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S-TiO_2 nanoparticles prepared from natural mineral rutile sand for photovoltaic device applications

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Dye-sensitized solar cells (DSSCs) have been accepted as one of the promising next-generation devices and an essential solution for energy demands and environmental remediation. The industrial applications widely attract DSSCs due to its cost-effectiveness, environment friendly nature, and relatively high-energy conversion efficiency [1]. The main intent of this research is to reduce the demerits of S-TiO_2 nanoparticles production, in requisites of the simple, cost-effective, and mass production parameters [2]. Using this approach, a simple cost-effective and mass-production technique is used for the production of S-TiO_2 nanoparticles from the natural mineral rutile sand. The research on metal/non-metal doped TiO_2 has started to improve the optical response in UV–visible region. S-TiO_2 nanoparticles encompasses numerous combinations including high crystallinity, high specific surface area, and improved UV–visible response with improved photogenerated electrons and reduced recombination rate of charge carriers to make the performance of DSSCs better.

Oxygen vacancies are created owing to the non-metal dopant (sulfur) in the samples and acts as additional effective traps for the photo-induced electrons and in reducing the radioactive recombination rate.

The results reveal that the S-doped TiO_2 improved the UV–Visible absorption from these optimization techniques, thereby escalating the photogenerated electrons and holes, and also reducing the recombination rate of charge carriers during the photocatalytic reaction. For their performance in DSSCs, the S-TiO_2 cells and pure TiO_2 cells are fabricated and investigated. Better correlation is found out from these obtained results (Figure 1). The efficiency of the pure-TiO_2 cells is two times lower than that of S-TiO_2 cells. The overall PCE of S-TiO_2 cells improved up to 4.32%; and EQE of S-TiO_2 cell to 32%. Consequently, S-TiO_2 can be used as an efficient material for high-efficiency DSSCs. Also, the approach is to utilize the natural mineral for mass production of visible light-absorbed nanoparticles for various catalyst applications including water purification, biological, solar cells, and hydrogen productions.

The XRD patterns for all the three samples are coordinated well with the reported phase (JCPDS card: 21-1272,1999) of anatase TiO_2 (Figure 2) Using the selected area diffraction pattern (SAED) pattern in the HRTEM, the crystalline nature of the samples are further confirmed. Raman spectroscopy applied an additional categorization to confirm the phase stability of the titania. In the XPS full survey, there is a moderate shift of the electrons from oxygen to sulfur and assign to coordinate SO_4^{2-} ions with the surface Ti^{4+} ions (Figure 3). There is a shift in the absorption peak to greater visible wavelength compared with the anatase type of TiO_2. This shift occurs because of the transfer of charge from the valance band to conduction band while its absorption peak is altered probably due to the absorption caused by plasma resonance of S dopant.

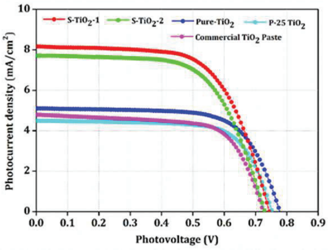

Figure 1: Current-voltage curves of the dye sensitized solar cells

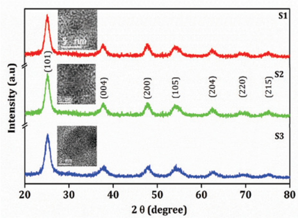

Figure 2: The XRD pattern of the samples S1 (from Natural mineral S-TiO_2), S2 (from Chemical precursor S-TiO_2) and S3 (un doped TiO_2)

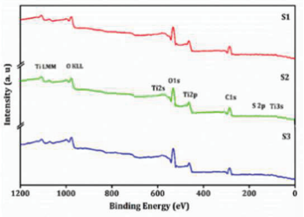

Figure 3: XPS scanning full survey spectrum and Magnified XPS Spectrum of the samples S1, S2 and S3

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