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# Strontium stannate Nanoparticle: Synthesis, Properties and Application

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***Abstract***
*Perovskites are materials with a wide range of possible uses, including humidity sensors, photocatalysts, transparent conductive oxides, and capacitors. A perovskite semi-conductor material with a broad band gap is strontium stannate (SrSnO3). To create SrSnO3, a number of synthesis techniques are frequently employed, such as hydrothermal, sol-gel, and solid-state reaction (SSR). High temperature calcination is necessary for the SSR process. However, the hydrothermal and sol-gel processes just require a lower calcination temperature to produce perovskite materials. Prior to calcination, a surfactant was added to a solution of Sr(NO3)2 and SnCl2 in water in order to perform the sol-gel procedures. SrSnO3 was formed by the hydrothermal process using the autoclave procedure before calcination. Determining the morphological and optical characteristics of SrSnO3 produced by sol-gel, hydrothermal, and SSR processes was the aim of this investigation. Using Kubelka-Munk relations, the band gap was determined to be 4.05 eV for hydrothermal, 5.50 eV for sol-gel, and 3.95 eV for SSR. For SrSnO3, sol-gel techniques revealed the largest band gap. Optical studies demonstrated that a perovskite produced using the various techniques has a distinct band gap.*

## I. Introduction

Perovskite-like nanomaterials have garnered interest due to their wide range of technological uses (Kumar et al., 2021). According to de Sousa Filho et al. (2020), the alkaline earth stannates have the general formula ASnO3, where A stands for alkaline-earth metals or lanthanides such as Ca, Sr, and Ba. Perovskites have a large band gap, but they also have a lot of other intriguing characteristics, such superconductivity and enormous magnetoresistance. The solid-state reaction (SSR) technique is one of the ways used to synthesise perovskites such as MSnO3 (M = Sr, Ba, Ca). Using this technique, metal oxides are combined in a mortar and then heated to high temperatures for calcination. By combining tin oxide (SnO2), strontium carbonate (SrCO3), and antimony oxide (Sb2O3) in a mortar and calcining it at about 1500 ˚C for 24 hours, Liu et al. created Sb doped SrSnO3 (Liu et al., 2011). Although this process is rather easy, it necessitates high calcination temperatures, which use a lot of power (Ecija et al., 2012). Sol-gel and hydrothermal techniques are substitutes that have lower calcination temperatures. Perovskite materials have been produced via the sol-gel approach, a wet-chemical synthesis of SrSnO3 (Xu et al., 2015; Para et al., 2016). Metal nitrates, chlorides, acetates, and other compounds in a solution are used in this process.

To aid in particle agglomeration and the perovskite formation process, the metal precursors are dissolved and combined with a surfactant. Prior to calcination, the precursors and surfactant are heated, mixed, and then dried. Fe-doped SrSnO3 was synthesised by Kumar et al. (2015) using the sol-gel technique and calcined for two hours at 650˚C. Although the synthesis is more complex, this technique needs a substantially lower calcination temperature for the creation of SrSnO3 (Ecija et al., 2012). It has demonstrated intriguing structural, electrical, and optical qualities for possible uses in solar cells, photocatalysis, gas sensors, (Mezni et al., 2017), and other fields. In particular, strontium stannate (SrSnO3) has a broad optical band gap of 4.1 eV at ambient temperature and the orthorhombic perovskite structure with space group symmetry Pbnm.

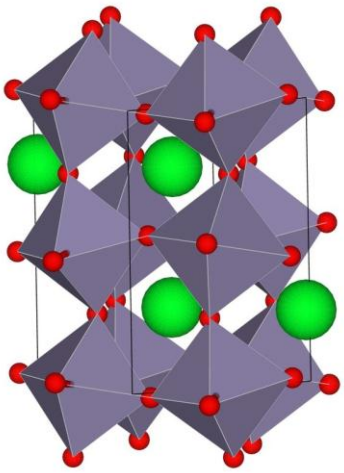

Fig 1: SrSnO3's orthorhombic perovskite structure. The red and green spheres represent oxygen and strontium, respectively. SnO6 units are shown by the grey octahedra.

**Synthesis of Strontium stannate Nanoparticles**

**No autoclave route (sol-gel)**

This study's sol-gel methodology was derived from Kumar et al. (2015). 30 millilitres of deionised water were mixed with reagent-grade strontium nitrate (99% pure; Sr(NO3)2), tin chloride (98% pure; SnCl2), and CTAB (>99% pure), all of which were acquired from Sigma Aldrich. After that, the mixture was swirled for four hours at 80˚C until it solidified into a white gel. After that, the gel was dried in air at 100 ˚C on a hot plate until it turned into a powder. To get rid of any last contaminants, the powder was cleaned with ethanol and allowed to dry. After that, the white powder, SrSn(OH)6, was calcined for two hours at 650˚C in a furnace to produce SrSnO3 powder. The formation of SrSnO3 can be described by the following equations 1 and 2:

$Sr(NO3)2 + SnCl2 + 4H2O \rightarrow SrSn(OH)6 + 2HCl + N2 + 2O2$ (1)

$SrSn(OH)6 \rightarrow SrSnO3 + 3H2O$ (2)

Equation 1 explains how SrSn(OH)6 is formed from the precursors, while equation 2 illustrates how SrSn(OH)6 is calcined to produce SrSnO3.

**Autoclave route (hydrothermal)**

Li et al. (2011) provide a more thorough reaction pathway incorporating the hydrothermal synthesis of SrSnO3. 30 mL of deionised water was mixed with 99% pure strontium nitrate (Sr(NO3)2), 98% pure tin chloride (SnCl2), and >99% pure CTAB. Drop by drop, 1 M NaOH was added to the solution while stirring to keep the pH at 13 until a white suspension formed. For 16 hours at 160 ˚C, the suspension was sealed in an autoclave. The suspension transformed into a white gel and was allowed to dry once the autoclave cooled to ambient temperature. The gel turned into a white powder of SrSn(OH)6 after drying. To create the SrSnO3 powder, the powder was further calcined for two hours at 650 ˚C.

**Solid-state reaction route (SSR)**

James et al. (2013) served as the basis for the SSR approach taken in this investigation. Sigma Aldrich provided 99% pure equimolar SrCO3 and SnO2 powders, which were combined using a mortar and pestle. To serve as a binder for the particles, acetone was added to the mixture. The powder was mixed, then moved to a porcelain boat and calcined at 800˚C for 12 hours. After that, the powder was crushed once again and calcined for eighteen hours at 850 ˚C. Following the last grinding, the material was again calcined for 24 hours at 900 ˚C. After calcination, SrSnO3 was reduced to a white powder. Equation 3 may be used to explain the basic solid-state reaction equation:

$SrCO3 + SnO2 \rightarrow SrSnO3 + CO2$ (3)

**Applications**

SrSnO3 nanoparticles have many applications, including:

**Photocatalysis**

Pollutants such as 4-nitrophenol and methylene blue dye can be broken down by SrSnO3 nanoparticles when exposed to visible light. Silver and other noble metals can be doped into SrSnO3 to enhance its photocatalytic activity.

**Dye-sensitized solar cells**

The efficiency of dye-sensitized solar cells can be enhanced by the creation of blocking layers using SrSnO3 nanorods (Abrari et al., 2019). The third generation of solar cells includes dye-sensitized solar cells. The

scientific community has recently been paying close attention to them because of their competitive power conversion efficiency and easy production method. Because of its high photoelectron production, mesoporous TiO2 has historically been widely employed as an electron transport layer. The separation of the photon absorption and charge transfer processes in dye-sensitized solar cells (DSSCs) is one of the primary distinctions between them and regular silicon cells. In order to improve stability and electron mobility over the traditionally employed TiO2, the research community recently concentrated on finding ternary wide-bandgap semiconductors to utilise as an electron transporter in dye-sensitized solar cells. The alkaline earth stannate family's strontium and barium stannate are ternary oxides that are more frequently utilised as an electron transport layer in dye-sensitized solar cells. Alkaline earth stannate nanoparticles have been created using a variety of methods, including the solid-state ceramic combustion process, hydrothermal approach, and sol-gel wet-chemical route. In this paper, we evaluate the several factors that affect dye-sensitized solar cells' performance and report on the latest developments and real-world applications of alkaline earth stannate nanoparticles as an electron transport layer.

**Antibacterial and sensing applications**

Applications for Ag/SrSnO3 triple metal oxides include antimicrobial and sensing. In order to accelerate chemical reactions, nanoparticles are also employed in catalysis. As a result, less catalytic material may be required, saving money and lowering pollutants. SrSnO3 nanostructures in conjugation with chitosan (CTSN) and silver (Ag) nanoparticles are used as antibacterial compounds in ultrafast smart ternary photocatalysts. High densities of uniformly dispersed Ag nanoparticles (4–15 nm) were used to create these particles. Bare SrSnO3, CTSN/SrSnO3, and Ag@CTSN/SrSnO3 nanocomposites were discovered to have bandgap energies (Eg) of 4.0, 3.94, and 3.7 eV, respectively. All of the recently developed photocatalysts' photocatalytic efficiencies were assessed using methylene blue (MB) dye and the antibiotic linezolid medication as target analytes. With rapid elimination of the linezolid medication at 96.02% within 25 minutes and nearly complete removal of the MB dye in just 12 minutes under UV light irradiation, the Ag@CTSN/SrSnO3 photocatalyst was determined to be significantly superior to all other samples under investigation. Compared to bare SrSnO3, the removal rate of the Ag@CTSN/SrSnO3 photocatalyst was 3.36 times quicker. The current research provides a very easy, basic, very successful, and highly promising treatment approach for the effective eradication of infamous and deadly contaminants, allowing for the proper management of contemporary environmental challenges.

**Light Emitting Diode**

The creation of light-emitting diodes (LEDs) or parts for phosphor-converted LEDs is an exceptional usage for perovskites (Pérez-Hernández et al., 2021). White light-emitting diodes, or W-LEDs, have become more and more popular in solid-state lighting in recent years (Yoon et al., 2013). This technology progressively replaces traditional incandescent and fluorescent lights because of its compact size, high luminous efficiency, extended operating duration, and energy-saving features, as well as the associated environmental benefits. Accordingly, the primary methods for examining the luminous characteristics of semiconductors, glasses, garnets, and perovskites have been doping with rare-earth (RE) ions and native defects produced during the manufacturing process.

To alter its luminous characteristics, many systems based on the perovskite SrSnO3 doped with rare-earth (RE) ions, such as Eu3+, Ce3+, and Er3+, have been suggested. Conversely, materials with near-white light emission capabilities that are helpful for the creation of white LEDs have been reported, including Sm3+ and Dy3+ co-doped SrZrO3 nanophosphors and Ho3+ and Yb3+ co-doped SrSnO3 perovskites. In particular, the blue/green (Tb3+) and reddish/orange (Sm3+) spectral regions were where the Sm3+, Tb3+ co-doped various matrices displayed high luminescence. These emission characteristics are important for solid-state lasers, white light-emitting diodes, colour displays, and high-density optical storage.

## II. Conclusion

SrSnO3 has been successfully synthesised using sol-gel, hydrothermal, and SSR techniques. The most consistent and regular particle morphologies in the form of nanorods were found in hydrothermally synthesised SrSnO3, followed by SSR and sol-gel, according to the SEM. Both sol-gel and hydrothermally synthesised SrSnO3 underwent a three-step dehydration process, according to the TGA study. The band gap values of 4.05 eV and 3.95 eV, respectively, obtained using the hydrothermal and SSR approaches, are comparable to the 4.1 eV value reported in the literature. Through the three distinct synthesis techniques, orthorhombic phase SrSnO3 nanoparticles were formed, as demonstrated by TX-ray diffraction patterns and X-ray photoelectron spectra. The hydrothermally produced SrSnO3 had the fewest impurities, according to the XRD, followed by SSR and sol-gel. Each element was well integrated into the main lattice, as evidenced by the high binding energy intensity of

the SrSnO3 XPS spectra generated using the SSR technique. Sol-gel and hydrothermal methods were used after the SSR procedure.

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