STRUCTURAL AND OPTICAL PROPERTIES OF SnS_2 NANOSHEETS FOR OPTO-ELECTRIC DEVICES

A DISSERTATION

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OF

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MAY, 2025

CANDIDATES'S DECLARATION

We, **PREETI KUMARI**, Roll No. **23/MSCPHY/80**, and **RIMPAL MORYA**, Roll No. **23/MSCPHY/42** students of M.Sc. Physics hereby declare that the project Dissertation titled **"Synthesis and Characterisation of SnS_2 Nanosheets by Sol-Gel for Multifunctional Applications"** which is submitted by us to the Department of Applied Physics, Delhi Technological University, Delhi in the partial fulfilment of the requirement for the award of the Degree of Master of Science, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I, hereby certify that the Project Dissertation titled **"Synthesis and Characterization of SnS_2 Nanosheets by Sol-Gel for Multifunctional Applications"** which is submitted by **PREETI KUMARI**, Roll No. **23/MSCPHY/80**, and **RIMPAL MORYA**, Roll No. **23/MSCPHY/42,** Department of Applied Physics, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Science, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree iof Diploma to this University or elsewhere.

Place: Delhi **Dr. Nitin Kumar Puri**

Date: 25/05/2025 **(Professor)**

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ABSTRACT

Tin disulfide (SnS_2) is a promising material for applications in hydroelectric cells, photovoltaics, photodetectors, and energy storage owing to its layered structure, excellent optical properties, electrical and high chemical stability. In this study, SnS_2 nanosheets were fabricated using the sol-gel technique, a method known for its efficiency in producing high-purity nanostructures on a large scale at a reasonable cost. To produce the final SnS_2 nanosheets, a precursor solution consisting of Sn and sulfur sources were prepared. This was followed by careful hydrolysis of Tin (IV) chloride pentahydrate with thiourea, forming a gel, which was dried and annealed to obtain crystalline SnS_2 nanosheets. X-ray diffraction (XRD), Transmission electron microscopy (TEM), Fourier transform infrared spectroscopy (FTIR), UV-Vis spectroscopy, and Photoluminescence spectroscopy (PL) were used to investigate the structural, morphological, chemical bonds, optical and electrical characteristics of the produced SnS2. While TEM showed a layered and distinct nanostructure, the XRD investigation verified the production of a pure hexagonal SnS_2 phase. UV-Vis spectroscopy estimates a band gap of 2.37 eV. PL spectra showed a prominent emission peak at 699 nm, suggesting a direct bandgap transition suitable for optoelectronic devices. The chromaticity diagram was created using PL data indicate the blue color emitted by the light source which can be used in electro-optical devices. FTIR analysis of sol-gel-synthesized SnS_2 confirmed the presence of Sn-S bonds, indicating successful compound formation. According to these estimations, the optical band gap falls within the range appropriate for optoelectronic applications. The results show that the sol-gel process is a productive way to create high-quality SnS_2 with adjustable characteristics, making it a good option for next-generation energy harvesting and electronic devices.

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LIST OF SYMBOLS, ABBREVIATIONS

NPs	Nanoparticles
nm	Nanometers
eV	Electron volt
SnS_2	Tin disulfide
XRD	X-ray diffraction
FTIR	Field transform infrared spectroscopy
TEM	Transmission electron microscopy
UV	Ultraviolet Visible
PL	Photoluminescence
JCPDS	Joint Committee on Powder Diffraction Standards
CIE	Commission International DeI'Eclairage

CHAPTER-1

INTRODUCTION

1.1 Nanotechnology

Nanotechnology operates at the nanoscale, applying technology to practical, real-world uses. The unique physical and chemical properties of nanomaterials can be utilized for societal gain. Recognized as a megatrend, nanotechnology has developed into a general-purpose technology [1]. In addition to incorporating these nanomaterials into larger systems, it includes the design and application of chemical, physical, and biological systems at scales ranging from individual molecules or atoms to submicron sizes. This field has the power to completely alter our assumptions and viewpoints while offering solutions for global problems. Through the discovery and use of carbon nanomaterials, several technological advancements have been realized in areas such as biosensors, bioelectronics, and nanomedicine. It is anticipated that a comprehensive understanding of the electrical, optical, magnetic, and mechanical properties of nanostructures will facilitate the creation of the next generation of functional materials with a variety of applications in the multidisciplinary field of nanotechnology, which has gained popularity recently [2].

Recent progress in nanostructured materials and nanotechnology is set to significantly impact various sectors, including energy technologies and biomedical applications. This includes areas such as solar energy, energy storage, environmental management, tissue engineering, bioprobes, biomarking, cancer diagnosis and treatment, and drug delivery systems. Nanotechnology, which

involves understanding and manipulating matter at dimensions around 100 nm and smaller, is inherently interdisciplinary. The physical, chemical, and biological properties of materials of this scale, which differ from those of individual atoms, molecules, or bulk substances, enable novel applications. Understanding and creating better materials, instruments, and systems that capitalize on these unique properties as they are found and studied is at the heart of nanotechnology research and development. Applications for nanotechnology may be found in many fields, such as heavy industry, consumer goods, agriculture, medical, energy, chemistry and the environment, and information and communication. Globally, both rich and developing nations have taken notice of this technology's potential [3].

1.2 Literature Review

1.2.1 Synthesis Methods of Nanoparticles

Current studies in nanotechnology have identified numerous techniques for creating nanoparticles (NPs) from a wide array of materials. This field is recognized as an expanding industry that integrates various disciplines such as biology, chemistry, physics, and medicine, offering specific advantages [4]. Chemical processes like chemical bath deposition [5], hydrothermal [6], sol-gel [7], sonochemical approach [8], electrochemical technique [9], and microwave assisted synthesis [10], and precipitation using organic solvents, toxic compounds, reducing agents along with production of harmful by-products are important techniques through chemical approach. For physical synthesis technique such as vacuum vapour deposition [11,12], ball milling, gamma radiation and plasma require high energy and time. To synthesize

nanomaterials effectively and in an environmentally sustainable manner, it is essential to consider the limitations of both chemical and physical methods.

1.2.2 Tin Disulfide (SnS_2)

Tin disulfide research has gained more attention recently because of its wide band gap having superior electrical and optical characteristics [13]. In recent years, there has been growing interest in metal sulfide materials due to their distinctive structures and exceptional properties, which have found widespread use in fields such as photocatalysis [14], battery technology [15], and gas sensing [16]. In contrast to metal oxides, metal sulfides possess a smaller band gap width, which facilitates a beneficial electron exchange between the carriers within the material and the gas molecules being measured [17]. However, SnS_2 is another n-type semiconductor that shows great promise.

Among the various metal sulfides, tin sulfide stands out as a semiconductor with a low bandgap, characterized by a narrow indirect bandgap and a high quantum yield [18]. The SnS_2 semiconductor's forbidden band gap ranges from 1.82 to 2.88 eV [19]. Various morphologies of SnS_2 nanostructures, such as nanoparticles, nanobelts, nanosheets [20], and nanoflakes [21], nanotubes [22], nanoflowers [23], nanograins [24], have been successfully synthesized up to this point [25,26]. Two-dimensional layered compounds, SnS_2, are highly useful in a variety of industries, including spintronics, lithium-ion batteries, photocatalysis, and electrocatalysis [27]. The layered structure of SnS_2, an n-type semiconductor, is composed of two hexagonally ordered planes of S atoms sandwiched by the neighbouring sulphur layers and a hexagonally ordered plane of Sn atoms weak van der Waals contacts, which make it simple to isolate layers via

chemical or mechanical exfoliation [28]. Another reason for conducting the study is that tin (Sn), known for its low toxicity, renders SnS_2 a material that is both non-toxic and environmentally friendly also its components, Sn and S, are naturally abundant [29,30]. Incorporating 3d transition metals like Fe, Ni, Co, and Cr into SnS_2 material results in the introduction of magnetic moments, which subsequently causes either ferromagnetic or antiferromagnetic characteristics. On the other hand, doping SnS_2 with 4d transition metals such as Ag, Mo, and Ru modifies its band gap, thereby improving its optical properties [31].

1.2.3 Sol- Gel Method

In present work, a facile sol-gel method has been used to prepare hexagonal SnS_2 nanosheets and investigated their electrical, optical and structural properties as active material for multifunctional applications. [32]. Sol-gel technology plays a crucial role in material processing. This technology is particularly valuable when it enables the creation of superior materials, allows for the production of target materials at significantly reduced costs, or is the sole method available for manufacturing the desired material. Over the past thirty years, extensive and intensive fundamental research has demonstrated the remarkable versatility of the sol-gel method. This technique is used to process a wide variety of materials, including metallic, inorganic, organic, and hybrid types. The materials produced through this method are utilized in both highly advanced applications and general use. The technological fields that benefit from this method range from photonics to biology, highlighting the sol-gel method's applicability to an exceptionally broad array of materials [33]. To develop high-performance devices based on SnS_2, it is essential to manage the electrically active defects within the material [34]. In the process of preparing tin disulfide nanoparticles, selecting an appropriate solvent is a critical step. This choice ensures that the initial solution is of high quality, which is essential for producing

SnS_2 with desirable properties for various applications. Many researchers have documented a range of transition metal-doped SnS_2 uses, such as attenuated magnetic semiconductors, field-effect transistors, and water splitting [35].

1.2.4 Applications of Tin Disulfide Nanaosheets

SnS_2 nanosheets have become a focal point of research due to their unique two-dimensional form, adaptable electronic properties, and environmental compatibility. Their expansive surface area and optimal bandgap (around 2.2–2.4 eV) render them ideal for numerous applications. In optoelectronics, SnS_2 nanosheets are prominently featured in photodetectors and solar cells, where their superior light absorption and high photoresponsivity enable efficient detection of visible light and energy transformation. In the context of energy storage, these materials are regarded as promising anodes for lithium-ion and sodium-ion batteries, attributed to their high capacity and dependable cycling stability, which are a result of their layered design and excellent conductivity. SnS_2 also excels in photocatalysis for environmental remediation and hydrogen production, as well as in gas sensing, where its high sensitivity and selectivity allow for the detection of toxic gases such as NO_2 and NH_3. Moreover, its biocompatibility and surface reactivity make it suitable for biosensors that detect biomolecules like glucose or DNA. These varied applications emphasize the versatility and technological potential of SnS_2 nanosheets in advanced electronic, energy, and environmental systems.

CHAPTER – 2

EXPERIMENTAL SECTION

2.1 Materials Used

The materials for this research were sourced from Sigma Aldrich and fisher scientific, tin (IV) chloride pentahydrate ($SnCl_4.5H_2O$), ethanol (C_2H_5OH), ethanolamine ($NH_2CH_2CH_2OH$), thiourea (CH_4N_2S). All of these compounds were employed in the production of pure SnS_2 without undergoing any further purification.

2.2 Why we choose SnS_2 for Synthesis

We selected SnS_2 for synthesis due to its layered structure, abundance in nature, and non-toxic characteristics, along with its appropriate bandgap of approximately 2.2–2.4 eV, which is suitable for visible light applications. Its excellent optical absorption, favorable electrical properties, and compatibility with cost-effective, scalable synthesis techniques make it an ideal candidate for photodetectors, solar cells, optoelectronic devices, and used for various multifunctional applications.

2.3 Synthesis of SnS_2 Nanosheets

The chemicals for this research were sourced from Sigma Aldrich and were utilized in their unmodified state. 3g tin (IV) chloride pentahydrate ($SnCl_4.5H_2O$) was dissolved in 60ml of ethanol (C_2H_5OH) at room temperature using magnetic stirrer for 24 hours ~0.02ml of

ethanolamine ($NH_2CH_2CH_2OH$) was poured after 10 minutes of stirring using pipette as a stabilizer and it turns the solution light yellow. After 30 minutes of stirring 4g of thiourea (CH_4N_2S) as a sulfur source was added to the mixture and, the solutions become white [36]. After 24h of stirring the solution became yellow and was stirred at 90°C for 5h to convert the solution into gel form. After cooling the solution, the gel was kept in oven at 150°C for 24h, so that the sample get dry completely. The successive steps employed in the synthesis of SnS_2 are presented in Fig. 1.

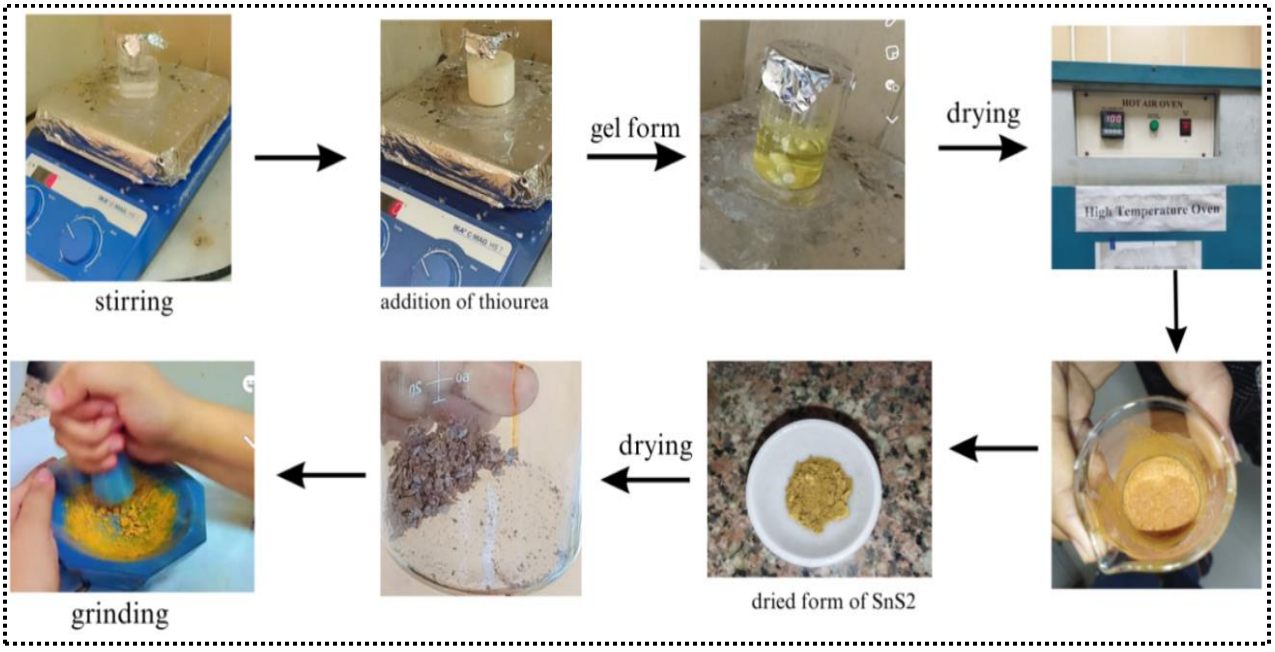

Figure 1 : Synthesis of SnS_2 nanosheets.

CHAPTER – 3

CHARACTERIZATION TECHNIQUES

3.1 X- ray Diffraction (XRD)

The lattice planes that the atoms in the crystal produce cause X-ray diffraction, a significant interaction between X-rays and crystalline materials. The X-ray's wavelength, the crystal's orientation, and its structure all affect how the X-ray beam is diffracted as it passes through it. When a certain wavelength of radiation is partly reflected between surfaces (i.e. ,the atomic planes), it will constructively interfere in the macroscopic perspective of X-ray diffraction, resulting in a path difference that is an integer multiple of the wavelength. This phenomenon is described by Bragg's law:

$$n\lambda = 2d\sin\theta,$$

where, d is the distance between surfaces, θ is the angle between the radiation and the surfaces, n is an integer, and λ is the wavelength of the radiation. According to this connection, interference effects only become noticeable when radiation interacts with physical dimensions that are about equal to the wavelength of the radiation. Diffraction techniques need radiation in the X-ray portion of the electromagnetic spectrum, or beams of electrons or neutrons with comparable wavelengths, since atoms or ions are separated by around 10^{-10} m (1Å). As a result, any crystalline substance may be identified and examined using X-ray spectra. The level of order or crystallinity will affect how well the outcomes turn out. A diffractometer is necessary to do this.

3.2 Fourier Transform Infrared Spectroscopy (FTIR)

Infrared spectroscopy is a crucial technique for characterizing materials, providing insights into molecular composition, structure, and morphology. Its advantages include wide applicability, non-destructive analysis, operation under normal conditions, and the ability to provide detailed structural information. Fourier transform infrared spectroscopy (FTIR), a computer-based technique that enables spectrum storage and processing, offers additional benefits beyond the inherent advantages of traditional dispersive infrared spectroscopy. These benefits include increased sensitivity, higher precision (with better frequency resolution and reproducibility), fast measurements, and extensive data processing capabilities. IR spectra are often seen as absorption spectra in the infrared spectrum and are caused by transitions between two vibrational modes of a molecule in its electronic ground state. A molecule has to have a persistent dipole moment in order to exhibit infrared absorption bands. Such a molecule can interact with the oscillating electric field of incoming infrared light when its permanent dipole vibrates. For this vibrational mode to be infrared active, meaning it produces a visible infrared band, there must be a change in the molecule's dipole moment during the vibration.

3.3 Transmission Electron Microscopy (TEM)

TEM offers strong methods with remarkably high spatial resolution for examining a variety of material characteristics. The study of shape, size distribution, crystal structure, strain, flaws, and atomic-level chemical information are all included in this. The data obtained from TEM is based on the interaction between electrons and the sample. Images are generated by capturing electrons that have traversed the thin sample, which is why it is called "transmission" electron microscopy. For electron transmission to occur, the TEM sample must be extremely thin, generally less than

200 nm thick, depending on the sample's composition and the specific details being sought from the TEM analysis.

3.4 UV- Visible

UV-Visible spectroscopy is recognized for its simplicity, speed, sensitivity, selectivity, and reliability in analyzing various synthesized nanomaterials and monitoring their interactions and stability. This method also facilitates the characterization of colloidal suspensions without requiring calibration. The technique is based on the absorption, reflection, and transmission of photons through samples, which can be in liquid form or as transparent and opaque solids, within the UV-Visible spectrum. This spectrum includes light photons from the UV range (200–400 nm) to the visible range (400–800 nm) of the electromagnetic spectrum, where electronic transitions occur in atoms and molecules. Absorption spectroscopy involves measuring the absorption of electromagnetic radiation based on wavelength or frequency, concentrating on the light beam that traverses the sample. The absorption spectra of a sample reveal its color in the visible range.

3.5 Photoluminescence (PL)

Luminescence is a broad term used to describe phenomena where energy absorption leads to light emission. Phosphors, which are luminescent substances, emit light when exposed to radiation and are typically found as microcrystalline powders or thin films that produce visible colors. After extensive research and development over the years, numerous phosphors have been created, with some finding widespread use in various fields. When a photon is absorbed, it can

excite luminescent materials that either fluoresce or phosphoresce. Generally, fluorescence occurs quickly, on a nanosecond scale, while phosphorescence is slower, lasting from hours to even days. For clarity, photoluminescence is categorized into two main types: one involving larger inorganic materials that mainly show phosphorescence, and the other involving smaller dye molecules and small-particle inorganic materials, or "nanomaterials," which can exhibit either fluorescence or phosphorescence. Their uses vary, and for many technical applications, it does not matter whether the luminescence is due to fluorescence or phosphorescence.

CHAPTER – 4

RESULT AND ANALYSIS

4.1 Structural Analysis

The XRD pattern of SnS_2 nanosheets synthesized via the sol-gel method is illustrated in Fig. 2, offering insights into the sample's crystalline structure. The XRD spectrum reveals prominent peaks associated with various SnS_2 crystalline planes, specifically (001), (002), (102), (111), (103), and (004), occurring at 15.27°, 29.55°, 40.16°, 51.5°, 54°, and 64.12°, respectively. These diffraction patterns align with the standard JCPDS card for hexagonal SnS_2 (JCPDS-23-0677). Notably, the X-ray reflection from the (001) crystal plane demonstrates a significant increase in peak intensity, characterized by its sharpness and strength, indicating a high degree of crystallinity in the sample. The interplanar spacing of the four most prominent peaks is calculated using Bragg's law.

$$n\lambda = 2dSin\theta$$

Here, 'd' signifies the calculated d-spacing values for various high-intensity planes in the SnS_2 nanosheets, and 'λ' is the utilized X-ray wavelength (0.15418 nm). Table 1 presents the d-spacing measurements obtained from XRD analysis of 2D SnS_2 nanosheets, offering valuable insights into their crystalline structure and orientation. These measurements indicate the gaps between atomic planes, substantiating the layered configuration typical of 2D materials and underscoring the nanosheets preferential alignment. The average lattice spacing of the SnS_2 nanosheets is determined to be 0.58 nm using the Bragg equation [37]. This orientation plays a crucial role in applications such as water splitting or optoelectronics, where the material's alignment significantly affects its operational efficiency [38][39].

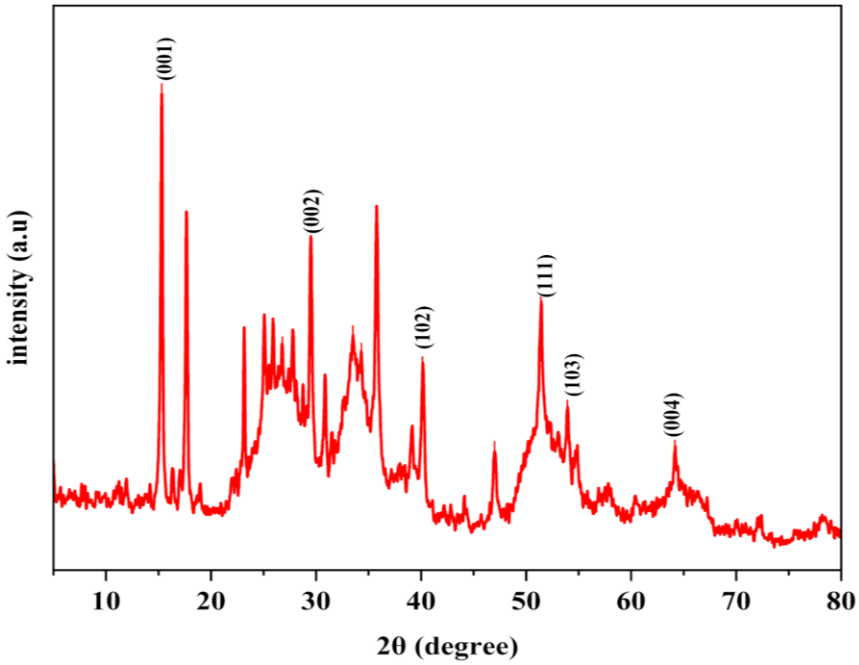

Figure 2 : X-ray diffraction pattern of as synthesized SnS_2 nanosheets.

Table 1: The d-spacing values calculated for various planes of SnS_2.

2θ (degree)	hkl plane	d-spacing (nm)
15.27	(001)	0.58
29.55	(002)	0.30
40.16	(102)	0.22
51.5	(111)	0.17

4.2 FTIR study

Figure 3 displays the Fourier transform infrared spectra of the SnS_2 nanosheets, captured within the range of 4000-300cm^{-1}. The sample exhibits peak formation at roughly 490 cm^{-1}, which can

be attributed to SnS_2 bonding, Water molecules bending vibrations (OH) are typically associated with the bands observed at 3627 cm^{-1} and 1139 cm^{-1}. The peak around 1412 cm^{-1}may indicate C=O stretching vibration, suggesting the possible presence of carbonyl groups or other oxygen-containing functional groups on the surface. There is also a band at 1746 cm^{-1} that is due to C=C stretching. The existence of the SnS_2 nanostructure is validated by the characteristic peaks of SnS_2 in the FTIR analysis and the XRD result ($2\theta = 15.27^{\circ}$) [40].

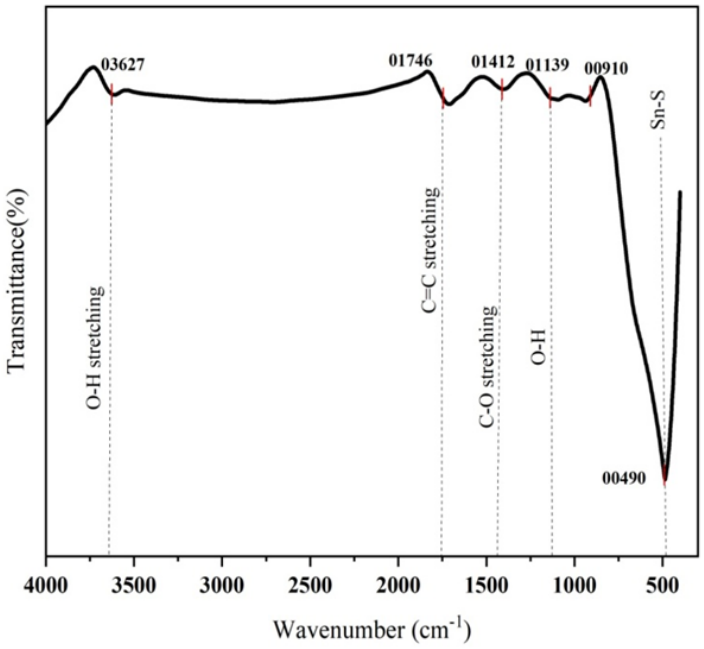

Figure 3 : FTIR spectra of as synthesized SnS_2 nanosheets.

4.3 Surface morphology analysis

Transmission Electron Microscopy (TEM) was employed to examine the morphological and structural characteristics of SnS_2 nanosheets synthesized via the sol-gel process, as depicted in Fig. 4, with a scale of 800 nm. SnS_2 features a layered structure similar to CdI_2, where layers of

cations (Sn) are positioned between two layers of anions (S), with the neighboring anionic layers held together by van der Waals forces [41]. The sheets were observed to be evenly distributed with minimal clumping, suggesting effective control over sheets formation during the synthesis process. The average sheet size was determined to be within the range of X–Y nm (537.79-520.60), confirming the nanoscale characteristics of the synthesized material. In the structure of SnS_2 nanosheets, tin cations and sulfur anions are robustly bonded, forming a monomolecular layer with a triple sandwich configuration [42]. These monomolecular layers in SnS_2 nanosheets are connected through Van der Waals interactions and form hexagonal SnS_2 nanosheets as confirmed by XRD spectra having sharp peak at (001) planes. [43][44][45].

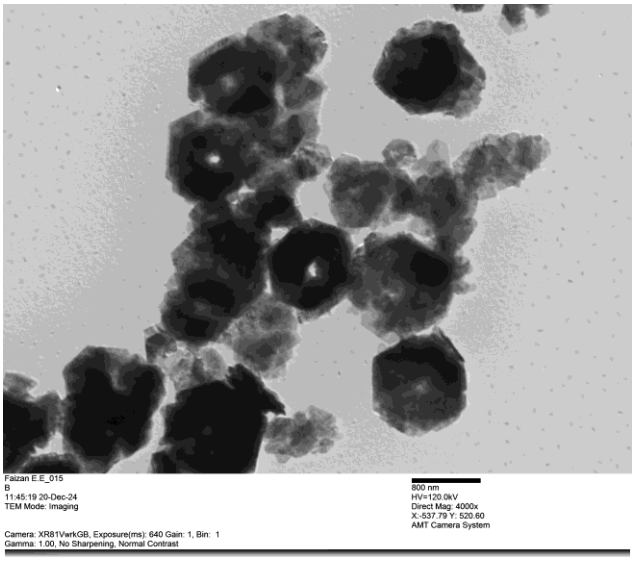

Figure 4 : TEM microscopy image of SnS_2 nanosheets.

4.4 Optical study

The optical absorption spectra of the as-synthesized SnS_2 nanosheets are shown in Fig. 5(a). UV-Vis's spectroscopy was employed to analyze the absorption spectra of the as-synthesized SnS_2 nanosheets. The optical absorption analysis in the UV-vis range unveiled a notable absorption

band spanning 200-800 nm wavelength, as illustrated in Figure. Peak absorption for the SnS_2 nanosheet occurred at 342 nm. The wide spectrum observed in the visible region indicates that SnS_2 nanosheets can effectively capture visible light, suggesting its potential as a photocatalyst under visible light exposure. Fig.5(b). demonstrates that the band gap of the SnS_2 nanostructures, calculated using the Tauc method, was approximately 2.37 eV. This value indicates the material's capacity to function as a photocatalyst when irradiated with visible light. The Tauc method utilizes the given equation.

$$(\alpha h\nu)^n = A\,(h\nu - Eg)$$

where v is the incident beam frequency, h is Planck's constant, n is the transition, and A is the optical transition dependent constant. Eg is the optical energy bandgap.

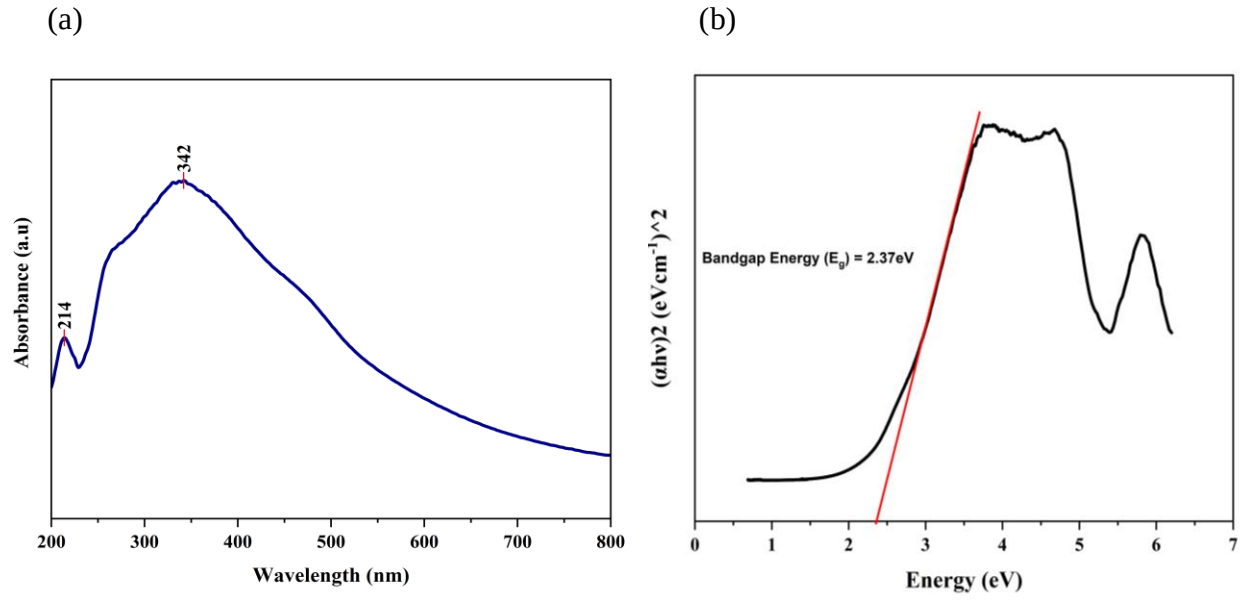

Figure 5 : UV spectra of as-synthesized SnS_2 nanosheets, (b) Energy band gap of SnS_2 nanosheets

4.5 PL analysis

Photoluminescence (PL) spectroscopy offers a highly effective, non-invasive method for assessing and analyzing the quality of surfaces and interfaces without physical contact. This technique also excels in examining defect levels within materials, making it a versatile tool for material characterization. Fig. 6(a) shows the PL spectra of SnS_2 recorded at an excitation wavelength of 350 nm in the range of 400 - 800 nm. It mainly consists of the peaks at 480 nm, 538 nm, and 699 nm. The wide-ranging emission spectra of SnS_2 can be attributed to numerous defects, including a high concentration of Sn and sulfur vacancies that are introduced during the manufacturing process. In addition to these vacancies, the nanosheets may also contain other types of imperfections, such as interstitial defects and stacking faults. The PL spectrum shows peaks centered at about 477 nm for blue, 539 nm for green and 699 for red radiations [47]. The deconvoluted photoluminescence spectra are shown in Figure 6(b), which shows four fitted Gaussian bands in the visible spectrum. About 402 nm, 477 nm, 539 nm, and 699 nm are the centers of these four emission peaks, which correspond to energies of 3.08eV, 2.59eV, 2.30eV, and 1.77eV, respectively. The excitation of an electron from its excited state to its ground state, which releases energy in the form of photons, is determined by the SnS_2 nanosheets' deconvolution curve. The strongest PL peak measured at 699 nm yielded an energy of 1.77 eV. SnS_2 nanosheets were found to exhibit both violet and blue emissions, with wavelengths of 402 nm and 477 nm, respectively. These emissions are ascribed to near band-edge emission and radiative recombination involving bound excitons, or they may be influenced by interstitial sulfur defects [46].

The green emission at 539 nm is attributed to the deep-level emissions within the electronic structures of SnS_2, potentially caused by interstitial tin atoms [47]. The emission peak observed at 699nm suggests that this shift in wavelength might reflect the impact of quantum confinement on electronic transitions within the nanoscale SnS_2 structures or the strain effect caused by the dopant ions within the SnS_2 lattice [47].

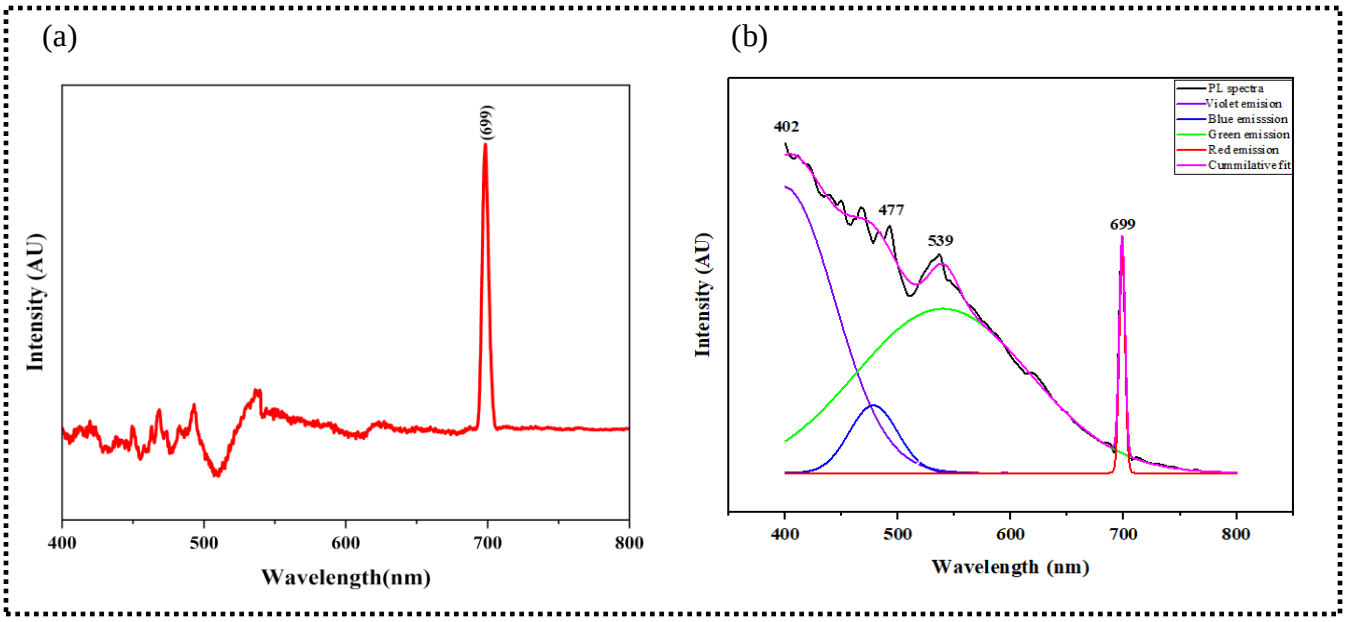

Figure 6: (a) PL spectra of SnS_2 nanosheets, (b) Deconvolution of photoluminescence spectra of SnS_2 nanosheets

4.6 The Commission International DeI'Eclairage (CIE) Chromaticity Diagram Analysis

Fig. 7 shows the CIE (Commission International DeI'Eclairage) chromaticity diagram of SnS_2 nanosheets excited by 350 nm laser. As depicted in Fig. 7, the chromaticity coordinates (0.25881, 0.28651) of colors were determined using the CIE chromaticity diagram were advances to blue light. The SnS_2 composite is potentially a suitable material for creating backlighting and other blue LEDs with a controlled composition. This would connect

chromaticity coordinates within the blue spectrum, making the composite a valuable material for the development of various electro-optical devices [48].

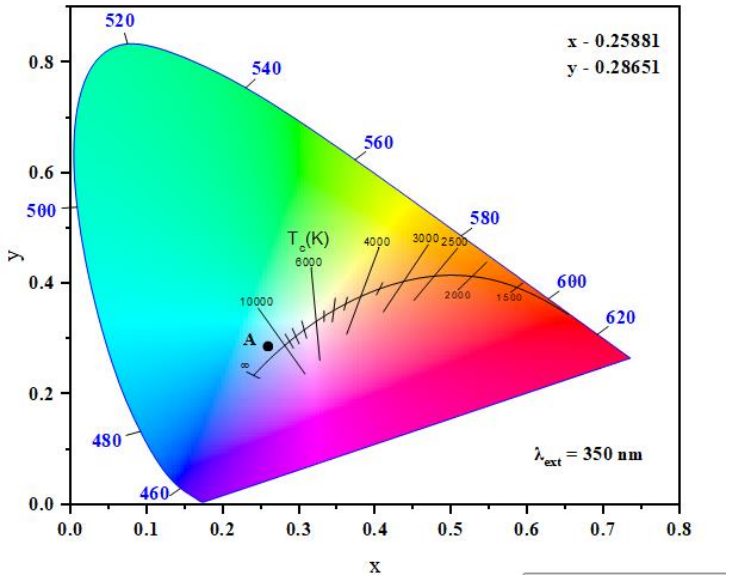

Figure 7: CIE chromaticity diagram of pure SnS_2

CHAPTER – 5

CONCLUSION

The hexagonal SnS_2 nanosheets, characterized by high crystal quality, have been successfully synthesized via the sol-gel method. The average lattice spacing of the SnS_2 nanosheets has been determined to be 0.58 nm using the Bragg equation. The presence of the SnS_2 nanosheets is confirmed by the characteristic peaks of SnS_2 observed in the FTIR analysis and the XRD result ($2\theta = 15.27°$). The bandgap of the SnS_2 nanosheets is approximately 2.37 eV, as determined by absorption measurements. The broad emission spectra of SnS_2 are attributed to various defects, including a significant presence of Sn and sulfur vacancies that occur during the production process. The energy calculated from the highest photoluminescence (PL) peak observed at 699 nm is 1.77 eV. The peak emission at 699 nm suggests that this wavelength shift may be due to the influence of quantum confinement on electronic transitions in the nanoscale SnS_2 structures or the strain effect induced by dopant ions within the SnS_2 lattice. Owing to its tunable band gap and unique properties, SnS_2 is a promising material for multifunctional applications.

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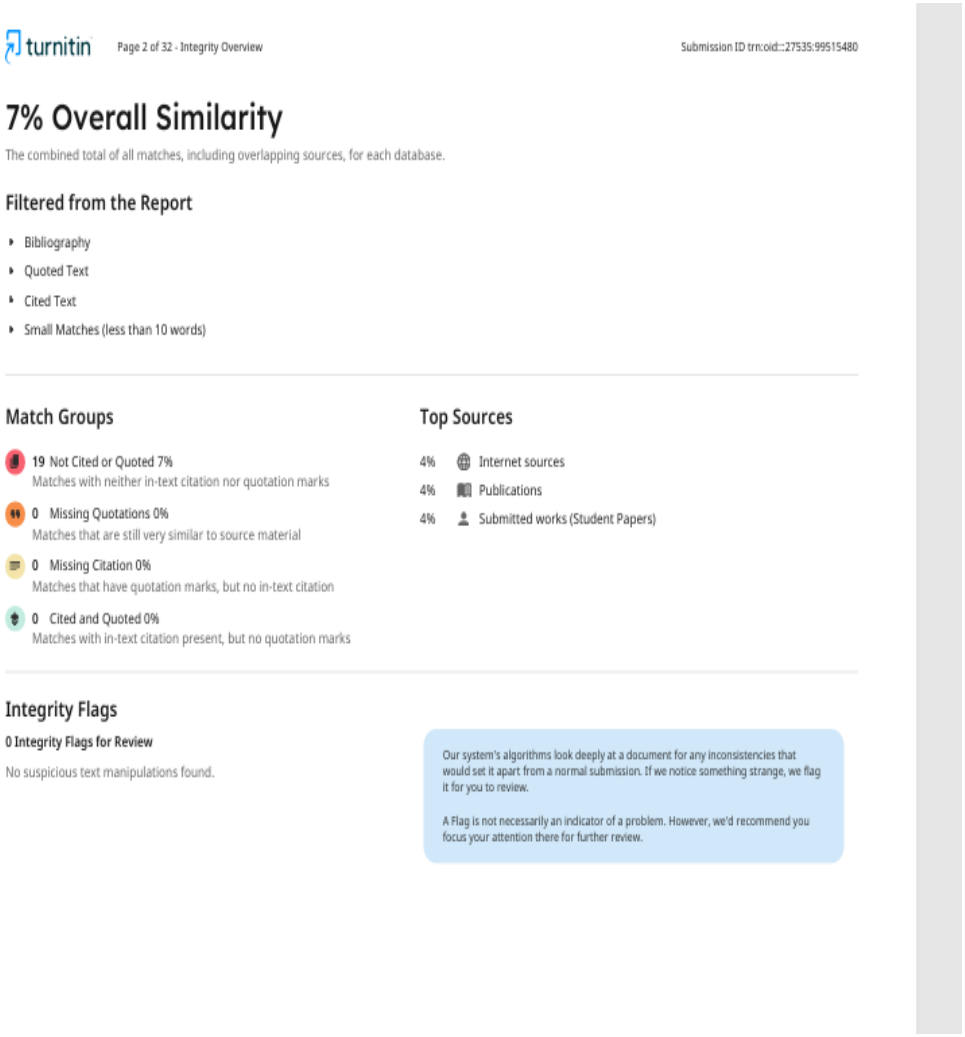

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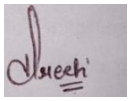

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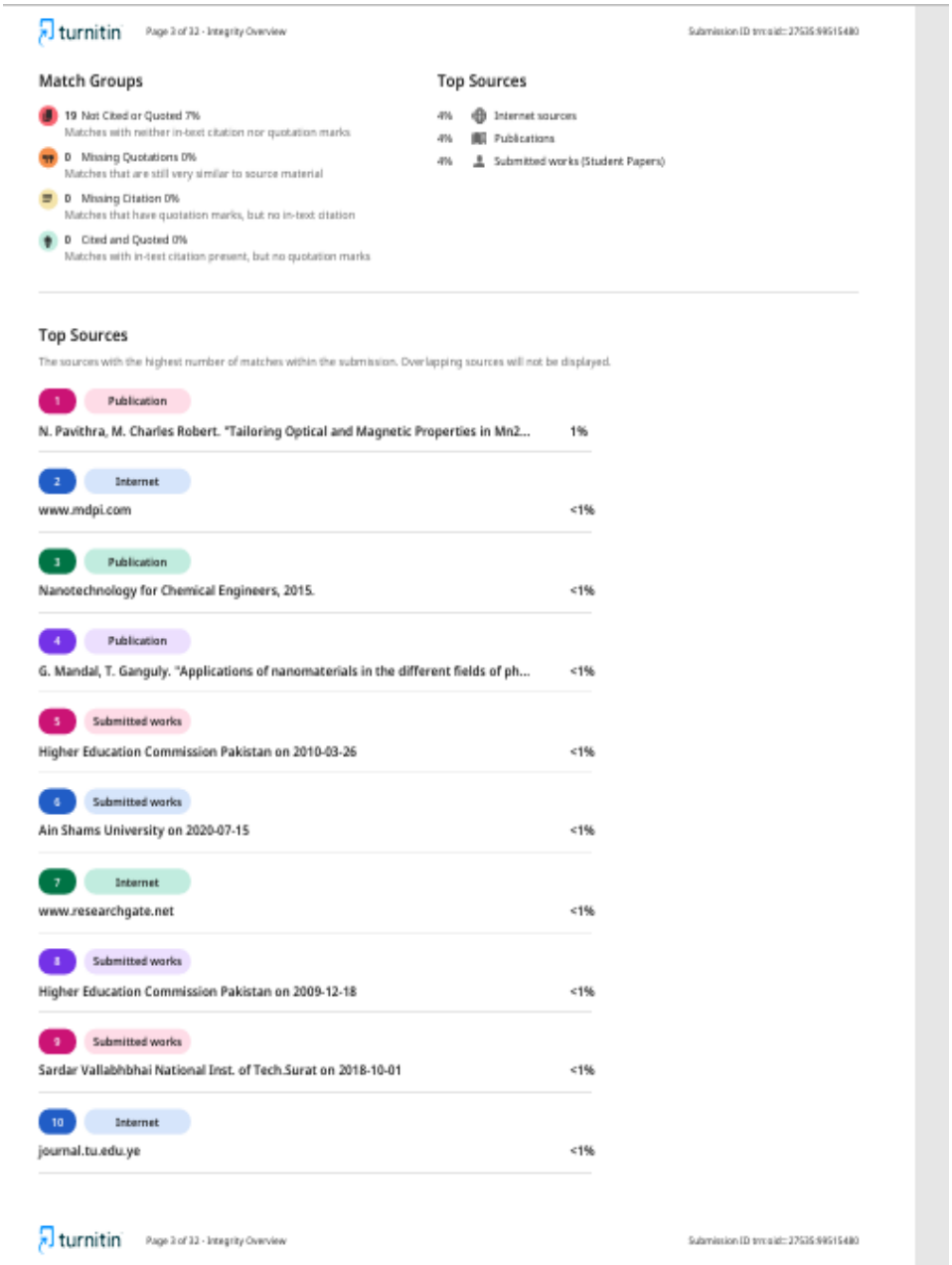

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Presented a paper titled SYNTHESIS AND CHARACTERIZATION OF SnS_2 NANOSHEETS BY SOL-GEL METHOD FOR MULTIFUNCTIONAL APPLICATIONS

in the International Conference (ICANN 2025) held at Rajdhani College, University of Delhi on March 05-06, 2025.

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Prof. Rajesh Giri
Principal, Rajdhani College

Dr. Jasvir
Convenor, ICANN-2025

ACCEPTANCE OF ABSTRACT

ICANN - 2025 <ann@rajdhani.du.ac.in> Thu, Feb 20, 4:14 PM

to me

Dear Preeti,

Subject: Acceptance of Abstract for Presentation at ICANN-2025

I am pleased to inform you that your abstract submitted for the **International Conference on "Advanced Nanomaterials and Nanotechnology" (ICANN-2025)**, scheduled to be held in hybrid mode on March **5-6, 2025**, has been accepted for presentation.

We appreciate your valuable contribution to the conference, organized by the **Department of Physics, Rajdhani College, University of Delhi, New Delhi.** Your research aligns well with the conference themes, and we look forward to your participation.

Please register yourself using the following link.

Registration link: https://forms.gle/QR1fSHWaKFP8UnGs9

Kindly confirm your participation by completing the registration process, we request you to do so at the earliest to ensure your participation.

We will provide you with the detailed technical program, including the schedule of sessions, keynote talks, and your presentation slot, closer to the conference date. Additionally, information regarding the publication of conference papers, including guidelines, timelines, and the associated publication process, will also be shared with you in due course.

We look forward to welcoming you to ICANN-2025 and an engaging discussion on cutting-edge advancements in nanomaterials and nanotechnology.

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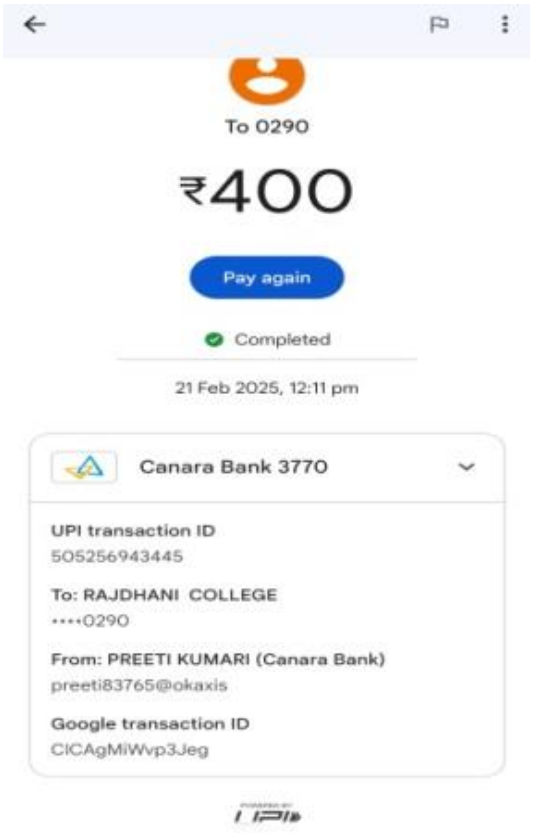

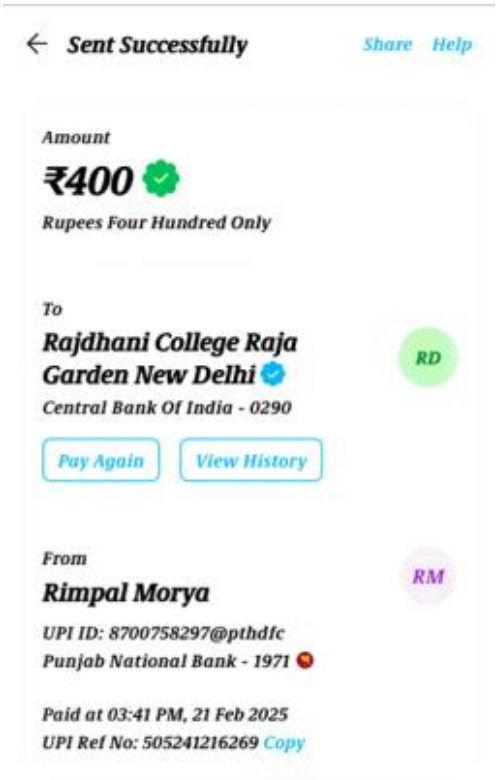

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From: **ICANN - 2025** <ann@rajdhani.du.ac.in>
Date: Saturday, June 7, 2025
Subject: Request for Consideration of paper Submission for ICANN2025
To: "Dr. Nitin Puri" <nitinkumarpuri@dtu.ac.in>

Subject: Acceptance of Paper for Conference Proceedings

Dear Dr. N. K. Puri,

Thank you for your submission.

We are pleased to inform you that your paper titled "Synthesis and Characterization of SnS_2 Nanosheets for Optical Applications by Sol-Gel Method" has been accepted for publication in the conference proceedings of ICANN 2025.

Congratulations, and we appreciate your valuable contribution.

Thanks and regards
Dr. Jasvir **D**alal,
Assistant Professor & Convener, ICANN-2025,
Department of Physics,
Rajdhani College, University of Delhi, Delhi- 110015

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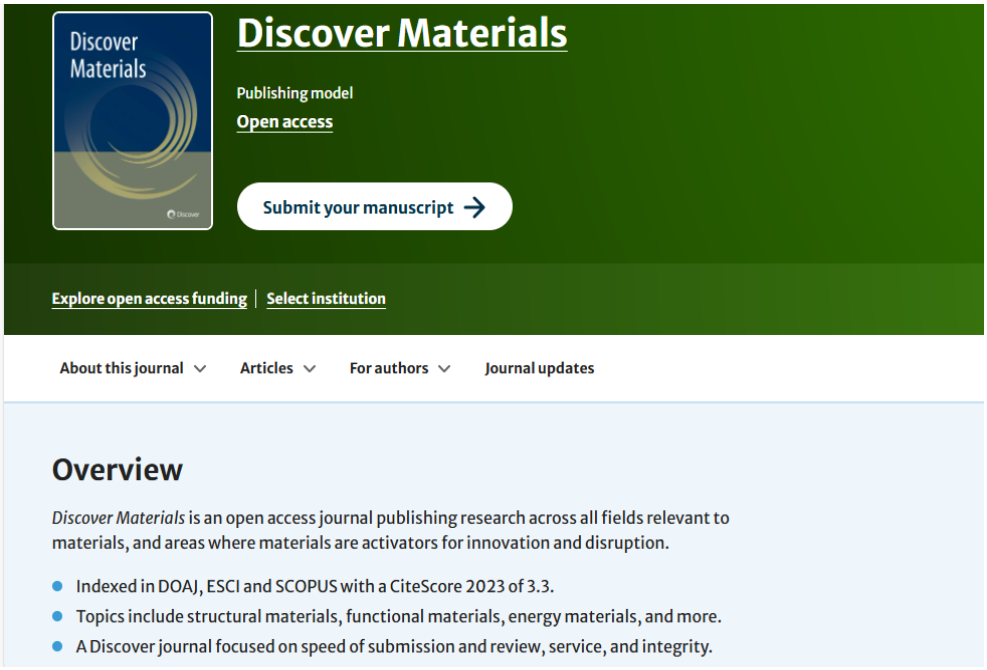

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Structural and Optical Properties of SnS 2 Nanosheets for Opto-electric Devices

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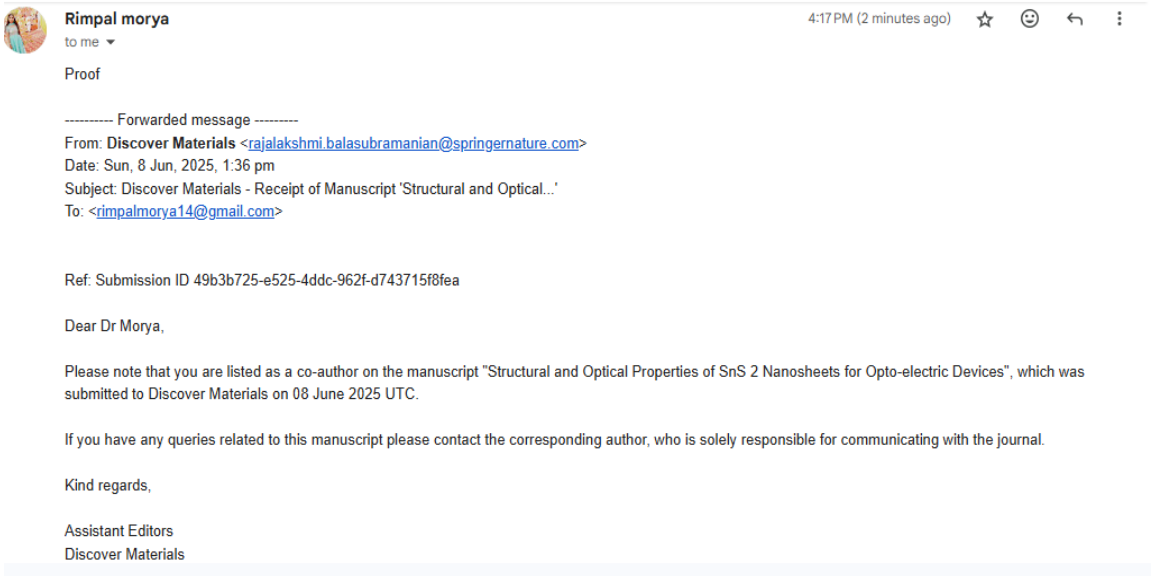

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Date: Sun, 8 Jun, 2025, 1:36 pm
Subject: Discover Materials - Receipt of Manuscript 'Structural and Optical...'
To: <rimpalmorya14@gmail.com>

Ref: Submission ID 49b3b725-e525-4ddc-962f-d743715f8fea

Dear Dr Morya,

Please note that you are listed as a co-author on the manuscript "Structural and Optical Properties of SnS 2 Nanosheets for Opto-electric Devices", which was submitted to Discover Materials on 08 June 2025 UTC.

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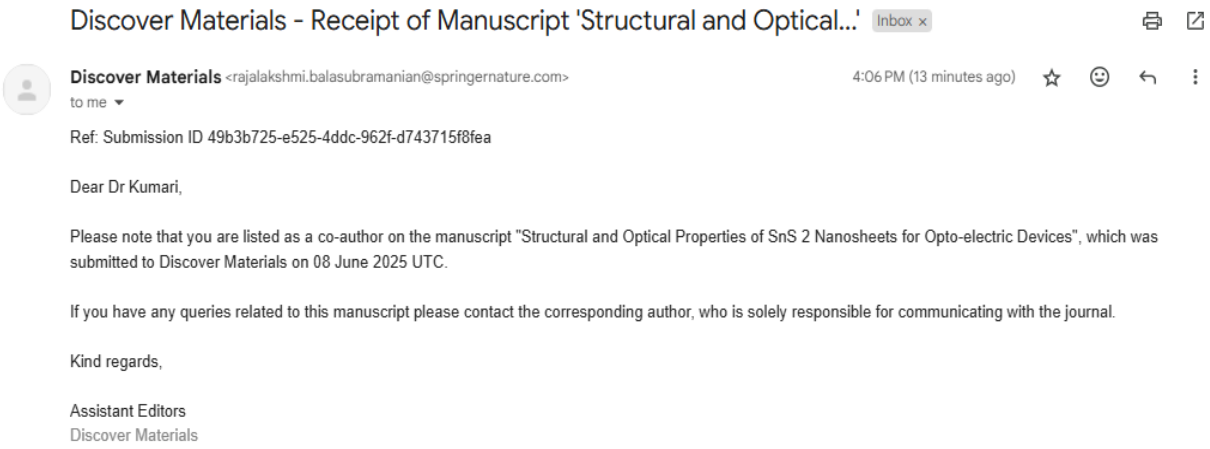

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to me

Ref: Submission ID 49b3b725-e525-4ddc-962f-d743715f8fea

Dear Dr Kumari,

Please note that you are listed as a co-author on the manuscript "Structural and Optical Properties of SnS 2 Nanosheets for Opto-electric Devices", which was submitted to Discover Materials on 08 June 2025 UTC.

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