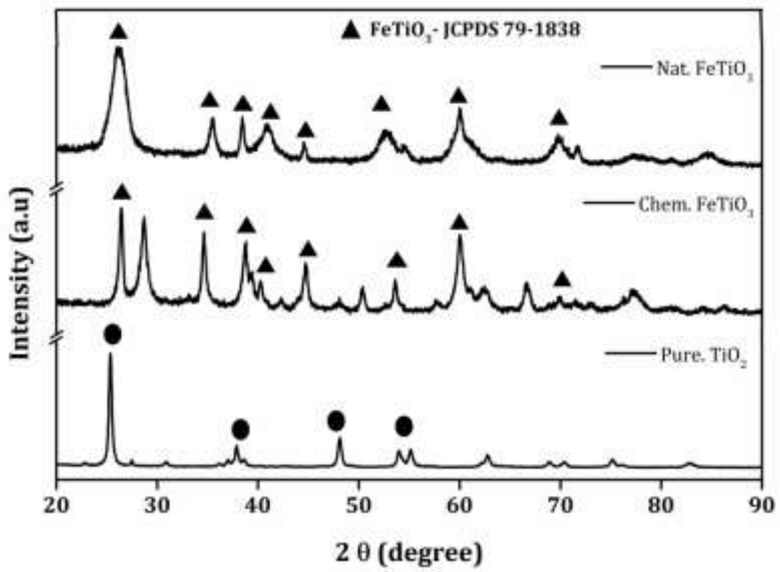

Fig 2: XRD results of FeTio3.

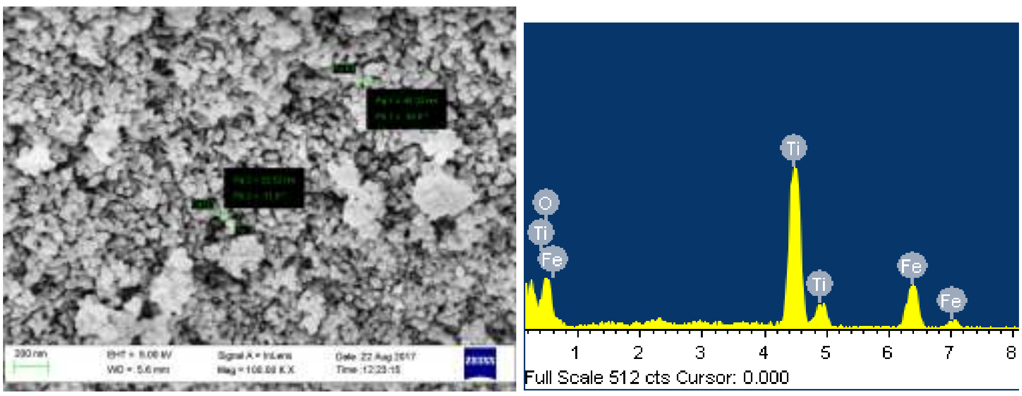

Fig 3: Nanoparticle SEM with EDAX Results Analysis.

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The materials that were produced appear as a collection of properly facilitated binary grains that have a spherical shape and diameters between 10 and 50 nm. Well-crystallized particle boundaries are further clarified by High-Resolution Transmission Electron Microscopy (HRTEM) pictures Fig 4, highlighting the accuracy and superior quality of the particle structure.

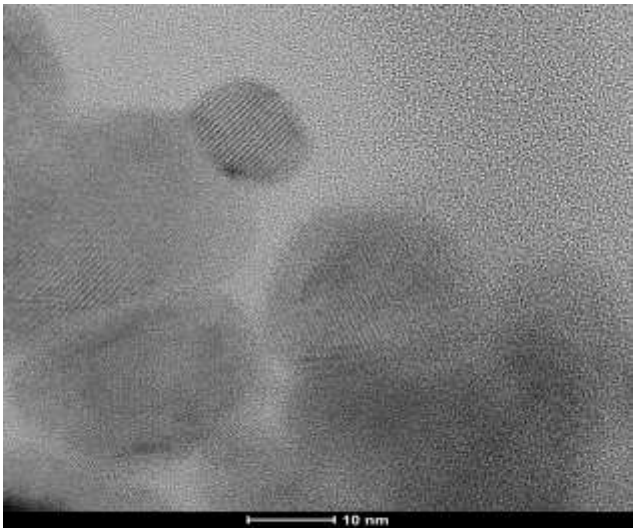

Fig 4: High-Resolution Transmission Electron Microscopy (HRTEM) pictures with spherical shape and diameters between 10 and 50 nm.

Remarkably, as compared to pure TiO_2, there is an apparent change in the absorption peak towards longer visible wavelengths with increasing Fe content. On the contrary present, charge transfer values fall in tandem with this increase in Fe concentration. remarkably, both charge transport and absorption operate at their most effective at 0.5M Fe concentration in TiO_2.

The nanoparticles extracted from natural $FeTiO_3$, which include favorable properties and functionalities of the two counterparts, TiO_2 and Fe_2O_3 systems ($FeTiO_3$), work in concert. This integration can be seen by the systematically optimization of energy band locations, charge transport, and light absorption that have been obtained via UV-Vis, PL, and C-V, Hall measurement studies.

4. Conclusion:

Notably, as compared to pure TiO_2 cells, the overall Power Conversion Efficiency (PCE) increases by a significant 50%. This result highlights the usefulness of $FeTiO_3$ in improving

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the performance of solar energy conversion technologies and validates its potential as an efficient material for high-efficiency DSSCs. These results mark a significant advancement in our knowledge of and ability to use FeTiO3 nanoparticles in the production of sustainable and effective dye-sensitized solar cells.

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