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Synthesis Of Pure Phase Of Zinc Stannate Nanoparticles And Its Application In Dye Degradation

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INTRODUCTION

The rapid expansion of industries, coupled with the increasing impact of activities has resulted in an increase, in industrial waste posing serious risks to both the environment and human well being. Among the challenges of our era, wastewater treatment and air cleansing emerge as crucial areas. In years dedicated efforts have been made by researchers to create eco highly effective and affordable technologies for eliminating harmful organic dyes and pigments from industrial wastewater, especially those utilized in textile production.

Several methods have been explored for treating wastewater, such as adsorption, ozonation, biological oxidation, chemical oxidation, photocatalysis and membrane separation. While each approach has its advantages photocatalysis stands out as an friendly option due to its lower energy consumption and cost efficiency. Nanomaterials exhibit potential in this domain owing to their characteristics and functionalities that make them ideal for environmental cleanup and energy storage purposes.

Within the realm of nanomaterials semiconducting metal oxides (SMOs) have shown promise in breaking down dyes due, to their quantum yield and intrinsic surface imperfections. Noteworthy is zinc stannate—a ternary oxide semiconductor—which has emerged as a favorable candidate. It is distinguished by its conductivity, minimal visible light absorption levels,elevated electron mobility and exceptional thermal endurance.

In contrast, to oxides zinc stannate demonstrates chemical stability and has been effective as a flame retardant and smoke inhibitor.

Nevertheless achieving control over the phase, shape, size and consistency of zinc stannate during synthesis continues to pose a challenge due to their critical influence, on its electrical and optical characteristics.

Traditional synthesis approaches such as sputtering, spray pyrolysis, plus thermal dissipation are expensive and also need innovative devices, while solution-based approaches commonly cause combined stages, endangering pureness.

Microwave-assisted synthesis has actually become an appealing option, providing various benefits over conventional techniques. By using electro-magnetic radiation created by a magnetron, microwave-assisted responses make it possible for consistent nucleation, rapid supersaturation and also much shorter crystallization times. In addition they call for reduced power intake and also accomplish greater temperature levels as well as stress in a much shorter duration contrasted to hydrothermal and also physical approaches. As a result microwave-assisted synthesis stands for an extra simple, time-efficient, and also cost-efficient technique for large-scale manufacturing of zinc stannate.

Due to unavailability of microwave I used probe sonicator for synthesis of zinc stannate nanoparticles. Probe sonicator is employed to break down larger particles into smaller ones, ensuring uniformity in size and distribution. This method is particularly useful for producing nanoparticles with controlled properties, such as size, shape, and surface characteristics. The sonication process helps in dispersing precursors and stabilizing agents, facilitating the formation of nanoparticles with desired attributes.

Crystal violet (CV) dye, additionally referred to as gentian violet or methyl violet 10B, is an artificial natural substance thoroughly made use of as a dye in numerous markets consisting of fabrics, printing and also healthcare. Its deep violet shade makes it preferred for passing away materials as well as as an organic discolor in microscopy.

The prevalent use crystal violet dye has actually elevated issues because of its possible negative results on the atmosphere along with human wellness. CV dye is commonly released right into water bodies throughout commercial procedures, resulting in water contamination. Furthermore, direct exposure to crystal violet has actually been connected to illness such as skin inflammation, respiratory system issues, and also also cancer causing impacts in some researches.

Initiatives to resolve these problems have actually resulted in study concentrating on the deterioration of crystal violet dye. Damage procedures goal to break down CV dye particles right into much less hazardous compounds, minimizing its ecological influence and also reducing health and wellness dangers related to direct exposure.

Different approaches have actually been discovered for crystal violet dye destruction consisting of physical techniques like photodegradation utilizing UV light, chemical approaches including oxidation or decrease responses, and also organic techniques using microorganisms or enzymes.

Recognizing crystal violet dye destruction is vital for creating effective plus lasting therapy techniques to reduce its unfavorable results on the setting coupled with human wellness. This record intends to give a review of the importance of crystal violet dye deterioration, the systems entailed, as well as the present research study landscape in this area

2. MATERIALS AND METHOD

2.1 Materials

Zinc chloride, stannous chloride, ethanol , Double Distilled water , hydrochloric acid , sodium lauryl sulphate (SLS) and sodium hydroxide.

2.2 Preparation of Zinc Stannate Nanoparticles

Here's a detailed explanation of each step:

1) Combining the Chemicals: Mix zinc chloride, stannous chloride, and 5 mL of sodium lauryl sulfate (SLS) in 50 mL of double-distilled water. Then, add 4 mL of diluted hydrochloric acid (HCl) to the mixture.
2) Titration: Gradually add sodium hydroxide (NaOH) from a burette to the mixture until the solution's pH reaches around 9 or 10. This step helps in determining the endpoint reaching a desired pH level for the solution.
3) Ultrasonication: Place the mixture in an ultrasonication probe and subject it to ultrasonic waves for 40 minutes. Ultrasonication helps in mixing, dispersing, and degassing the solution by creating high-frequency sound waves.
4) Cooling and Centrifugation: After ultrasonication, allow the solution to cool down. Then, centrifuge it using a mixture of double-distilled water and ethanol. Centrifugation separates the components of the solution based on their densities, allowing for further purification.
5) Transfer to Oven: Once centrifugation is complete, transfer the solution to an oven for drying. Drying removes excess solvent and water from the solution, leaving behind the desired compounds or materials.
6) Transfer to Silica Crucible: After drying, transfer the dried material to a silica crucible. Silica crucibles are often used for high-temperature applications and can withstand the heat of the calcination process.

7) Calcination: Perform the calcination process in a muffle furnace at 350°C. Calcination involves heating the material at high temperatures in the absence of air to drive off volatile substances, decompose organic matter, or induce phase transformations.

calcinated product

3.RESULT AND DISCUSSION

3.1 Characterization :-

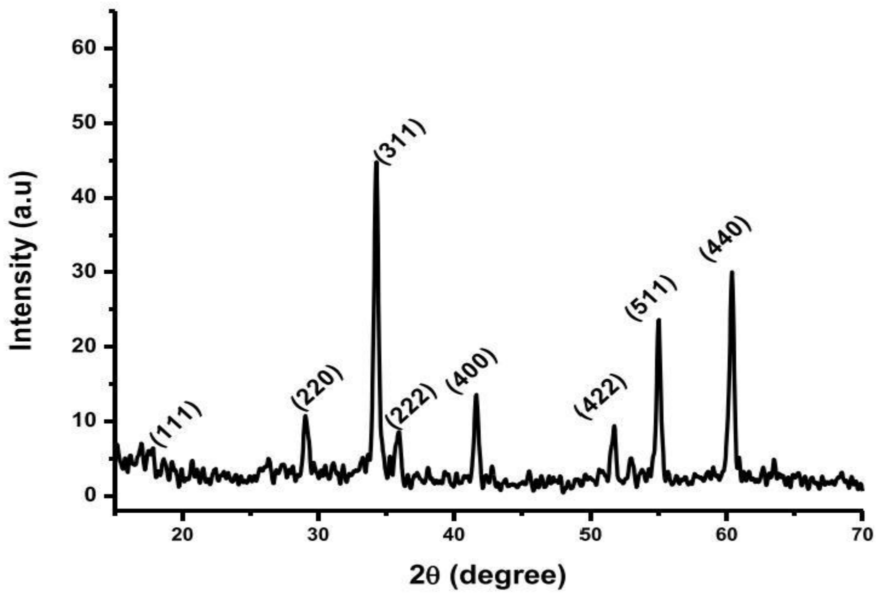


Fig.1 X-ray diffraction spectrum (XRD) of Zn2SnO4 nanoparticles.

The powder X-ray diffraction (XRD) pattern of the synthesized sample, as depicted in Figure 1, closely corresponds to the standard JCPDS powder diffraction file no. 24-1470, indicating the formation of a face-centered cubic spinel structure with a lattice constant of a = 8.657 Å. This alignment suggests that the reaction has reached completion, yielding nanoparticles close to the anticipated stoichiometric ratio. The average crystallite size was determined using the Scherrer equation (1), where D represents the average grain size in nanometers, k is a constant (0.89), λ is the X-ray wavelength, and θ and β denote the diffraction angle and full-width at half-maximum of the observed peaks, respectively. From the data presented in Table 1, the mean crystallite size is calculated to be 20.95 nm.Compared to other synthesis methods, highly crystalline powders with narrow size distribution and high purity can be expected via probe sonicator synthesis route without any post treatment at high temperature, which makes it an excellent method to synthesise Zn2SnO4 nanoparticles.

$D = k*\lambda / \beta \cos \theta.$ …… (1)

Table 1

Parameters calculated from XRD pattern of Zn2SnO4 nanoparticles.

Position (2θ)	hkl	d-spacing	Crystallite size (nm)
17.794	111	4.9806	17.79
29.073	220	3.0713	18.16
34.293	311	2.6149	22.07
35.858	222	2.5023	22.16
41.645	400	2.1687	22.56
51.659	422	1.7694	19.53
54.979	511	1.6701	23.77

UV spectroscopy technique was used for recording spectra of dye degradation

UV spectroscopy, short for ultraviolet-visible spectroscopy, is a technique used to analyze the absorption of light by molecules in the UV and visible regions of the electromagnetic spectrum. It's commonly employed in chemistry, biochemistry, and materials science to determine the concentration of a substance, study chemical reactions, and investigate molecular structures.

In UV spectroscopy, a sample solution is irradiated with UV or visible light, and the absorbance of the light at various wavelengths is measured. The absorbance is then plotted against the wavelength to generate a UV-visible spectrum. This spectrum provides information about the electronic transitions occurring within the molecules in the sample.

3.2 Dye degradation

Crystal Violet dye

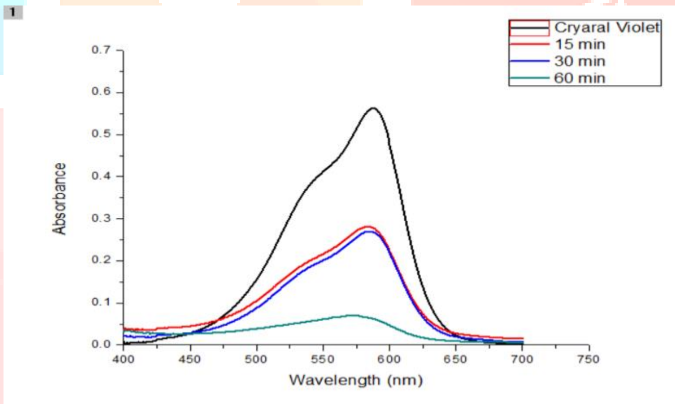
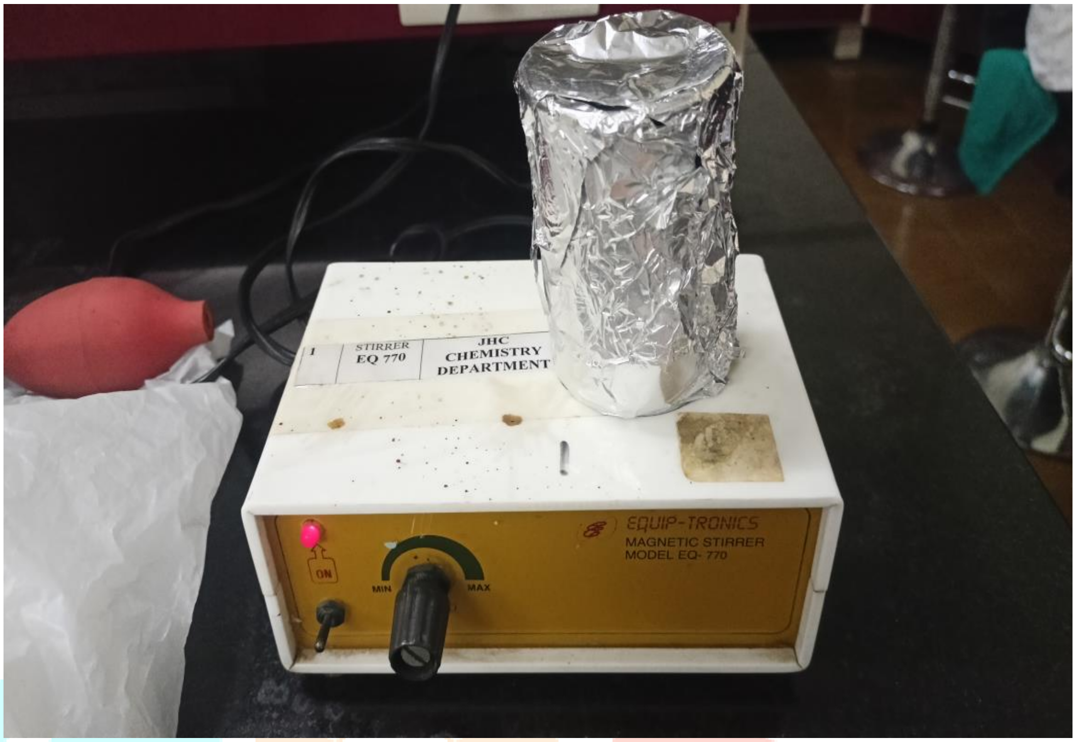


Fig.2 UV spectra of crystal violet dye degradation

The degradation of crystal violet dye using Zinc Stannate nanoparticles is an intriguing area of research in environmental science and nanotechnology. Zinc Stannate nanoparticles have shown promise as catalysts for the degradation of organic pollutants due to their unique properties, such as high surface area and catalytic activity. The process typically involves the adsorption of the dye molecules onto the nanoparticle surface followed by degradation through photocatalytic or catalytic processes, often utilizing mechanisms such as electron transfer and generation of reactive oxygen species. This research holds potential for developing efficient and sustainable methods for wastewater treatment and environmental remediation.

Process:- In the experimental process, a 100 ml beaker containing 20 ml of crystal violet dye solution with a concentration of 5 ppm was utilized. To this solution, 0.02 g of zinc stannate nanoparticles was added This mixture was then exposed to sunlight, and spectra were recorded at 15-minute intervals. The obtained results, as depicted in Fig. 2, demonstrated a decrease in absorption over time, indicating a positive outcome. adsorption maxima were found to be diminished gradually and completely disappeared after 60 min. .This decrease in absorption suggests that the addition of zinc stannate nanoparticles led to the degradation or removal of crystal violet dye molecules from the solution, possibly through catalytic or photocatalytic mechanisms.

methylene blue dye



methylene blue dye containing beaker wrapped with foil paper

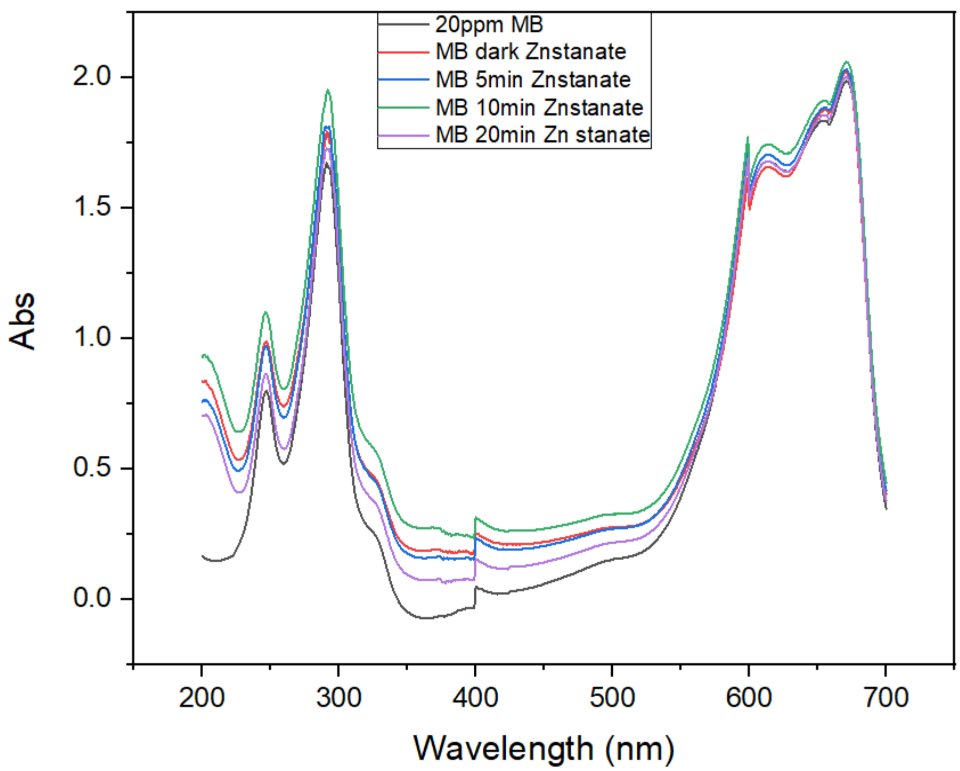


Fig.3 UV spectra of methylene blue dye degradation

Methylene blue is a synthetic dye that has been used for various purposes, including staining biological tissues for microscopic examination, detecting certain medical conditions, and as a medication for some medical issues. It's also used in the textile industry and as a redox indicator in chemistry experiments.

Process- A solution containing 20 ml of methylene blue dye with a concentration of 10ppm was placed in a 100 ml beaker. Then, 0.02g of zinc stannate nanoparticles was introduced into the solution, which was covered with foil paper and stirred using a magnetic stirrer for 30 minutes. Subsequently, the foil paper was removed, and the solution was exposed to UV light in a chamber. Spectra were recorded at 10-minute intervals. However, contrary to expectations, there was no decrease in the absorption band observed in the recorded spectra, indicating that the addition of nanoparticles did not lead to the degradation of the methylene blue dye.

4.Conclusion

One-dimensional Zn2SnO4 nanorods were successfully synthesized using a straightforward and economical probe sonicator method, resulting in highly crystalline, uniform, and pure structures. The photocatalytic degradation of CV dye under visible light exposure was investigated, demonstrating that Zn2SnO4 efficiently decomposed CV dye within 60 minutes with remarkable effectiveness. However, MB dye was not degraded under similar conditions. These findings suggest that Zn2SnO4 nanorods hold promise for the efficient degradation of organic dyes and wastewater treatment due to their low energy requirements and cost-effectiveness, making them suitable for large-scale production.

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