Research Article

Nano-Spherical Tin Oxide Derived from Pandan for Photocatalysis

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Abstract: *Currently, a significant challenge revolves around the release of harmful wastewater burdened with synthetic dyes from various industries such as textiles, paper, cosmetics, food and beverages, and pharmaceuticals. These synthetic dyes carry considerable risks to human health, organisms, and the environment. The environmentally friendly production of SnO_2 nanoparticles (SnO_2 NPs) is gaining recognition for its cost-effectiveness and reduced environmental impact compared to traditional chemical and physical methods, which are both costly and hazardous. In this study, Pandan extract was utilized in the biosynthesis process due to its containing compatible phytochemicals that can act as capping and reducing agent to prepare SnO_2 NPs. The degradation of methylene blue dyes through the photocatalytic process was observed to reach 79.8% within a span of 70 minutes. Additionally, the dependence on catalytic loading revealed that only a moderate amount of catalyst is necessary for effective photodegradation.*

Keywords: Tin (iv) oxide nanoparticles; Pandan; photocatalytic.

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1. INTRODUCTION

Currently, the issue of water pollution arising from the discharge of wastewater from textile industries is a significant concern, primarily due to the elevated levels of synthetic dyes it contains. These artificial dyes present considerable hazards to both organisms and the environment owing to their toxicity and resistance to biodegradation. The removal of these dyes from contaminated water poses challenges due to their intricate structures and robust bonds, resulting in prolonged and expensive removal processes that frequently lead to secondary pollution. In response to this challenge, photocatalytic techniques have emerged as a promising solution. These approaches offer several benefits, including simplicity, safety, environmental sustainability, and high efficacy. Recently, there has been notable interest in the utilization of metal oxide nanoparticles for photocatalysis, particularly tin oxide nanoparticles (SnO_2 NPs). This metal oxide renowned for its diverse applications such as in lithium-ion batteries, gas sensors, and solar cells, possess attributes such as stability, a high surface-to-volume ratio, low resistivity, and robust adsorption capabilities.

Utilizing a biosynthesis process involving plant extracts, it offers a sustainable and environmentally friendly method for preparing SnO_2 NPs. Hence in this study it is strongly suggested that Pandan leaves (*Pandanus amaryllifolius*) as illustrated in **Figure 1** to be used as the bio-template since this plant extracts contain phytochemicals that serve as reducing and capping agents in biosynthesis mechanism, thereby avoiding the need for hazardous high-energy processes. The flavonoids present in Pandan leaves are particularly effective at reducing Sn^{4+} to Sn^0 during nanoparticle synthesis. Characterization of the synthesized SnO_2 NPs was performed using techniques such as X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM) and UV-Visible Diffuse Reflectance (UV-DRS). These analyses provide insights into the nanostructures of the particles and their properties. The photocatalytic performance of SnO_2 NPs was evaluated by measuring the degradation percentage of simulated dyes, such as methylene blue (MB), demonstrating their effectiveness in water remediation applications (Katheresan et al., 2018; Najjar et al., 2021; Haritha et al., 2016; Gebreslassie & Gebretnsae, 2021; Jadhav & Kokate, 2020; Buniyamin et al, 2023; Gebre & Sendeku, 2019; Ghasemzadeh & Jaafar, 2013; Zulpahmi et al., 2023; Gawade et al., 2017; Buniyamin et al., 2023)

Figure 1. Pandan leaves.

2. METHOD & MATERIAL

Pandan extract was combined with a solution of $SnCl_4{\cdot}5H_2O$ precursor salt and allowed to react for three hours. The resulting jelly-like solution underwent centrifugation to separate the supernatant, after which the precipitate was collected and dried overnight. Subsequently, the dried precipitate was ground and subjected to calcination at 600°C for two hours to yield pure SnO_2 NPs. Characterization procedures were then conducted to verify the nanostructure and purity of the synthesized SnO_2 NPs. Following this, 100, 200, and 300 mg of photocatalyst (SnO_2 NPs) were stirred in 100 ml of MB (15 ppm) for 30 minutes without exposure to light to achieve adsorption-desorption equilibrium before UV irradiation was applied. Every 10 minutes, 5 mL of the solution was extracted and centrifuged. The resulting transparent supernatant was subsequently analyzed using UV-Vis spectroscopy (Bhosale et al., 2018; Buniyamin et al. 2023).

3. FINDINGS

XRD analysis was employed for crystallinity identification, FESEM analysis for morphological structure determination, and UV-DRS for measuring the energy band-gap value. Subsequently, the pure SnO_2 NPs were tested for photocatalytic activity to determine the degradation percentage of MB dye.

3.1 XRD analysis

The main diffraction peaks of the SnO_2 NPs are shown in **Figure 2**, corresponding to the (110), (101), and (211) planes, with 2θ angles of 27°, 34°, and 51°, respectively and appear in sharp and intense fashion. These peaks align with the tetragonal structure, consistent with findings from previous reports. The reducing and capping action of the flavonoid groups during the biosynthesis mechanism in Pandan leaves seems to guide the nucleation and growth of the nanoparticles, thereby enhancing their crystallinity (Makarov et al., 2014; Subramaniam et al., 2018; Philip & Vidhu, 2015; Buniyamin et al., 2023; Singha et al., 2009).

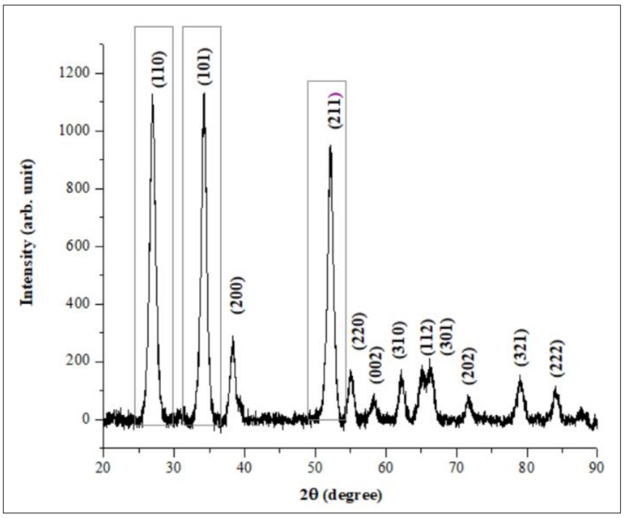

Figure 2. XRD diffraction of SnO_2 NPs.

3.2 FESEM analysis

FESEM image shows SnO_2 NPs has tinny spherical-like shapes tend to be sponges-like, with even distribution. Most of the study in biosynthesis of SnO_2 NPs using plant extract resulted in spherical-like shaped and evidence either in uniform or aggregation pattern. In this finding, the even distribution is presumed to be attributed by the uniformity of capping ability of flavonoid groups in the leaves extract (Matussin et al., 2020; Gorai, 2018; Buniyamin et al., 2021; Liaqat et al., 2023).

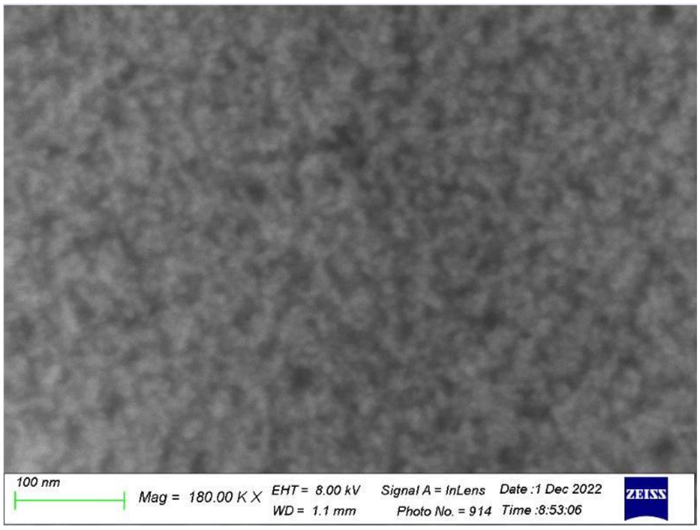

Figure 3. FESEM image of SnO_2 NPs with tinny-spherical shape

3.3 UV-DRS analysis

The Kubelka-Munk function (**Equation 1**) was utilized for converting the reflectance value into band gap energy. This process entailed plotting the square of the Kubelka-Munk function against energy and extrapolating the linear portion of the curve, as depicted in **Figures 4** (Liu et al., 2013; Chetri et al., 2013).

$$F(R) = (1-R)^2/ 2R = k/s$$ …….(**Equation 1**)

The energy band-gap of SnO_2 NPs derived from Pandan is determined to be 3.3 eV, rendering them suitable for application in photocatalytic reactions, as evidenced by prior research. It is apparent that Pandan extract aids in the formation of SnO_2 NPs, yielding nanomaterial with a reduced energy band gap compared to bulk SnO_2 typically known to be approximately 3.6 eV. This alteration could be attributed to factors such as limitations in unoccupied electronic states, carrier concentration and the induction of uniform oxygen vacancies. The identification of this energy band gap holds promising implications for SnO_2 NPs synthesized from Pandan in photocatalytic reactions, proposing the possibility involvement of heightened photo-generated electrons and holes (Ayeshamariam et al., 2014; Buniyamin et al., 2023; Yang et al., 2017; Naif et al., 2018).

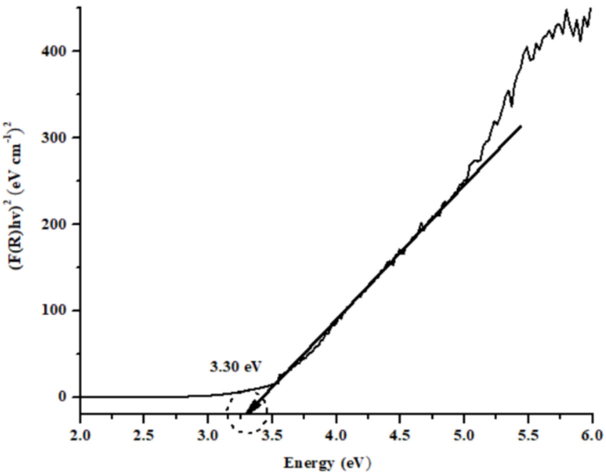

Figure 4. The energy band-gap for SnO_2 NPs

4. DISCUSSION

Figure 5 shows the MB degradation percentage, which has been calculated using **Equation 2**. C_0 and C_t are the concentrations of MB at an initial time and after irradiation. It was found that the degradation efficiency of MB follows the increment of UV irradiation time. Among three loading being introduced (100, 200 and 300 mg), the highest degradation at of MB was recorded for 200 mg catalyst loading. The significant degradation could result from the supersaturation volume of SnO_2 NPs and the optimum generation of electron and hole. The catalytic loading independence of SnO_2 nanoparticles has been demonstrated, showing that only a moderate amount of catalyst is required for photodegradation (Vasiljevic et al., 2020; Wan, 2018; Abbas, 2021).

$(C_0 / C_t) / C_0 \times 100$ …... (**Equation 2**)

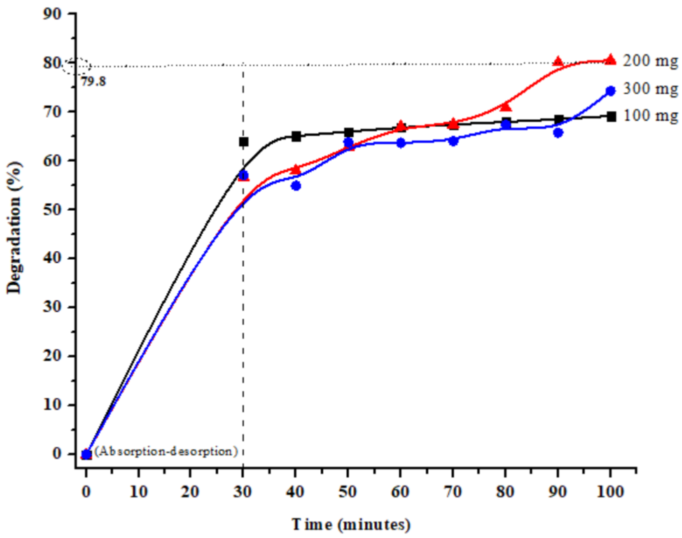

Figure 5. Photocatalytic degradation of SnO_2 NPs.

5. CONCLUSION

This study introduces a straightforward, environmentally friendly, and efficient approach for the green synthesis of SnO_2 NPs using Pandan extract. The resulting SnO_2 NPs exhibit high crystallinity and a spherical shape, with a band gap value of 3.3 eV. The photocatalytic activity achieved 79.8% degradation of the environmentally concerning dye MB within 70 minutes, indicating abundant active sites to enhance photo-excitation independently of the loading amount. Thus, the synthesized SnO_2 nanoparticles present a promising solution for addressing water polluted by dyes, with potential benefits for human health and the environment.

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