Synthesis and Characterizations Tin Oxide Thick Films Developed by Screen Printing Technique

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Abstract:
In the industry today, demand for optical and solar cell technologies is booming. Numerous scientists are engaged in the synthesis of new nanomaterials for the development of optical devices as well as applications for energy conversion and storage. Metal oxide semiconductor (MOS) nanoparticles just revealed an exciting pathway for invention in practically all scientific fields. MOS nanoparticles are connected to contemporary research, and scientists anticipate their use in all branches of science and technological advancement in the future. Tin oxide (SnO_2) is the most promising material for solar cell as well as other applications form few decades. Due to its valence band gap, high mobility, and wide band gap SnO_2 is also the best material for development of perovskite solar cells. In the present investigation, we are focused on the synthesis of SnO_2 nanoparticles by precipitation method and developed SnO_2 Thick films by Screen Printing Technique. The electrical and optical properties of developed thick films were studied. The conductivity of pure SnO_2 thick films was found to be 2.78 × 10^{-5} Ω^{-1}-m. The thickness of film was estimated 87 µm. The optical study was carried out using static photo response system. The light-dependent current variation of prepared SnO_2 thick films was investigated for an optical sensor application.

Keywords: **Tin oxide, precipitation method, thickness, conductivity, optical sensor.**

Published in IJIRMPS (E-ISSN: 2349-7300), Volume 11, Issue 4, July-August 2023

1. INTRODUCTION:

Nanomaterials play a crucial role in various fields, including photonics, electronics, renewable energy, optical, and solar cell [1]. These materials possess unique properties at the nanoscale, which make them highly desirable for a range of applications. Nanomaterials exhibit size-dependent optical properties, enabling enhanced light absorption, scattering, and emission. They can manipulate light at the nanoscale, leading to improved optical sensing, imaging, and communication devices [2, 3]. Nanomaterials, such as quantum dots, nanowires, and perovskites, have shown promising performance in converting sunlight into electricity. Their unique properties, including tunable band gaps and large surface areas, allow for efficient capture and conversion of solar energy. Nanomaterials enable the development of lightweight and flexible solar cells, which can be integrated into various form factors, such as wearable electronics, portable devices, and building-integrated photovoltaics (BIPV). This flexibility opens up new possibilities for solar energy harvesting in unconventional applications. Optical nanomaterials have revolutionized the field of optoelectronics. They have enabled the development of high-performance light-emitting diodes (LEDs), lasers, photodetectors, and displays [3-5].

Tin oxide (SnO_2) is a well-known nanomaterial with diverse applications due to its unique properties like electrical, optical, physical and chemical. Tin oxide is a wide-band gap (3.6 eV) semiconductor, which means it has a large energy gap between its valence and conduction bands [5, 6]. It is n type semiconductor. This property makes it transparent in the visible light range while being electrically insulating. However, when doped or exposed to certain conditions, it can exhibit excellent electrical conductivity. Tin oxide-based materials are being explored for energy storage applications, including lithium-ion batteries and supercapacitors. SnO_2 exhibits a high theoretical capacity for lithium-ion storage, which makes it a promising candidate for next-generation battery technologies. Additionally, tin oxide nanomaterials can be used as electrodes or active materials in supercapacitors, offering high energy storage capabilities [7, 8]. Due to its transparent and conductive nature, tin oxide finds use in optoelectronic devices such as thin-film transistors (TFTs), light-emitting diodes (LEDs), and solar cells. Tin oxide thin and thick films can be employed as transparent electrodes or active layers, contributing to the functionality and performance of these devices. It is can be synthesized through various methods, including chemical vapor deposition (CVD), sol-gel, hydrothermal synthesis, precipitation, hydrothermal, and green synthesis methods. The precipitation method is a common technique used for synthesizing various materials, including SnO_2. This method involves the precipitation of a solid product from a chemical reaction occurring in a solution [5-8].

Screen printing is a versatile and popular printing technique used to transfer ink onto various surfaces, such as textiles, paper, ceramics, glass, metal, and plastic. It is commonly employed in the production of apparel, posters, signage, packaging, and other promotional materials [9]. Screen printing involves creating a stencil, known as a screen, and using it to apply ink through the open areas onto the desired substrate. It is mostly used to developed thick films [9- 10].

In the present research work, author synthesis of SnO_2 nanoparticles by precipitation method and developed SnO_2 thick films by screen printing technique and investigated the electrical and optical properties of developed thick films of synthesized SnO_2 nanoparticles.

2. EXPERIMENTAL WORK:

2.1 Synthesis of SnO_2 nanoparticles by precipitation method:

The nanoparticles of SnO_2 were synthesis using precipitation method. The hydrated stannic chloride ($SnCl_4.5H_2O$) is used as precursor or source of Sn and NaOH is used as precipitating reagent [11, 12]. Synthesis process of SnO_2 nanoparticles is display in Figure 1.

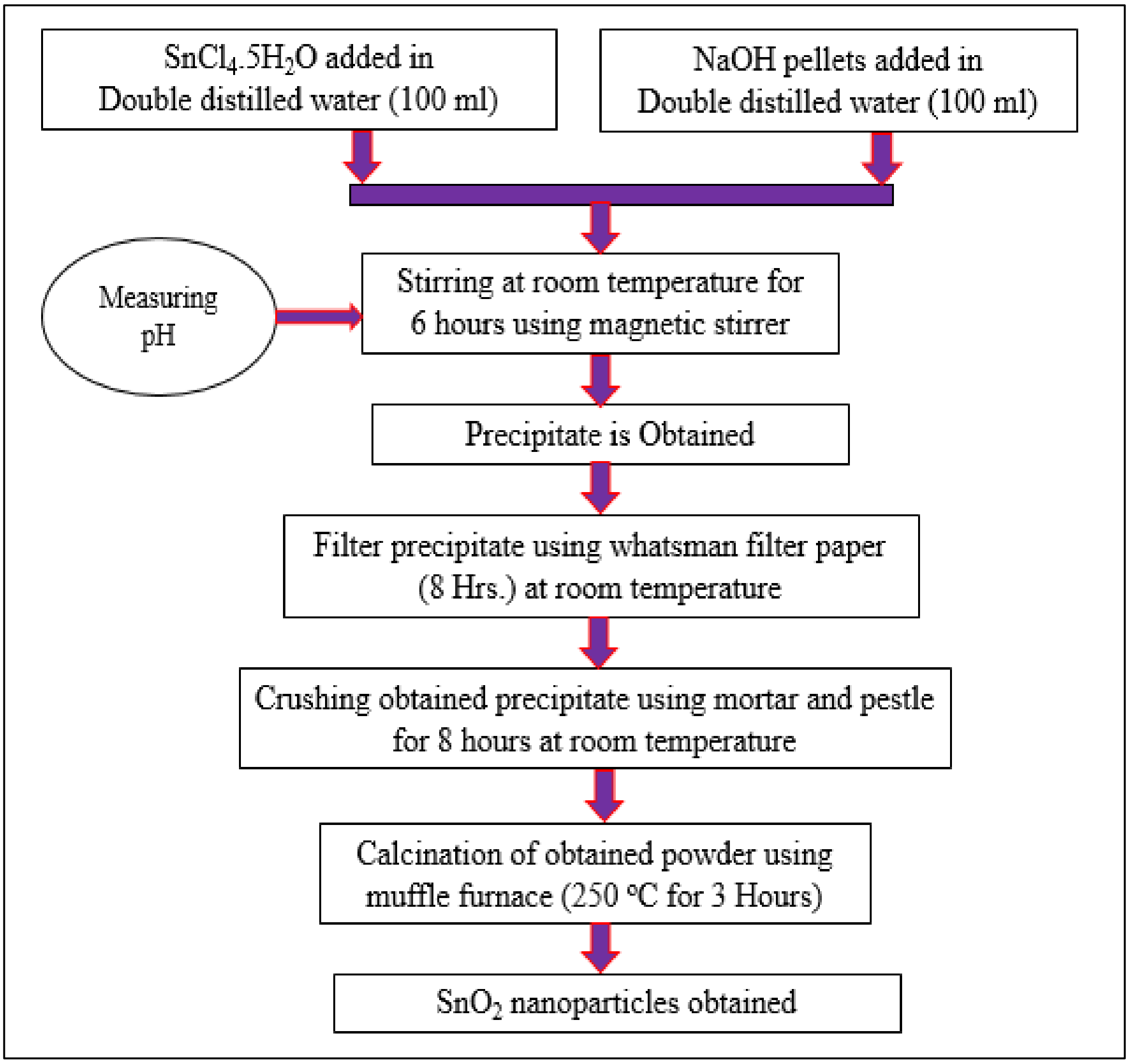

Figure 1. Synthesis process of SnO_2 nanoparticles using precipitation method

2.2 Development of SnO_2 thick films using screen printing technique:

In the current research work, synthesized SnO_2 nanoparticles were used for the development of thick films. The films were deposited on glass substrate. Before deposition of material the substrates, the substrates were properly clean by distilled water and acetone and then kept in under IR lamp for 30 minutes. The 70 %: 30% inorganic (SnO_2) and organic material (EC+BCA) ratio was used for the development of films [13]. By using standard screen printing set up pure SnO_2 thick films were developed. The development of thick films of pure SnO_2 is illustrate in figure 2.

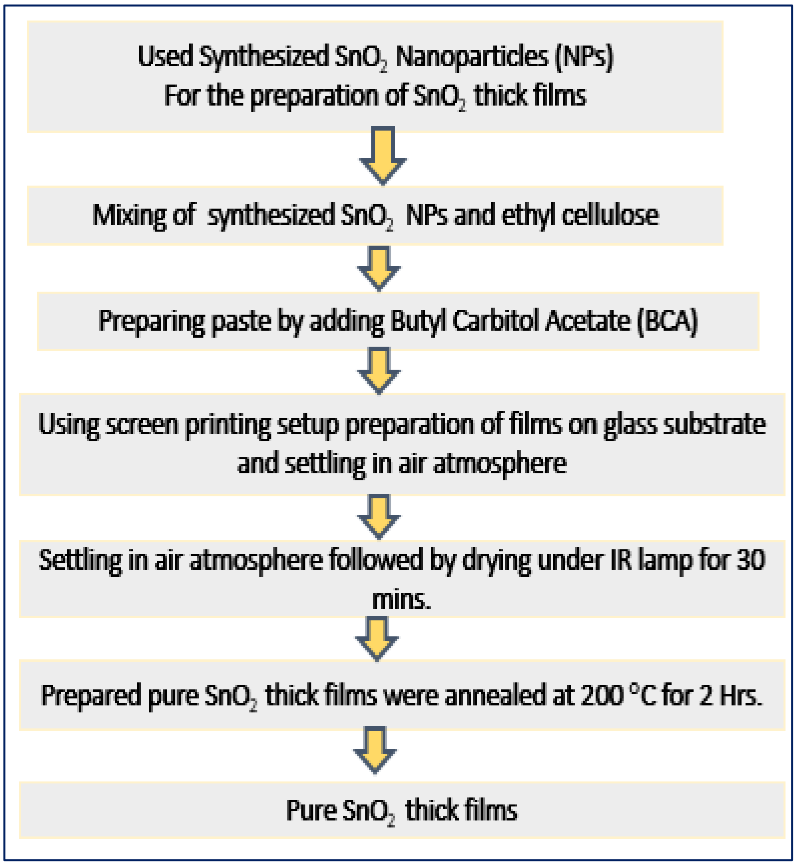

Figure 2. Steps of development of pure SnO_2 thick films

3. RESULTS AND DISCUSSION

3.1 Electrical Properties

The electrical properties of pure SnO_2 thick films were studied using static electrical system in which the electrical response was measure in the form of current. The variation of current with respective temperature also measure to investigate the semiconducting nature of the prepared films [14].

The conductivity of pure SnO_2 thick films at constant temperature was determined by using the equation 1 [16],

$$\sigma = l / R*b*t \quad \Omega^{-1}\text{-m} \qquad (1)$$

Where,

l = length of the thick film,

R = Resistance of thick film at room temperature,

t = thickness of the film,

b = breadth of the thick film.

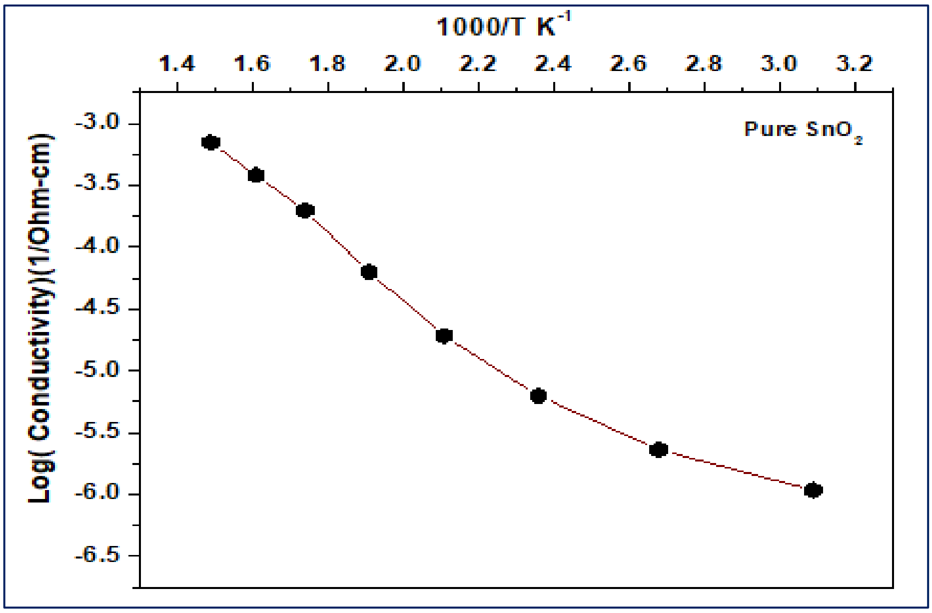

Figure 3: Variation of conductivity of SnO_2 thick films with temperature.

The temperature dependence of the conductivity of thick, pure SnO_2 films in an environment with air is shown in Figure 3. As the temperature rises, the conductivity of these films continues to rise, suggesting a negative temperature coefficient (NTC) of resistance. This demonstrates that the films are semi-conducting nature. Figure 4 displays the I-V characteristics of pure SnO_2 films at ambient temperature in an air environment. The symmetry of the characteristics seen points to the ohmic nature [15, 16]. The conductivity of pure SnO_2 thick film was found to be $2.78 \times 10^{-5}\ \Omega^{-1}$-m [17].

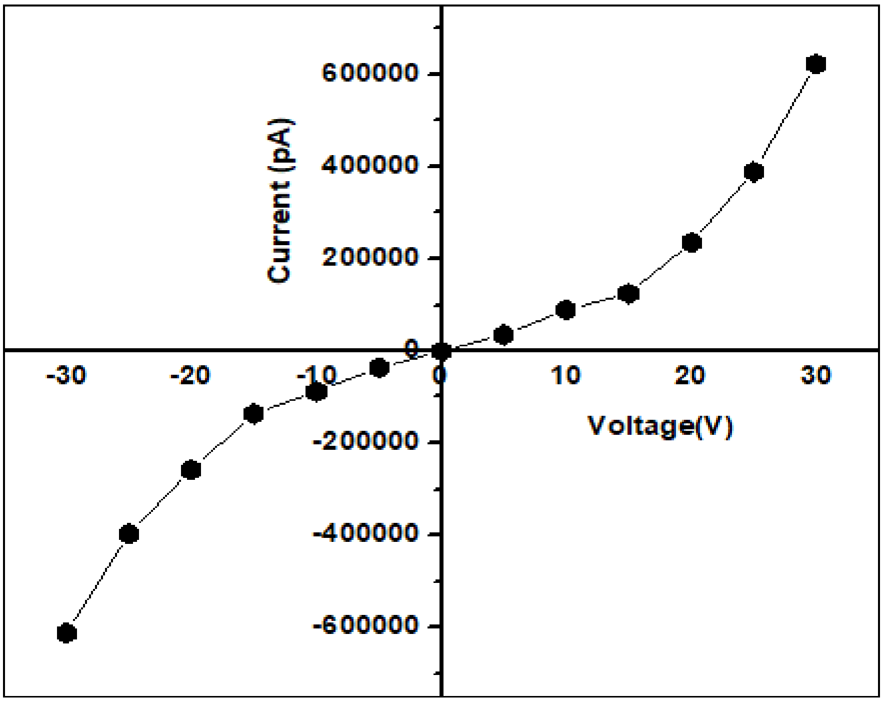

Figure 4: I-V characteristics of SnO_2 thick films at room temperature

3.2 Study of Photoresponse of pure SnO_2 thick films

Investigations into developed thick films' light-dependent conductance variation as an optical sensor were carried out. The light sensing characteristics of developed thick films were examined at multiple wavelengths of 640, 550, 510, and 450 nm using red, yellow, green, and blue color filters and a Photoresponse characterization system. Photoresponses characterization static system consist of a 5 Watt light source, a distance adjustment feature, a color filter holder, a sample holder, and a +5VDC fixed power supply. The change in current was evaluated in relation to the light intensity in this arrangement by rotating light source form the thick film. A variation in current of film with an alteration in intensity across a distance ranging from 2 cm to 40 cm was measured using a Lux meter. The photocurrent through the film was measured by the position of filter is kept fix the near SnO_2 film and change the position i.e. distance of light source is vary from film to another point and measured response photocurrent response through the prepared film [18]. Figure 5 illustrations the current response of pure SnO_2 thick film for different used color filters. From fig. 5, it has been observed that as distance is increased the photocurrent decreased of the films. From this plot it is confirmed that, prepared pure SnO_2 thick film shows optical response or photo response and it could be used for optical device applications.

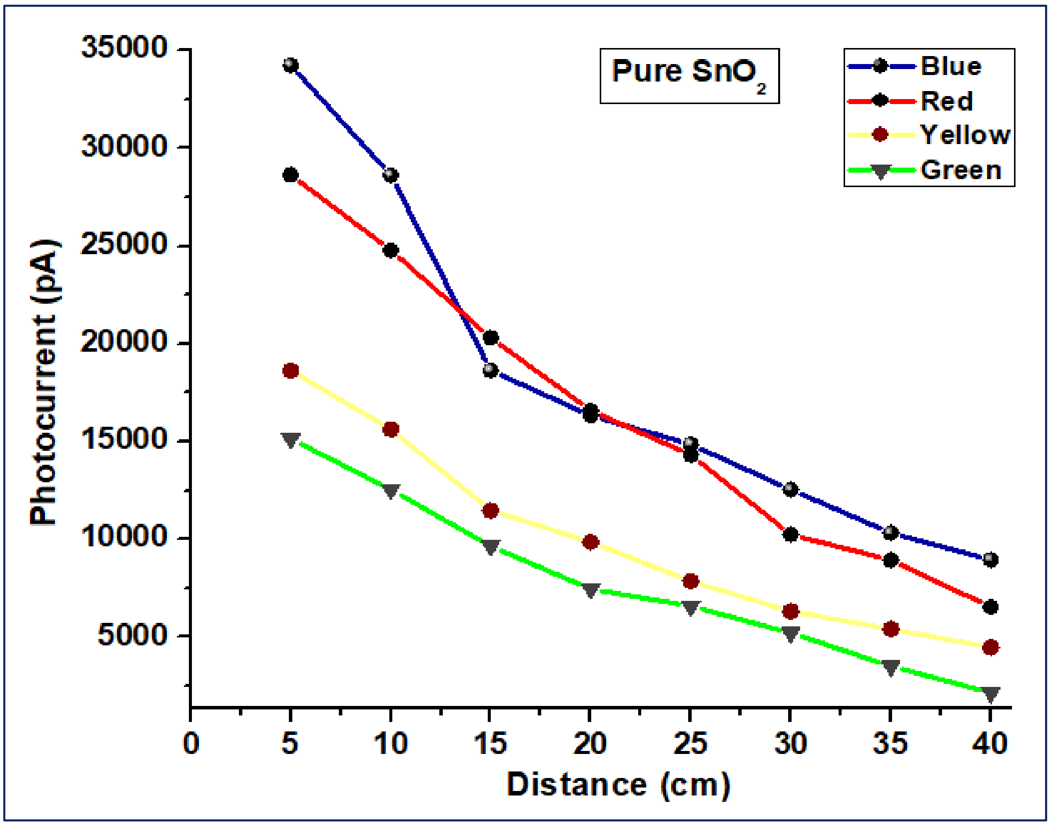

Figure 5: Distance versus photocurrent plot of SnO_2 thick film

CONCLUSION AND FUTURE SCOPE:

In summary, the SnO_2 nanoparticles can be synthesized by participation method. The thick films of SnO_2 can be developed using screen printing system. Prepared SnO_2 thick films shows good electrical properties as well as photo response which indicate that it could be used for photodetectors development application. The optical and solar cell nanomaterials offer numerous benefits, including enhanced light-matter interaction, efficient energy conversion, cost reduction, lightweight and flexible device design, environmental sustainability, advances in optoelectronics, miniaturization, and tailorable properties. Tin oxide is a versatile material with notable properties that make it useful in photovoltaics, and development of optical devices. Ongoing research continues to uncover new applications and refine the properties of tin oxide for a wide range of technological advancements.

ACKNOWLEDGEMENT:

Author is very much thankful to MGV's, Arts, Science and Commerce College, Nampur, Tal- Santana, India for providing lab facilities. I would also thanks to Principal of our college, for his constant guidance and extensive support to encourage for this work.

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