Synthesis and Characterization of Pristine SnO_2 Thin Film for Solar Cell Application by Sol Gel Spin Coating Technique

Submitted in partial fulfillment of the requirements for the award of Master of Science degree in Physics

By

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DEPARTMENT OF PHYSICS

SCHOOL OF SCIENCE AND HUMANITIES

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INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **VIJAYA DHARANI. S (40590016)** who carried out the project entitled "**Synthesis and Characterization of Pristine SnO_2 Thin Film for Solar Cell Application by Sol Gel Spin Coating Technique**" under my supervision from **NOVEMBER 2021 TO MAY 2022.**

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Submitted for Viva voce Examination held on____________________

Internal Examiner
(Name in Capital Letters
with seal)

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With Seal)

DECLARATION

I **VIJAYA DHARANI. S (40590016)** hereby declare that the Project Report entitled **"Synthesis and Characterization of Pristine SnO_2 Thin Film for Solar Cell Application by Sol Gel Spin Coating Technique"** done under the guidance of **Dr. C. RAMESHKUMAR** is submitted in partial fulfillment of the requirements for the award of Master of Science degree in Physics.

(VIJAYA DHARANI.S)

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(VIJAYA DHARANI. S)

ABSTRACT

In this study, SnO_2 solution was successfully deposited on a glass substrate, and the films were characterized. The solvent was taken as ethanol, and the precursor was chosen as Tin (II) chloride dehydrate. The sol-gel spin-coating process was presented for fabricating SnO_2 thin films on glass substrates. A transparent SnO_2 sol was formed after continuous stirring. The thin film formed from SnO_2 sol were deposited on a glass substrate using spin coating at 1000 RPM for 80 seconds. Tin oxide's optical, electrical, and structural properties were beneficial for solar cells, gas sensors, optical-electronic devices and displays. The structural characteristics were carried out by using X-Ray Diffraction (XRD) measurement and Raman shift. Optical investigation was investigated using an UV visible spectrometer. Electrical characteristics was carried out using Hall effect measurement. The x-ray diffraction pattern revealed that the as deposited film had tetragonal crystal structure with preferable orientation along (110) plane. The tetragonal structure of all prepared samples was confirmed by X-ray diffraction spectra and the Raman scattering. Optical characteristics was investigated using a UV visible spectrometer. The optical band gap of tin oxide is calculated using Tauc's plot. The value is found is about 3.39-3.49 for solution and thin film samples. The transmittance of pure SnO_2 sample is about above 90. Therefore, it is found suitable for photo voltaic devices. The carrier concentration 7.0E+018 cm^3 and the mobility is $2.2cm^2/s$. The Resistivity value is 0.62 Ω-cm the undoped sample. Thus, the carrier concentration and resistivity values show the good conductivity nature of undoped tin oxide thin film.

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LIST OF ABBREVIATIONS

PV	Photo Voltaic
LED	Light Emitting Diode
LCD	Liquid Crystal Diode
OLED	Organic Light-Emitting Diode
CVD	Chemical Vapor Deposition
PVD	Physical Vapor Deposition
ALD	Atomic Layer Deposition
PLD	Pulsed Laser Deposition
MBE	Molecular Beam Epitaxy
CE	Chemical Etching
RPM	Rotation Per Minute
UV-VIS SPECTROSCOPY	Ultra Violet-Visible Spectroscopy
XRD	X-Ray Diffraction

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CHAPTER 1

INTRODUCTION

1.1 THIN FILM TECHNOLOGY

The current era of photovoltaic device technology celebrated its Golden Jubilee in 2003 **(Prince M et al., 2003).** Since the discovery of a p–n junction Si photovoltaic device in 1954, the science and technology of photovoltaic devices (solar cells) and systems have improved dramatically **(Chapin DM et al.,1954).** The most efficient single crystal Si solar cells presently achieve a 24.7 percent efficiency, vs a theoretical maximum of 30 percent **(Maycock PD et al.,2003).** In 2002, solar cell manufacturing on a wide scale surpassed 500 MWp, with single crystal Si cells accounting for 40%, multi crystalline Si cells for 51%, and thin-film amorphous Si solar cells accounting for 8% **(Martinot E et al.,2002).** Around 2 GW of solar cells are used in various applications all around the world **(Chopra K.L et al., 2004).**

It has a microscopically thin layer of material sediment onto metal or semi conducting materials. Thin-film studies have helped to advance new areas of research in both physics and chemistry which are based on phenomena unique characteristics like thickness, geometry, and structure of the film. Thin layers are used to customize or improve the performance of a device. When we consider a very thin film of some substance, we have a situation in which two surfaces are so close to each other. So, atoms can have a direct effect on the physical properties of the substance. The decrease of distance between surfaces and their interaction can result in the rise of completely new phenomena **(Agashe C et al.,2009).**

One dimension of the material is reduced to an order of magnitude of several atomic layers, creating an intermediate system between macro systems and molecular systems and thus providing us with a method for investigating the micro physical nature of processes. The film is particularly suitable for microelectronics and integrated optics applications. However, the physical properties of thin films (such as resistivity) are not significantly different from those of bulk materials. The film is two-dimensional, and the thickness of the film varies from nano meters to several microns.

When analyzed in the form of thin films, the properties of the materials are significantly different. Thin film technology is based on the fact that characteristics can be particularly controlled by thickness parameters. Thin films are of great importance in microelectronics, magnetic recording films, magnetic sensors, gas sensors, antireflection films, photoconductors, infrared detectors, interference filters, solar cells, and polarizers. Temperature controller in satellite superconducting film, anti-corrosion, and decorative coating **(Anwar M et al.,2008).**

1.2 DEFINITION

A thin film is a thin layer of material with a thickness ranging from a fraction of a nano meter to several micrometers. The principal applications that profit from thin-film fabrication are electronic semiconductor devices and optical coatings. The household mirror, which typically includes a thin metal coating on the back of a sheet of glass to generate a reflecting surface, is a well-known application of thin films. Silvering was previously a typical method for producing mirrors. Two-way mirrors are made using a very thin film covering. When a thin-film coating consists of numerous layers of varied thicknesses and refractive indices, optical coating performance is often improved **(Definitions.net. 2022).**

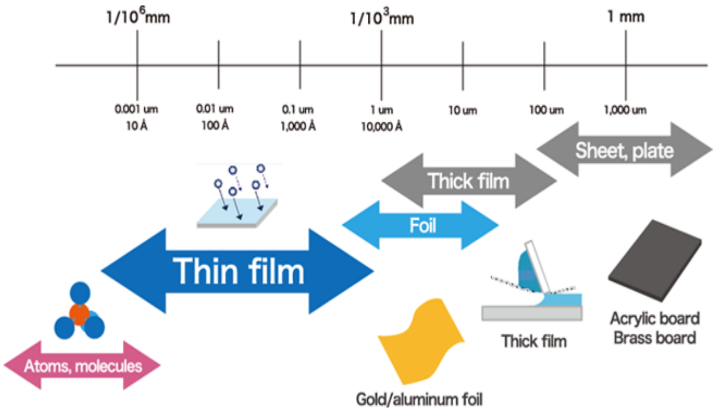


Fig 1.1 Thin film technology

Batteries, electronics (typically printed) such as diodes, transistors, and memory, and thin film photovoltaic (PV) solar cells are just a few of the uses for thin-film foil textiles in the electronics field. Thin-film electronics is also finding a rising demand in medical and wearable applications.

Thin film semiconductor electronics have grown in popularity in recent years as a result of its advantages over traditional silicon devices, such as improved efficiency, smaller weight, reduced space consumption, and shape flexibility.

Thin films can be made in a variety of methods. A mirror, for example, is made composed of a sheet of glass with a thin metal coating placed to the reflective surface. Sputtering, the modern method for making a mirror, is part of a larger category of processing processes known as deposition. Magnetic recording media, semiconductor devices, optical coatings (such as mirrors and antireflective coatings), hard coatings on cutting instruments, and energy generation are all examples of thin film deposition applications (e.g., thin-film solar cells) **(Blyler. J et al., 2022).**

1.3 IMPORTANCE OF THIN FILM

Thin film has become such an integral part of human existence that it is difficult to imagine a sector of action where it is not present. The first-time thin films were used for optical purposes was in 1912. Pohl and Pringsheim published a notable paper on the manufacturing of mirrors utilizing a high-vacuum vaporization technique of metals such as Ag and Al from an MgO crucible. Thin film coatings have since been used in a variety of optical applications, including anti-reflective coatings, scratch-resistant coatings, UV - and IR-reflective coatings, and so on. Decorative coatings, tribology coatings, biomedical coatings, self-cleaning coatings, and other technical disciplines began to profit from this technique at the same time. One of the areas where thin films are not as it were valuable, but too they constitute the key fabricating innovation, is the industry of semiconductors, which incorporates: broadcast communications gadgets, coordinates circuits, transistors, sun based cells, LEDs, photoconductors, LCDs, magneto-optic recollections, compact plates, electro-optic coatings, recollections, flat-panel shows, smart windows, computer chips, magneto-optic drives, microelectromechanical frameworks , and multifunctional coatings.

1.3.1 Thin Film in Optical Coating

Optical coating includes storing one or more layers of a metallic and/or ceramic fabric over an optical fabric such as a glass- or plastic-made focal point, pointing to change its transmission and reflection properties. Utilize of anti-reflective coating is a case of optical coating which diminishes reflection of optical surfaces, e.g., photographic focal points. This impact can be gotten without significatively modifying the fetched of the component, since the substrate fabric, and the relative fabricating innovations, remains the same, whereas the fetched of the coating itself is astoundingly low.

1.3.2 Thin Film in Preventing Corrosion and Wearing

Thin films help in preventing the corrosion of steel parts of many gadgets in addition to guard against wear. Substances together with jewelry, wrist watches, and knives are regularly covered to avoid corrosion. Thin film coatings are used also as anti-tarnish safety for some sensitive materials, like Silver, in rings packages. Metals which include chromium and zinc are usually used for the coating to save you corrosion, whilst some extraordinarily hard ceramic substances like titanium nitride, chromium nitride and alumina are used for preventing sporting of devices and gear.

1.3.3 Thin Film in Semiconductor

Integrated circuits and conjointly distinct semiconductor gadgets area unit made of a stack of thin films of semi conductive, semiconductor, additionally to insulating substances. Thin films area unit deposited on a completely flat substrate once creating Associate in nursing enclosed circuit, frequently made of chemical element or carbide. Then, a fastidiously designed stack of thin films is deposited over this substrate -which is additionally known as the “wafer”, whereas every layer is fastidiously floral the utilization of planography technologies, therefore taking into thought the manufacturing of a completely giant vary of energetic and passive devices at the equal time. every small tool is in flip crafted from the interconnection of otherwise-doped thin film layers, and therefore the interconnection between distinctive gadgets is managed by victimization the usage of thin-film metal layers, generally created with Al or copper. This generation caused the chance of miniaturization of the many elementary semiconductor gadgets, like BJTs, FETs, MOSFETs and diodes, that-in turn- allowed for the producing of the stylish computers, recollections and excessive overall performance incorporated circuits.

1.3.4 Thin Film in Optoelectronics

Some other subject in which thin movie era has grown to be fundamental is optoelectronics. With technologies much like that employed for the producing of included circuits (deposition/lithography), the manufacturing of some very vital devices in these day’s existence is viable: LED and OLED gadgets for lights and for display applications, LCDs, CMOS sensors for video cameras, and so on. Remarkably, thin movie technology permits additionally for the deposition of electrically conductive, obvious films: for instance, Indium Tin Oxide (ITO) coatings are often used inside the shape of undeniable and notice through electric conductive electrodes. Thin film generation has additionally been used to produce thin-film batteries that have been then be inserted into chips.

1.3.5 Thin Film in Protective and Decorative Coating

Thin films square measure used for protecting the ground of the many artifacts, specifically optical parts, from placed on, scratches, fingerprints, or maybe from corrosion. A protective thin film coating, can even own secondary options, like e.g., an ornamental impact, redaction the surface gloss, its apparent shade, and its texture. someday, thin films square measure used strictly for decorative functions, like within the case of metal coatings revamped a plastic substrate, which may be created to boot the utilization of AN evaporation techniques, beneath excessive-vacuum things, averting the harmful typical procedures based on galvanic deposition.

1.3.6 Thin Film in Solar Cell

The depletion of fossil fuels and climatically amendment has created the utilization of renewable energy sources a lot of distinguished. For what issues the utilization of alternative energy as a viable mean for the assembly of energy with property processes, there are 2 established technologies available: thermal star, and electrical phenomenon. Thermal star systems convert an energy from the sun (radiant energy) into thermal energy with the assistance of energy money handler known as the solar furnace. The solar furnace is of 2 types; concentrating and non-concentrating. Thin films play a job within the coating of the solar furnace which boosts the photo-thermal conversion potency. The second technology i.e., electrical phenomenon is dominated by the utilization of silicon-based cells, that -in their producing process- want the deposition of some thin-film practical layers to reinforce their potency. Moreover, the niche technology of thin-film star cells contributes to the producing of very-high potency electrical phenomenon cells, that area unit employed in room-critical applications (e.g., medium satellites, military, etc.), wherever high dependability and potency area unit the key figures of benefit.

1.3.7 Thin Film in Nanotechnology

In nanotechnology is one of the maximum current advances in the take a look at of thin films. This involves coating with nanocomposite materials thereby giving the substances progressed mechanical residences because of a so-referred to as "length impact". The very last purposeful outcomes which can be obtained are: oxidation resistance, excessive adherence, low thermal conductivity, put on-resistance, higher longevity, and hardness. In this subject, generally the magnetron sputtering approach is used for deposition, due to the excessive purity and coffee stage of defects which are allowed by means of this technique. In conclusion, the function thin films play in our daily lives is limitless as many greater inventions are being made in the have a look at of thin films. Thin film era has been used to this point from the textile or fabric enterprise, to the gadgets, utensils, vehicles, gear, buildings (roads), scientific examination, decoration, and many others., all of which are products very beneficial in our normal life. Thin film technology has performed an important position in making lifestyles simpler for all of us **(Anon,2022)**.

1.4 HISTORY

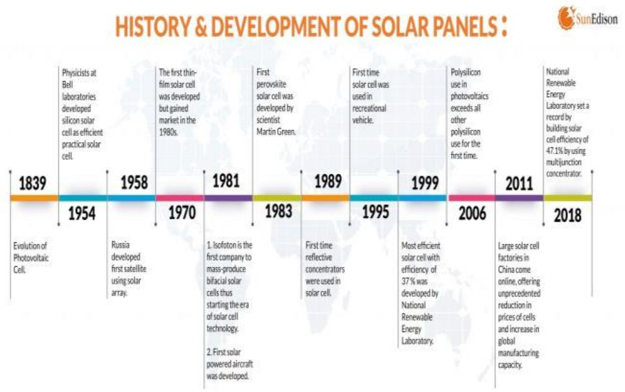


Fig 1.2 History and development of thin film

1839 - Evolution of Photovoltaic cell.

1954 – Physicists at Bell laboratories developed silicon solar cell as efficient practical solar cell.

1958 – Russia developed first satellite using solar array.

1970 – The first thin film solar cell was developed but gained market in the 1980’s

1981 – Isofoton is the first company to mass-produce bifacial solar cells thus starting the era of solar cell technology.

1983 – First perovskite solar cell was developed by Martin Green.

1989 – First time reflective concentrators were used in solar cell.

1995 – First time solar cell was used in recreational vehicle

1999 – Most efficient solar cell with efficiency of 37% was developed by National Renewable Energy Laboratory.

2006 – Polysilicon use in photovoltaics exceeds all other polysilicon use for the first time.

2011 - Large solar cell in China come online, offering unprecedented reduction in prices of cells and increase in global manufacturing capacity.

2018 – National Renewable Energy Laboratory set a record by building solar cell efficiency of 47.1% by using multijunction concentrator **(Anon, 2021)**.

1.5 PROPERTIES

1.5.1 Optical Property

Optical experiments are a good approach to investigate semiconductor characteristics. Measuring the absorption coefficient for various energies, in particular, provides information about the material's band gaps. Understanding the electrical properties of a semiconductor necessitates knowledge of these band gaps, which is of enormous practical importance **(Heavens O.S. et al.,2002), (Acosta E et al., 2021)**

1.5.2 Mechanical Property

Thin films' mechanical characteristics are frequently different from those of bulk materials. The nanostructure of thin films, as well as the fact that they are linked to a substrate, can help to explain this. Thin films can withstand extremely high residual stresses due to their high yield strengths. Plastic deformation, thin film fracture, or interfacial delamination can all be used to release residual stress during manufacturing or during device operation. Thin film characterization relies on both elastic and plastic characteristics. Tensile testing of freestanding films and the micro beam cantilever deflection technique can also be used to determine thin film mechanical properties, however nanoindentation is the most convenient method because no additional sample preparation is necessary and tests can be performed quickly **(Tomastik et al.,2012), (Acosta E et al., 2021).**

1.5.3 Electrical Property

Metal, semiconductor, and dielectric materials are the three categories of electron materials. Obviously, the form of electrical transport varies depending on the type of material, hence It's impossible to put everything into words. Scaling effects, on the other hand, start to appear in thin film form. In the same way, electrical characteristics of materials are influenced. The thickness of the film, the lattice size, purity, surface roughness, and level of imperfection. The nature, mechanism, and stability of the layer are all important aspects to consider transport by electricity **(Zhang X et al., 1995)**.

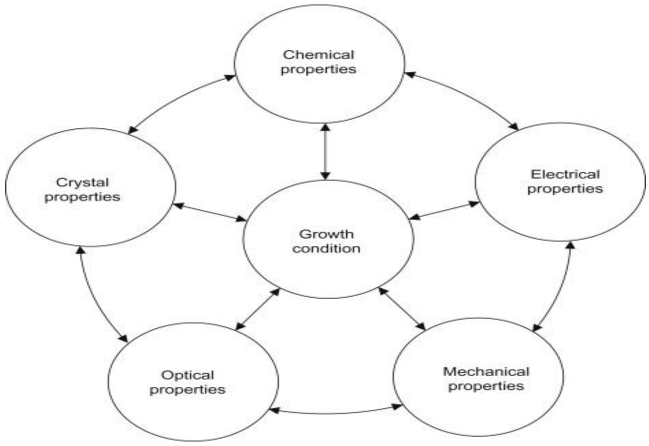


Fig 1.3 Properties of thin film

1.6 APPLICATION

In electronics they used in making flexible polymer light emitting displays. They are used in optical coating and anti-reflex films for umbrella glass. Used in making super conducting films called SQUIDS. They are helpful in making highly efficient magnetic films which can be used for storage and reading. They are used in making window coating. Thin films are great heat resistance and corrosion resistance which are used in making turbine blade coating for energy preparation. Due to strong mechanical strengths, they are used for making super hard coatings. They are used in decorative coatings and protective coatings. Because of their high optical conductivity, they are used in making photovoltaic cells solar cells. These materials have already been used in semiconductor devices, wireless communication, telecommunications, integrated circuits, rectifiers, transistors, solar cells, light-emitting diodes, photo conductors, light crystal displays, magneto optic memories, audio and video systems, compact discs, electro-optic coatings, memories, multi-layer capacitors, flat panel displays, smart windows, computer chips, lithography, micro- electromechanical systems and multifunctional coatings as well as other emerging cutting technologies **(Naghdi et al., 2021)**.

Fig 1.4 Application of thin film

1.7 DEPOSITION TECHNIQUES

The properties and flexibility of the thin films will be obtained by choosing proper technique of film deposition. Thin film deposition ways will be broadly speaking classified as either chemical or physical ways **(Rogers, J.A et al.,2009)**. The distinction between the chemical and physical thin film deposition ways depends upon the method of depositing thin film material on the substrate. In chemical deposition technique, fluid precursor is employed that with chemicals react with the substrate **(Chi L et al.,2010)**. Since the thin film material is conducted through the fluid precursor, chemical deposition is conformal approaching the substrate while not preference to a selected direction. A conformal is associate degree uneven interface with the body and incorporates a constant thickness on horizontal and vertical surfaces **(Diaz Fernandez, Y.A. et al., 2014)**.

Deposition techniques for thin films the terms "top-down" and "bottom-up" pertain to the construction of engineered surfaces **(Choi Y et al.,2016)**. Bottom-up fabrication focuses on fabrication techniques that can place atoms or molecules on the surface to form the desired nano structuring, whereas top-down fabrication is linked to corrosive procedures (e.g., dry etching, lithography, chemical etching) to sculpt micro/nanostructures in a large parent entity **(Wang Y et al.,2016)**. Top-down manufacturing procedures were previously a feasible alternative for nano structuring, but the integration of bottom-up methodologies has resulted in high-resolution nanopatterning materials coupled into complex and functional hierarchical devices **(Katakam P et al., 2015)**.

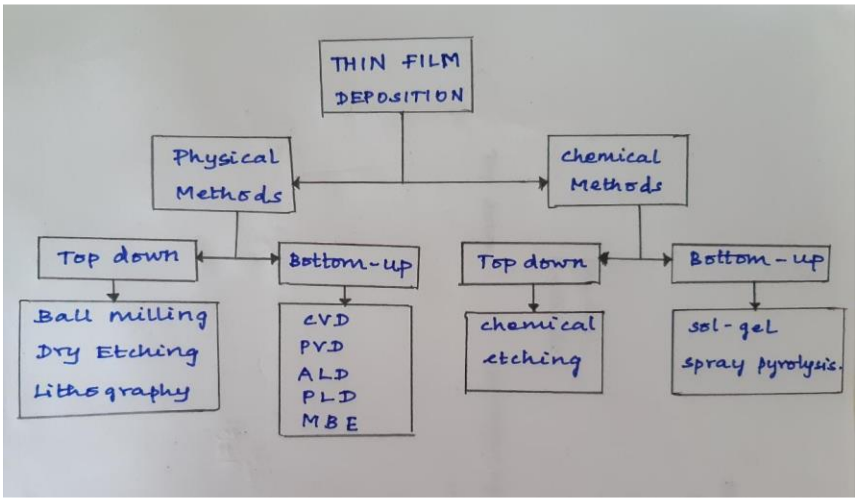


Fig 1.5 Deposition technique

1.7.1 Physical Methods

1.7.1.1 Top Down

i. Ball Milling

Ball milling is a mechanical technique for blending materials and grinding powders into small particles. It has a wide range of applications in industry all over the world because it is an ecologically safe and cost-effective approach. Because the focus of this mini-review is on the conditions used to prepare and functionalize nanocellulose derivatives in a ball mill rather than the machinery itself, the various types of machines available in industry will not be discussed. Nonetheless, this section includes a general summary of the many sorts of equipment. Different varieties of ball mills exist, depending on the use. However, it usually consists of a hollow cylindrical shell that rotates around its axis and is partially filled with steel, stainless steel, ceramic, or rubber balls **(Piras C et al.,2019)**.

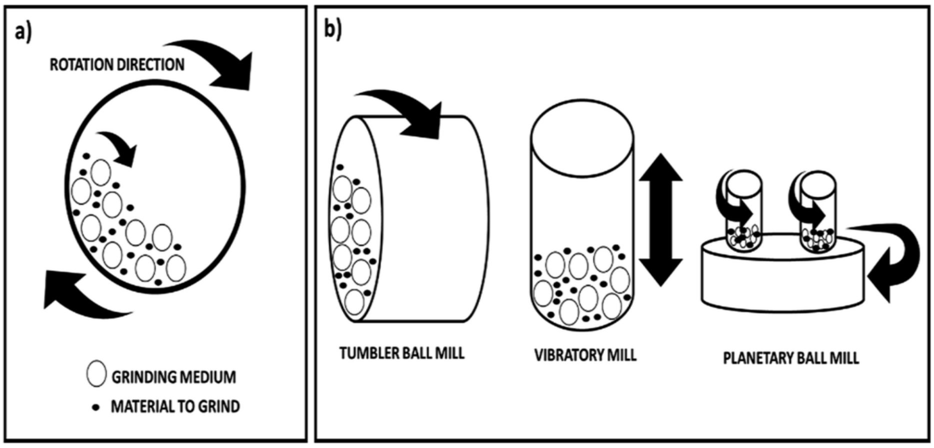


Fig 1.6 Schematic representation of a ball mill (horizontal section)

ii. Dry Etching

Dry etching is the process of removing material, usually a masked pattern of semiconductor material, by bombarding it with ions (usually a plasma of reactive gases like fluorocarbons, oxygen, chlorine, and boron trichloride; sometimes with the addition of nitrogen, argon, helium, and other gases) that dislodge portions of the material from the exposed surface. Reactive-ion etching is a frequent type of dry etching. Unlike many (but not all) of the wet chemical etchants used in wet etching, the dry etching method often etches in a directed or anisotropic manner **(En.wikipedia.org. 2022)**.

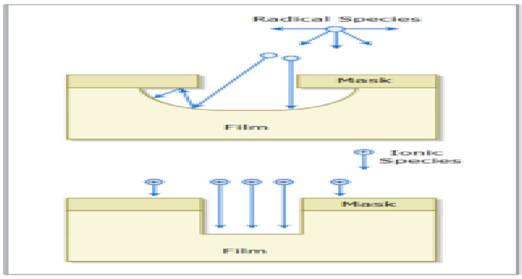


Fig 1.7 Dry etching

iii. Lithography

The ongoing trend toward smaller and high-performance systems has sparked fresh research and development in novel materials and devices with enhanced and original capabilities. In this regard, the high sensitivity of modern submicron technologies offers up possibilities for thin film functional devices including capacitors for power components, sensing devices for biomedical applications, and magnetic thin film structures for data processing technology. The majority of these devices were made in a top-down view, employing deposition techniques mixed with lithography and finally etching. In this chapter, we'll show how conventional and non-conventional lithography can be used to fabricate thin film functional devices when used in conjunction with the PVD process **(Aassime A et al., 2022)**.

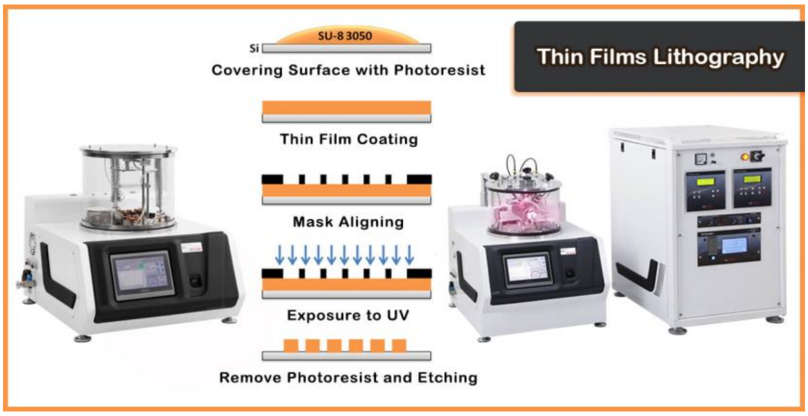


Fig 1.8 Lithography

1.7.1.2 Bottom Up

i. Chemical Vapor Deposition

CVD may be an activity during which the gaseous precursors are used. Precursor gases are affected into a chamber with the substrate. The chemical process between the substrate and also the precursor is sustained at extreme temperature until the required thickness of the film is obtained **(2022. [online])**.

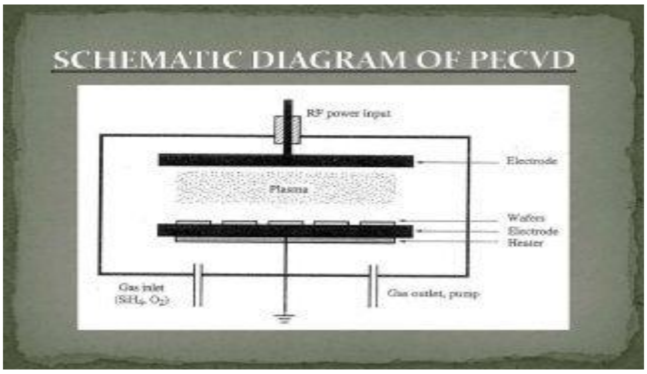


Fig 1.9 Schematic diagram of CVD

ii. Physical Vapor Deposition

The high-purity solid coating material (metals such as titanium, chromium, and aluminum) is either evaporated by heat or bombarded with ions in the physical vapor deposition process (sputtering). At the same time, a reactive gas (such as nitrogen or a carbon-containing gas) is injected; it reacts with the metal vapor and creates a thin, highly adherent coating on the substrate. As a result, the film has a very strong bond with the tooling substrate, as well as customized physical, structural, and tribological properties **(Corrosionpedia. 2022)**.

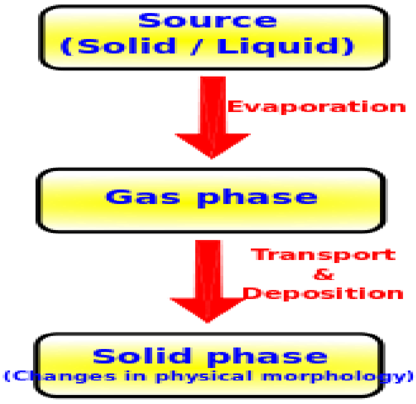


Fig 1.10 PVD

iii. Atomic Layer Deposition

ALD is a surface-controlled layer-by-layer deposition method that produces thin films one atomic layer at a time. During reaction cycles, layers are produced by pulsing precursors and reactants alternately and purging with inert gas in between each pulse **(Asm.com. 2022)**.

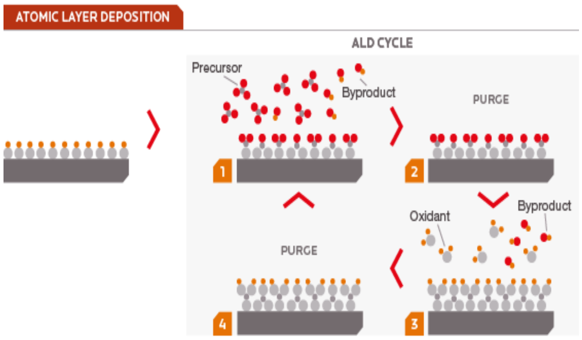


Fig 1.11 ALD

iv. Pulsed Laser Deposition

In recent years, pulsed-laser deposition (PLD) has attracted a lot of attention due to its ease of use and success in depositing materials with complex stoichiometry. PLD was the first technology to deposit a superconducting YBa2Cu3O7 thin film successfully. Since then, PLD has successfully deposited a variety of materials that are often difficult to deposit using conventional methods, particularly multi-element oxides **(Groups.ist.utl.pt. 2022)**.

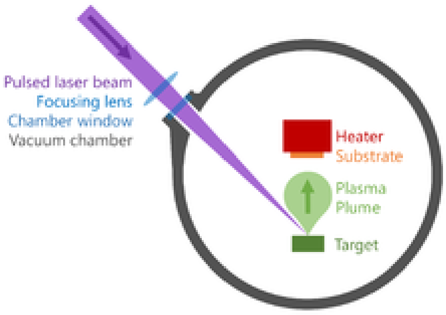


Fig 1.12 PLD

v. Molecular Beam Epitaxy

MBE combines benefits of both chemical and physical ways for thin film deposition. Firstly, the target materials to be deposited are heated directly till they convert from solid to gaseous type. Then the gaseous parts are allowed to react with chemicals with the substrate to grow the thin film. In MBE, target material is deposited within the sort of layers however one layer at a time. MBE may be a slow methodology however the degree of purity during this methodology is extremely high **(Joyce B et al., 1985)**.

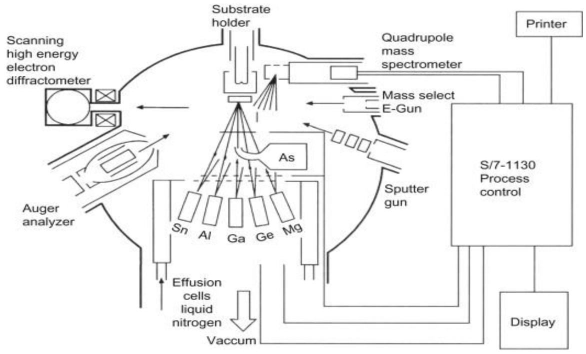


Fig 1.13 MBE

1.7.2 Chemical Methods

1.7.2.1 Top Down

i. Chemical Etching

Chemical etching, also known as chemical milling or photo etching, is a subtractive sheet metal machining process that use chemical etchants to produce complex and very precise precision components from practically any metal **(Precision Micro. 2022)**.

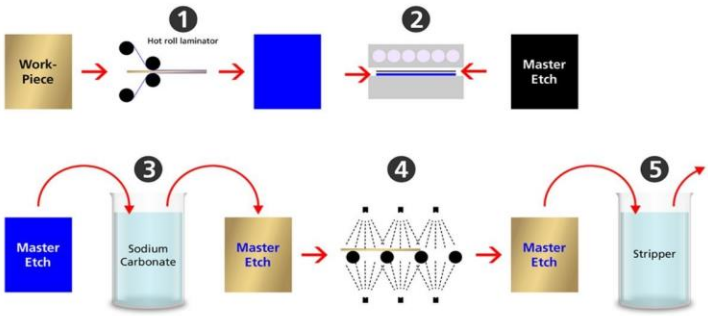


Fig 1.14 CE

1.7.2.2 Bottom Up

i. Sol Gel Technique

The sol-gel process combines several methods for synthesizing materials from solutions, including gel formation being one of the phases of processing. Controlled hydrolysis of chemicals, generally alkoxides, is the most common method of sol-gel synthesis. M (OR) x (M = Ti, Si, V, Zr, V, Mo, Al, Sn, W, Zn, Ge, etc.) or corresponding chlorides, in an organic or aqueous medium.

Dip coating technique could be a method where the substrate to be coated is immersed in a coating sol wherever a wet layer is created so it's withdrawn with a well outlined withdrawal speed below controlled temperature and region conditions. The atmosphere controls evaporation of the solvent and it ends up in a gelation method which ends in formation of film. The ensuing film has got to be densified by thermal treatment and also the concretion temperature depends on the composition. The method of dip coating is shown as delineated within the figure.

In the spin coating method, the substrate spins around an axis that is perpendicular to the coating space. The spinner is meant to coat thin films of liquids on the wafer surface. The wafer surface is then soaked with BLT solution. The wafer is then turned with optimum speed. The excess BLT sol is driven off as a result of force feat leaving film of BLT on the wafer surface. The thickness of wafer is controlled by spin speed, spin time and consistency of the solution. In spin coating method, evaporation is that the primary technique of film dilution once the fluid flow ceases. Evaporation is that the advanced method by that some of the excess solvent is absorbed into the atmosphere. If evaporation happens before the time, it should cause the formation of a solid skin on the fluid surface and leads to coating defects. A range of film thickness are often deposited by spin coating, because of film thickness being roughly reciprocally proportional to the square root of spin speed **(Isca.in. 2022)**.

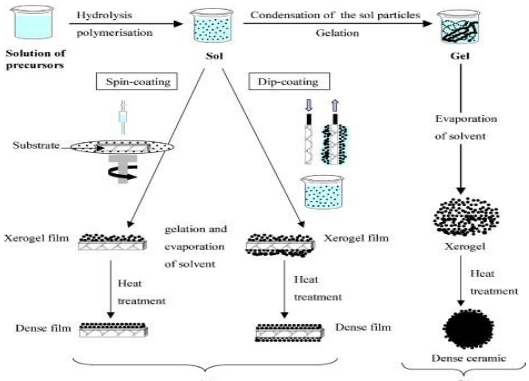


Fig 1.15 Sol gel thin film deposition

ii. Spray Pyrolysis

In spray technique, spray solution is spread on hot substrate and other volatile by products and excess solvent are removed in the form of vapors. Spraying technique apparatus involves spray nozzle, motor, liquid level monitors, hot plate, gas regulator value and air tight fiber chamber **(Staff.ustc.edu.cn. 2022)**

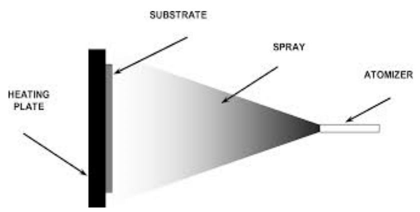


Fig 1.16 Spray pyrolysis

CHAPTER 2
LITERATURE SURVEY

According to **Rameshkumar, C., et al., (2021)** In this article, we used a spin coating approach to make transparent nanofilms (SnO_2) for solar cell applications. Fabrication costs are low, because raw materials are used in small quantities. SnO_2 is a transparent metal oxide with excellent electrical, thermal, and optical conductivity. The thickness of the nanofilm layer determines the efficiency of the solar cell nanofilm. For good SnO_2 production, optimizing parameters such as solute concentration, spin rate, turn table time, Nanofilm thickness, and heat treatment procedures must be taken into mind. Tin chloride is used as a precursor, and ethanol is used as a solvent to make SnO_2 film. As a result, spin-coated nanofilms are exposed to several characterization procedures in order to examine the nanofilm layer and its application.

According to **Soumya, S. S., et al., (2021)** Tin oxide (SnO_2) thin films were produced in this paper utilizing a simple spin coating sol-gel process with non-alkoxide $SnCl_4.2H_2O$ as a precursor. XRD, SEM, TEM, FTIR, PL, and UV–vis techniques were used to investigate the film's structural, optical, electrical, and gas sensing capabilities. The samples feature a tetragonal rutile structure, according to X-ray Diffraction (XRD). The average particle size, according to Transmission Electron Microscopy (TEM), is 11.26 nm. For ethanol gas, the gas detection performance of a manufactured SnO_2 thin film was examined at various operating temperatures and concentrations.

According to **Roguai, Sabrina et al., (2021)** At 450 C, thin films of SnO_2 were deposited using an ultrasound pyrolysis spray method. X-ray diffraction, Fourier transformed infrared (FTIR), ultraviolet–visible, and photoluminescence spectroscopy were used to analyses the films. X-ray diffraction revealed the tetragonal rutile-type structure with an average crystallite size of 35 nm. Furthermore, the FTIR analysis revealed the presence of two unique distinctive absorptions, which correspond to (0-Sn-O) deformations and (O- Sn) stretching modes, respectively. The band gap energy was calculated using the Wemple-DiDomenico model for optical characteristics. The presence of inherent flaws is attributed to PL characteristics.

According to **Adjimi, Amel, et al., (2018)** In this study, undoped (SnO_2) and fluorine-doped tin oxide (FTO) thin films were made using a sol-gel solution including ($SnCl_2$, H_2O), (NH4F), and ethanol combination. The influence of fluorine concentration on SnO_2 films structural, optical, and electrical properties is examined. The electrical characteristics of FTO films formed using sol gel are poorer than those created using other methods. In this study, we attempt to clarify this distinction. The composition of the films and the FTIR examination of the produced precipitate during film growth show that only a little amount of fluorine is incorporated in the SnO_2 network, with the majority of fluorine atoms remaining in the solution. The film resistivity is lowered from 1.1 cm for undoped films to 0.8 cm for doped films

According to **Muliyadi, Lalu, et al., (2019)** The sol-gel spin coating process was used to create a thin layer of tin oxide doped with fluorine. The goal of the synthesis is to determine the quality of thin layers generated as a function of temperature and layer number. The basic material is $SnCl_2.2H_2O$, while the doping material is NH_4F, with dopant concentrations ranging from 0, 5, 10, 15, 20, and 25%. Glass was used as the substrate, with dimensions of 10 x 10 x 3 mm. Substrate preparation, sol-gel preparation, thin film preparation, and the heating process are all part of the thin layer synthesis. SnO_2: F is deposited on a glass substrate using the sol-gel spin coating process at a concentration of sol 1 M with Fluorine doping values of 0, 5, 10, 15, 20 and 25%, respectively, and were matured for 24 hours. Using a spin coater at 2000 rpm for 3 minutes to make a thin layer. One layer, two layers, three layers, and four layers make up the layer. The resulting layer demonstrates that the higher the doping percentage, the greater the layer's transparency. Furthermore, the higher the number of layers, the lower the amount of transparency**.**

According to **Doyan, Aris, et al., (2020)** The sol-gel spin coating process was used to successfully synthesize tin oxide thin films with doping aluminum, fluorine, and indium (SnO_2: Al + F + In). The goal of this synthesis is to assess the quality of the thin film generated by doping aluminum, fluorine, and indium. The basic material is $SnCl_2.2H_2O$, with $AlCl_3$, NH_4F, and $InCl_3.4H_2O$ as doping materials. The percentages of the basic components and the doping mixture of aluminum, fluorine, and indium (SnO_2: Al +F +In) employed were 100: 0 %, 95: 5%, 90: 10%, 85: 15%, 80: 20%, and 75:25%. A glass substrate (10 x 10 x 3) mm is used in the synthesis. Substrate preparation, sol-gel preparation, film preparation, and sample heating are all part of the coating synthesis process. There are 1 to 4 layers in the layers that are created. The results revealed that the layer created had a high degree of transparency as the doping material percentage was increased. The higher the aluminum, fluorine, and indium doping concentrations, the more transparent the resultant layer. Furthermore, the more layers there are, the lower the transparency level of the levels**.**

According to **Karmaoui, M. et al., (2018)** Tin oxide (SnO_2) is an extremely attractive transparent conducting material for applications in low-emission window coatings and solar cells, as well as in lithium- ion batteries and gas sensors, due to its electrically conducting properties combined with excellent thermal stability and transparency throughout the visible spectrum. For oxidation reactions, it also serves as a catalyst and catalytic support. We present a nonaqueous sol–gel synthesis method for making tin oxide nanoparticles (NPs) with a minimal NP size dispersion. The nonhydrolytic approach, which comprises the interaction of tin chloride with an oxygen donor, 1- hexanol, without the use of a surfactant or subsequent thermal treatment, is the key to this method's effectiveness. This one-pot approach is carried out at low temperatures (between 160 and 260 °C), making it suitable for coating procedures on flexible plastic supports. Powder X-ray powder diffraction, entire powder pattern modelling, and high-resolution transmission electron microscopy were used to investigate the NP size distribution, shape, and dislocation density. The particle sizes of the SnO_2 NPs were found to be between 3.4 and 7.7 nm. The synthesis of dienyl ether and 1-chlorohexane was confirmed by liquid-state 13C and 1H nuclear magnetic resonance (NMR) analysis of the reaction products.

The NPs were investigated using a combination of solid-state NMR (13C, 1H, and 119Sn), as well as FTIR and Raman spectroscopy. The existence of organic species produced from the 1-hexanol reactant was detected in the samples using 13C SSNMR, FTIR, and Raman data. The band gap (E_g) changed progressively to lower energy with decreasing NP sizes, according to optical absorption measured with UV–visible spectroscopy. Mechanical forces within the tiniest NPs, possibly connected with the organic ligands covering the NP surface, could explain this odd outcome. As the size of the NPs grew larger, we saw a correlation with a higher density of screw dislocations within the NPs, which could suggest stress relaxation

According to **AYDIN et al., (2021)** Using a simple sol-gel process, nanocrystalline SnO_2 powder was effectively synthesized. To make SnO_2 nano powder, the sol-gel was rinsed and calcined at 400 degrees Celsius. X-ray diffraction (XRD) was used to explore the structural properties of (SnO_2) nanocrystalline powder. UV-Vis Spectroscopy was used to investigate the optical properties by recording the absorbance and transmittance spectra. The creation of a rutile structure of SnO_2 nano crystallites was demonstrated by the XRD pattern of the as-prepared sample. The Scanning Electron Microscopic (SEM) study revealed a uniform distribution of very tiny grains across the examined area. The UV-Vis absorbance spectra also revealed a distinct peak of absorption at 312 nm, which corresponded to SnO_2. The graph of variation of $(\alpha h\nu)^2$ vs hv was used to calculate the energy band gap for nanocrystalline SnO_2 thin film.

Optical bandgap energies for SnO_2 thin films have been recorded at 3.78 eV.

The results demonstrate that the synthesized SnO_2 film has a transmittance of 78 percent in the spectral region 350 nm to 800 nm.

According to **Susilawati, et al., (1970)** A thin layer of SnO_2: F was produced on a glass substrate with multiple layers using the sol-gel spin coating process (one to four layers). The goal of the synthesis was to figure out how thin layers' optical properties, including as transmittance, absorbance, energy bandgap, and activation energy, worked. UV- VIS spectrophotometers with a wavelength of 200-1100 nm were used to determine the optical characteristics of the layers. The results showed that as the number of layers increased, the absorbance value fell at a wavelength of 300 nm. The absorbance values obtained for variations in layers (one to four layers) for the percentages of 95:5 percent and 75:25 percent were 3.59-2.85 and 4.30-3.42, respectively, while the transmittance value reduced to 96.8-79.6 percent and 98.3-81.1 percent. Furthermore, when the number of particles increases, the energy bandgap obtained lowers. The energy bandgap for direct allowed dropped from 3.69-3.56 eV and 3.59-3.42 eV to 4.00-3.91 eV and 3.96-3.83 eV for indirect allowed. From 0.23-0.07 eV to 4.35-1.43 eV, the activation energy dropped.

CHAPTER 3

AIM AND SCOPE

3.1 AIM

We aimed to understand the efficiency of pure SnO_2. To synthesize the SnO_2 thin film and to analyze the characteristics of the film. The SnO_2 thin film was synthesized using ethanol. we choose the sol-gel technique for the preparation of SnO_2 thin film to reduce the cost and time required for the preparation. Synthesis was mainly focused on the solar cell application. Structural characteristics was determined by XRD. Optical characteristics were investigated using the Raman effect and a UV visible spectrometer. Electrical characteristics was carried out using hall effect measurement.

3.2 SCOPE

Due to rising electricity usage and a scarcity of non-renewable energy sources, we are in desperate need of renewable energy sources today. This project's scope is primarily concerned with solar cell applications. As a result, we intended to examine the Tin oxide thin film layer in order to improve solar energy efficiency. Because of its good optical and electrical qualities, SnO_2 is said to be widely used in a variety of fields. Tin oxide is a common n-type semiconductor with a large band gap. It is also used in a variety of industries, including energy-saving devices, anti-electrostatic films, electro-magnetic shielding materials, anti-reflective coatings, and so on. As a result, we used this material to improve the efficiency of the solar cell.

CHAPTER 4

MATERIALS AND METHODOLOGY

4.1 MATERIALS

- Stannous chloride
- Ethanol

➢ **STANNOUS CHLORIDE**

Chemical name	Stannous Chloride dihydrate
Chemical formula	$SnCl_2.2H_2O$
Molar weight	37 - 38°C/lit
Boiling point	652°C/lit
Density	2.71 g/cm^3
IUPAC name	Tin (II) chloride
Solubility	Hydrochloric acid
Synonyms	Salt of Tin

Table 4.1 Properties of Stannous Chloride

Tin (II) Chloride is the chemical name for Stannous Chloride. $SnCl_2$ is the chemical formula for stannous chloride. In its solid state, stannous chloride appears as a crystalline mass. Its colors form a stable dihydrate, but they tend to hydrolyze. when reacting with aqueous solutions, especially if the compound is heated. Tin dichloride, Stannous Chloride, and Tin Protochloride are some of the other names for Tin (II) Chloride. The molecule's lone pair of electrons, which are bent in the gaseous state, is one of the compound's most prominent properties. Tin (II) Chloride does not have a distinguishing odor as a chemical **(Vedantu.,2020)**.

Fig 4.1 stannous chloride

- **ETHANOL**

Chemical name	Ethyl alcohol
Chemical formula	CH3CH2OH
Molar weight	46.069 g/mol
Melting point	- 114.14°C
Boling point	78.24℃
Density	0.7893 g/cm^3
IUPAC name	Ethanol
Solubility	Water
Synonyms	Spirits of wine

Table 4.2 Properties of Ethanol

Ethanol, commonly known as ethyl alcohol, grain alcohol, or alcohol, is a member of the alcohols class of chemical substances with the molecular formula C_2H_5OH. Ethanol is a common industrial chemical that is used as a solvent, in the production of other organic compounds, and as a fuel additive (forming a mixture known as a gasohol). Many alcoholic beverages, such as beer, wine, and distilled spirits, contain ethanol as an intoxicating element.

The fermentation of carbohydrates (the method used for alcoholic beverages) and the hydration of ethylene are the two basic processes for producing ethanol.

Fermentation is the process of converting carbohydrates to ethanol using yeast cells **(Britannica, The Editors of Encyclopaedia.,2021**)

Fig 4.2 Ethanol

4.2 METHODOLOGY

4.2.1 Spin Coating Principle

When a material and solvent solution is spun at high speeds, the centripetal force and the liquid's surface tension combine to form an equal covering. Spin coating produces a thin film with a thickness ranging from a few nano meters to a few microns after any remaining solvent has evaporated **("Spin Coating: Complete Guide to Theory and Techniques." *Ossila*,2020)**.

4.2.2 Spin Coating Process Description Substrate Cleaning

STEP: 1

- Cleansing and drying the slides(substrate)
- Made solution of potassium dichromate + dil. HCL to a beaker.
- Slides are dipped into it for little less than 20 hour
- Beaker closed with aluminum foil **(*PubChem Compound Database*, U.S. National Library of Medicine,2000)**

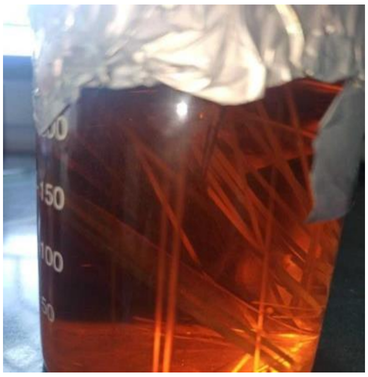


Fig 4.3 Glass substrates in potassium dichromate + HCl solution

STEP: 2

- Slides took out from the solution and placed on the tissue.
- Rinsed and kept inside Millipore water in a beaker **(*Cleaning Laboratory Glassware*,)**

Fig 4.4 Glass Substrate in Millipore Water

STEP: 3

- This setup is put into sonicator.
- Sonicator filled with 1.5 l of water and started the process for 15 minutes (sonicated)
- After that it taken out

Fig 4.5 Sonicator

STEP: 4

- Placed in the oven
- It maintained at 123.8 ℃
- For 3 hours **(deposition, s., film,2022)**

Fig 4.6 Hot Air Oven

Fig 4.7 Outside the Oven

4.3 EXPERIMENTAL PROCEDURE

4.3.1 Solution Preparation

- In this project we use the basic components are tin chloride dehydrate 4.515 gram with the molar mass of 225.63 grams per mole and purity of 95%
- The solvent uses 20 ml ethanol with the molar mass of 46.07 gram per mole and purity of 99.99%
- This is done by dissolving $SnCl_2.2H_2O$ into 20 ml of Ethanol with a fixed concentration of 1 M.

- Then this solution stirred using magnetic stirrer until the solution is homogeneous for 1 hour, and the solution is left for 24 hours **(Muliyadi, Lalu, et al.,2019)**

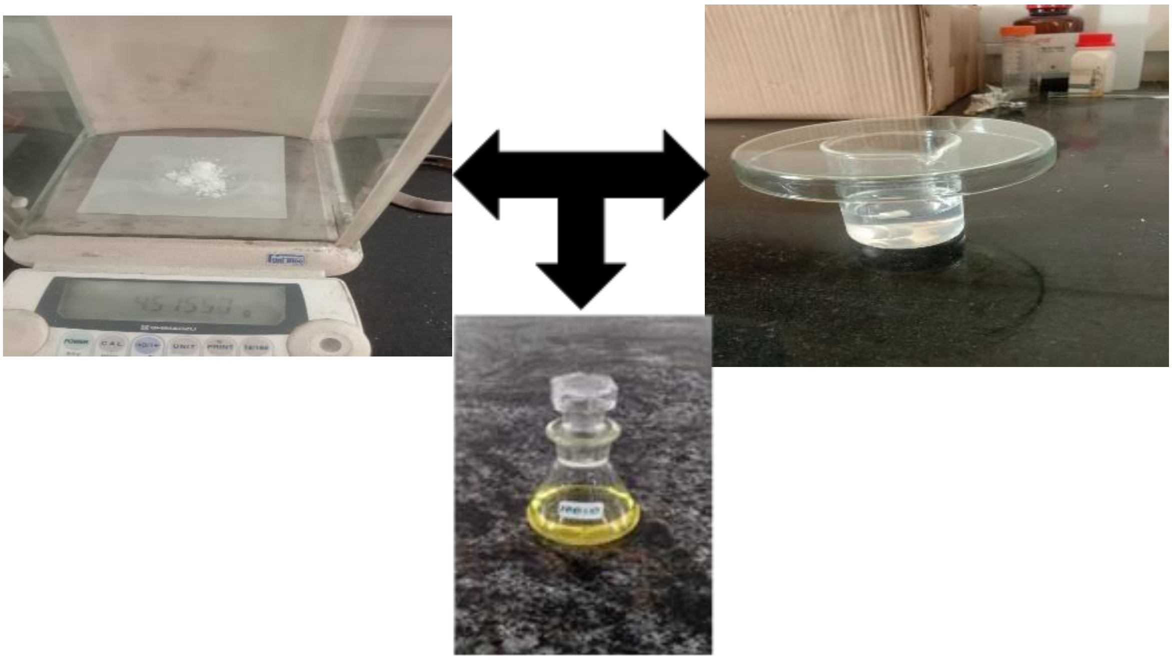


Fig 4.8 Solution Preparation

4.3.2 Preparation of SnO_2 Thin Film

- A thin layer of SnO_2 is formed on the glass substrate using the sol gel spin coating process.
- A programmable spin coater is used for this spin coating.
- This spin coater programming is done with SCU software.

Fig 4.9 Programmable spin coater

4.3.3 Procedure to Operate the SCU Software

- Switch on the PC and Rotary pump connected to the Instrument
- Click on the spin coater software icon (SCU).
- Click warmup (Check for RPM) and stop
- Click add protocol and add new
- Set the start RPM and end RPM and time
    - ✓ 0 – 500 for 10 seconds
    - ✓ 500 – 1000 for 10 seconds
    - ✓ 1000 – 1000 for 40 seconds
    - ✓ 1000 - 500 for 10 seconds
    - ✓ 500 – 0 for 10 seconds
- And click run
- Save the protocol
- Choose already loaded program or you may create a new program.
- Calibration is must before any experiment
- After calibration, a message box appears to instruct place the substrate on the holder.
- Once the substrate is placed, it is sucked on to the substrate holder substrate through vacuum created by rotary pump.
- Click OK on the message box.
- Place the substrate and power on the vacuum for holding a substrate
- And then click calibrate.
- After calibrating dispense the solution using 100 µl micro pipette
- After completion of the program, coated generates the result of time and speed and they can be, we can be saved for the future use.
- Remove our sample
- Switch off the instrument and clean the spin coater chamber.
- The coated substrate is annealed at 150 °C for one hour **(Apex et al.,2011.)**

Fig 4.10 Substrate holder

Fig 4.11 Protocol and output from SCU

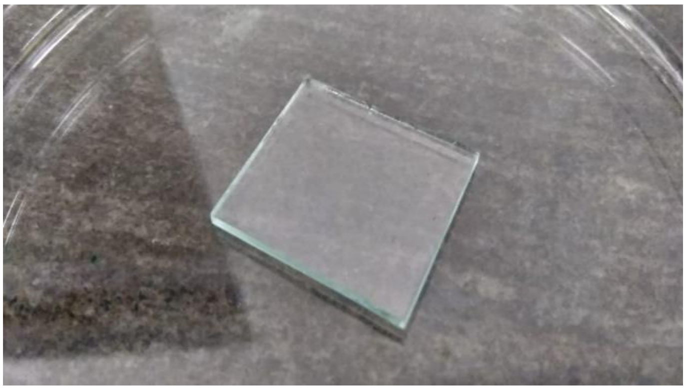


Fig 4.12 SnO_2 thin film

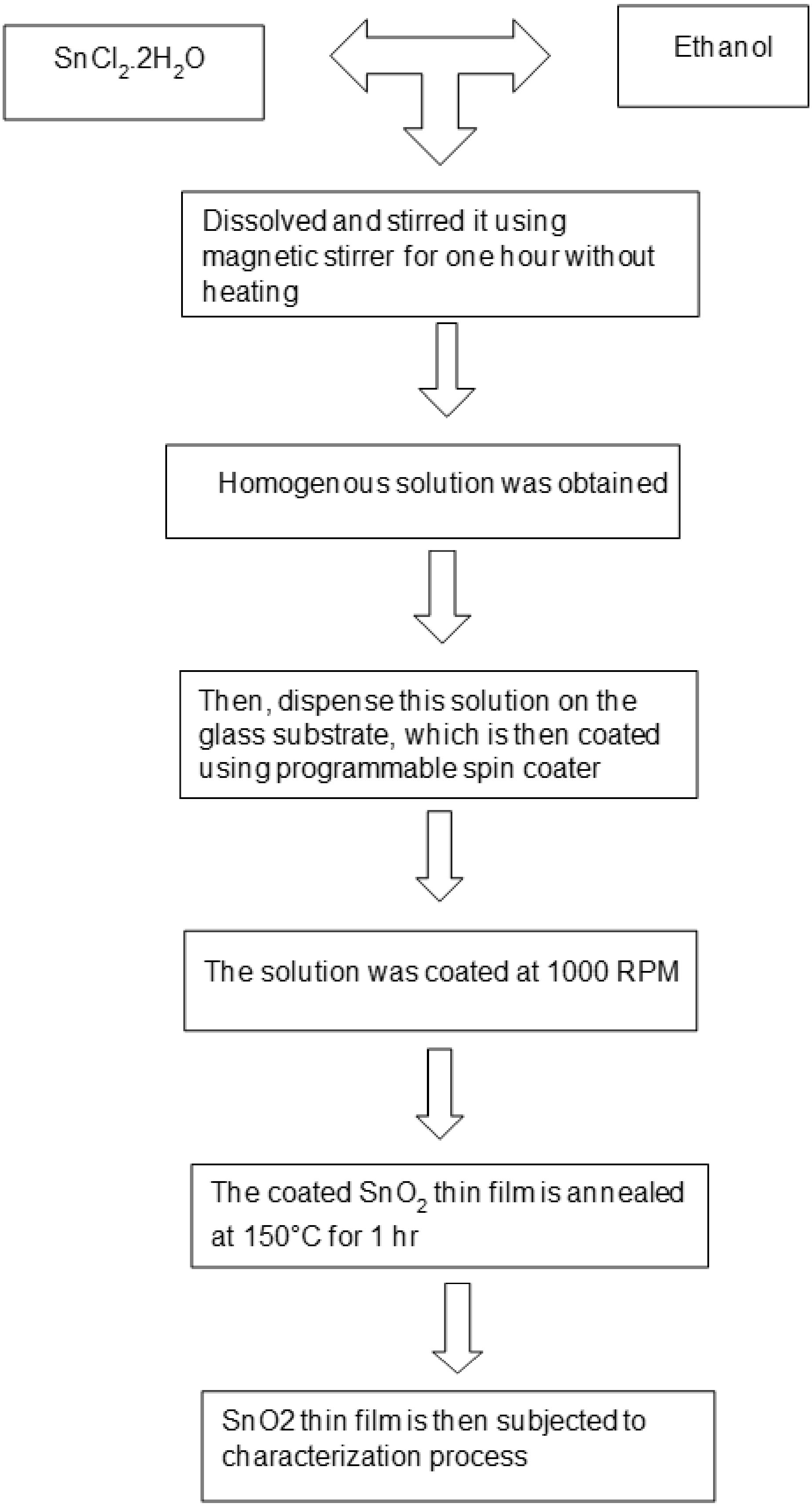


Fig 4.13 Flow chart for pristine SnO_2 synthesis

4.3 APPLICATION

Spin coating applications come in a wide variety of shapes and sizes. Small substrates (a few mm square) or flat panel TVs with a diameter of a meter or more can be coated using this process. Photoresists, insulators, organic semiconductors, synthetic metals, nanomaterials, metal and metal oxide precursors, transparent conductive oxides, and a variety of other materials are used to coat substrates. In a nutshell, it's everywhere in the semiconductor and nanotechnology R&D/industrial industries **(Ossila. 2022)**.

4.4 SPIN COATING ADVANTAGES AND DRAWBACKS

The simplicity and relative convenience with which a process may be set up, as well as the thin and homogeneous coating that can be achieved, are the benefits of spin coating. Due to the ability to spin at high speeds, rapid airflow results in quick drying times, which contributes to great consistency on both macroscopic and nanoscales. The downside of spin coating is that it is a batch (single-substrate) process, which means it has a lower throughput than roll-to-roll techniques. Fast drying durations can also result in lower performance for some nanotechnologies that demand it (small molecule OFETS, for example). Now is the moment for self-assembly and or crystallization. Finally, the actual material used in a spin coating process is often relatively low (about 10% or less), with the remainder thrown off to the side and discarded. While this isn't generally an issue in research, it can be in some cases. It is definitely wasteful for production in terms of the environment. Despite these disadvantages, spin coating is frequently used as a starting point and standard for most academic and industrial operations that require a thin, homogeneous coating **(Text-id.123dok.com. 2022)**.

CHAPTER 5

CHARACTERIZATION TECHNIQUE

5.1 XRD

X-ray diffraction (XRD) is a non-destructive analytical technique that offers useful information on the lattice structure of a crystalline substance such as unit cell dimensions, bond angles, chemical composition, and crystallographic structure of natural and synthetic materials. XRD is based on the idea of constructive interference of x-rays and the crystalline sample in question. The x-rays produced by a CRT are filtered, collimated, and directed at the sample. The subsequent interaction results in constructive interference, which is based on Bragg's law, which links the wavelength of incident radiations to the diffraction angle and lattice spacing.

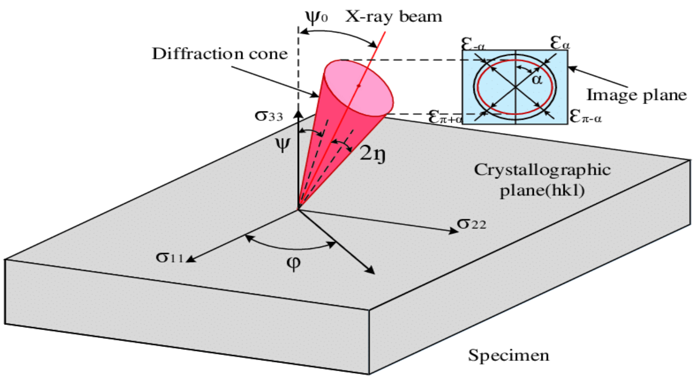
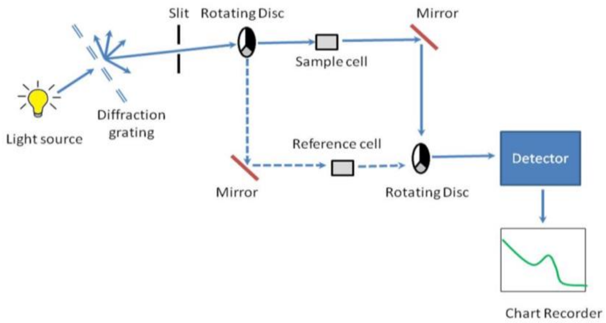


Fig 5.1 Schematic diagram of XRD

X-ray powder diffraction (XRD) is a quick analytical technique that can offer information on unit cell dimension and atomic spacing and is mostly used for phase identification of crystalline materials. The X-ray is produced by a cathode ray tube, which is then filtered to produce monochromatic radiation, collimated to concentrate it, and aimed onto the sample. When the incident monochromatic rays interact with the sample, constructive interference (and diffracted ray) results when the conditions satisfy Bragg's Law. $2d \sin\theta = n\lambda$. By scanning the sample through an arrangement of two angles, this equation connects the wavelength (λ) of electro-magnetic radiation to the diffraction angle (θ) and the lattice spacing (d) in a crystalline sample. Because of the random orientation of the powdered components, all of the conceivable lattice diffraction directions are achieved **(Boddolla et al.,2018)**

5.2 UV-VIS SPECTROSCOPY

UV spectroscopy is a physical technique of optical spectroscopy that uses light in the visible, ultraviolet, and near-infrared ranges. It is based on the Beer-Lambert law, which states that the absorbance of a solution is directly proportional to the concentration of the absorbing species in the solution and the path length. As a result, for a given path length, it can be used to calculate the concentration of an absorber in a solution. It is crucial to understand how quickly the absorbance changes with concentration. UV-VIS spectroscopy has been widely used for the last 37 years and has evolved into the most important analytical tool in the modern laboratory. Other techniques could be used in many applications, but none compare to UV-VIS spectroscopy in terms of simplicity, versatility, precision, speed, and cost-effectiveness. When radiation produces an electronic transition within a molecule or ion, it will absorb in the visible or ultraviolet area. As a result, light absorption by a sample in the ultraviolet or visible area is accompanied by a change in the electronic state of the molecules in the sample. Light energy promotes electrons from their ground state orbital to a higher energy, excited state orbital or anti-bonding orbital. Three different sorts of ground state orbitals could be involved **(Verma, G. et al., 2015).**



5.2 Schematic diagram of UV Vis Spectroscopy

5.3 HALL EFFECT

An electric current (electrons) flowing through a material is created by the action of a magnetic field on the current (electron). Because of its discovery in a metal, the Hall Effect has become widely used in semiconductors, particularly thin films, to characterize their properties. When it comes to semiconductor manufacturing, Hall Effect measurements are useful for characterizing practically every material that is employed. For the examination of electrical properties in semiconductor materials, such as resistivity, carrier density, and mobility, the Van Der Pauw method is one of the most widely used measuring techniques. Despite the fact that the Van Der Pauw method can be used to calculate samples of any shape, several basic sample conditions must be met in order to obtain accurate measurements. For example, the thickness of the sample must be constant, point contacts placed at the edges of the samples must be used to take measurements, and the sample quality must be homogeneous. Because the vast majority of semiconductor samples meet these requirements, this easy testing method is frequently used in semiconductor research. To create high performance innovative devices, the majority of semiconductor thin films are now in research. A straightforward measurement method for evaluating semiconductor thin films, the Van Der Pauw method is described here. Consequently, new thin films will occasionally be assessed using the Van Der Pauw method to establish film quality as a reference, independent of their homogeneity, in order to determine film quality. Many studies have been conducted to determine whether inhomogeneity has an effect on Van Der Pauw measurements of such unintentionally inhomogeneous samples, and a number of these studies have been published **(Maqsood, A et al.,2012)**.

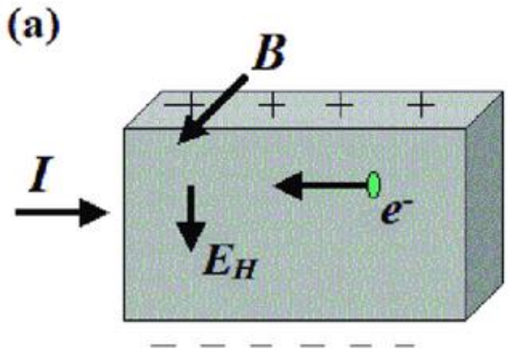


Fig 5.3 Schematic diagram of hall effect

5.4 RAMAN EFFECT

Raman spectroscopy is a technique that uses scattering. It is based on the Raman Effect, which states that the frequency of a small percentage of scattered radiation differs from the frequency of monochromatic incident radiation when the two are combined. It is based on the inelastic scattering of incident radiation that occurs as a result of the interaction of incident radiation with vibrating molecules. It is used to investigate the molecular vibrations.

A sample is irradiated with a monochromatic laser beam, which interacts with the molecules of the sample and causes a dispersed light to be emitted from it. In order to generate a Raman spectrum, it is necessary to use scattered light with a frequency that differs from that of the incident light (inelastic scattering). Spectra of Raman radiation are produced as a result of inelastic collisions between monochromatic radiation and molecules in the sample. When a monochromatic radiation beam reaches a sample, the radiation scatters in all directions as a result of its interaction with the sample molecules. Rayleigh scattering is the term used to describe a large portion of this dispersed radiation that has a frequency equal to the frequency of the incident radiation. Raman scattering is a type of scattering in which only a small fraction of the scattered radiation has a frequency that is different from the frequency of the incident radiation.

This is true when both the frequency of incident radiation and the frequency of dispersed radiation are higher than one another. When the frequency of incident radiation is higher than the frequency of scattered radiation, Stokes lines form in the Raman spectrum, indicating that the incident radiation is more frequent than the dispersed radiation. Anti-Stokes lines, on the other hand, appear in the Raman spectrum when the frequency of incident radiation is lower than the frequency of scattered radiation. Radiation scattered from an object is typically measured at a right angle to incident radiation.

Stokes shifted Raman bands are formed by transitions from lower to higher energy vibrational levels, and as a result, Stokes bands are more intense than anti-Stokes bands, and as a result, Stokes bands are used to quantify Raman spectroscopy in its conventional form. In contrast, anti-Stokes bands are determined using fluorescing samples because fluorescence interferes with the determination of Stokes bands. The magnitude of Raman shifts is not dependent on the wavelength of the incident radiation, as is the case with other optical effects.

The wavelength of the incident radiation has an effect on Raman scattering. The presence of a change in polarizability during molecular vibration is a necessary condition for obtaining the Raman spectrum of a material. Water is an excellent solvent for dissolving materials since the amount of Raman scattering caused by water is minimal. In Raman spectrophotometers, optical components such as mirrors, lenses, and sample cells can be made of glass ***(Gurvinder Singh Bumbrah et al.,2016)***

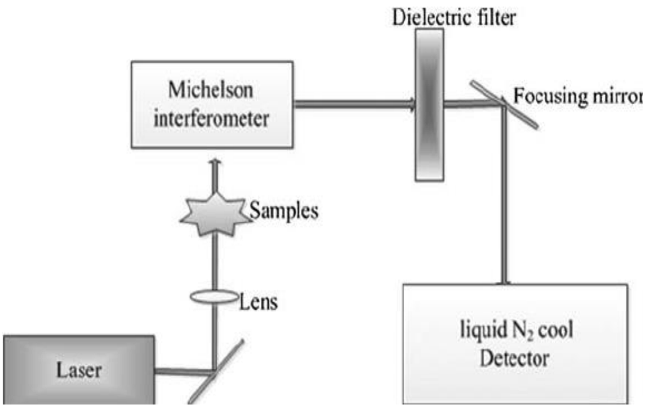


Fig 5.4 Schematic diagram of Raman effect

CHAPTER 6

RESULTS AND DISCUSSION

6.1 STRUCTURAL PROPERTIES

6.1.1 XRD

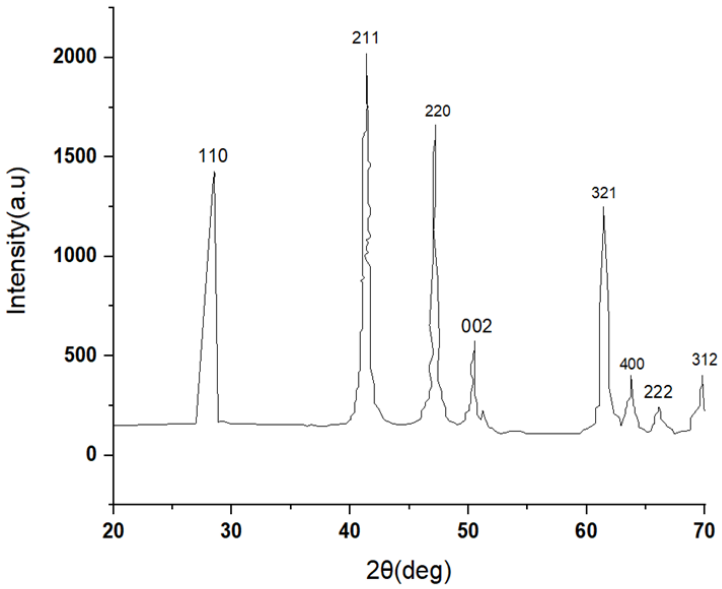


Fig 6.1 XRD Pattern of the SnO_2

The XRD pattern of the SnO_2 is shown in Figure 6.1. The peaks at 2θ values of 28.44°, 41.38°, 47.22°, 50.60°, 63.74°, 66.20°,69.85 can be associated with (1 1 0), (2 1 1), (0 0 2), (3 2 1), (4 0 0), (2 2 2), (3 1 2) respectively. The x-ray diffraction pattern revealed that the as deposited film had tetragonal crystal structure with preferable orientation along (110) plane. which are in good agreement with the literature values (JCPDS card no. 41-1445).

6.1.2 RAMAN SHIFT

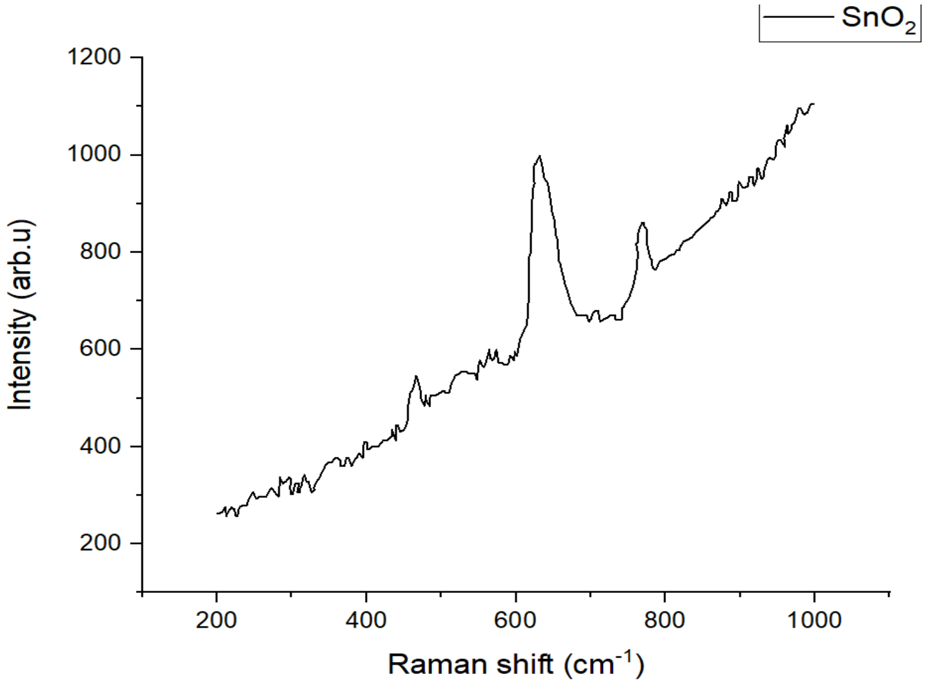


Fig 6.2 Raman shift graph for SnO_2 thin film

Raman spectroscopy is an effective instrument for characterizing nanoscale materials and can be used as a qualitative probe to determine the presence of lattice faults in crystalline solids. The crystalline quality can be determined by analyzing the peak shapes and selection rules. Tetragonal SnO_2 belongs to the space group D^{14}_{4h}, and the following optical phonons can be presented at the Brillouin zone point based on group theory:

$\Gamma = 1A_{1g} + 1A_{2g} + 1A_{2u} + 1B_{1g} + 1B_{2g} + 2B_{1u} + 1E_g + 3E_u$

According to group theory, the following

The Raman active modes are three non-degenerate modes A_{1g}, B_{1g}, B_{2g}, and doubly degenerate E_g, while the IR active modes are two (A_{2u} and triply degenerate E_u). The two silent modes, on the other hand, are A_{2g} and B_{1u}. The A_{1g}, B_{1g}, and B_{2g} modes are caused by oxygen atom vibration with the plane perpendicular to the c axis, whereas E_g is caused by vibration in the direction of the c axis. Figure 6.2 shows the Raman spectra of undoped SnO_2 samples collected in the frequency range 100–1000 cm^{-1}. Pure SnO2 has three distinct Raman peaks at 474, 632, and 772 cm^{-1}, which are ascribed to the E_g, A_{1g}, and B_{2g} modes, respectively **(Saleh, S. et al.,2016).**

6.2 OPTICAL PROPERTY

6.2.1 UV- VISIBLE ANALYSES

- ***TRANSMITTANCE GRAPH***

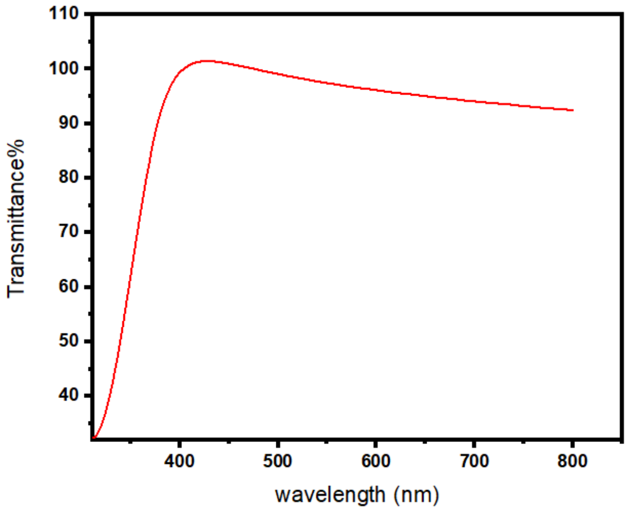


Fig 6.3 Transmittance Graph of SnO_2 thin film

It shows the SnO_2 thin film's optical transmittance spectrum in the wavelength range of 280 to 800 nm. Optical interference is responsible for the many peaks in the transmission spectrum. The film is very transparent in the visible spectrum, with an average transmittance of up to 90-100%, and has a sharp ultraviolet cut-off of around 290 nm. Because the size of grains and the surface texture of transparent films like SnO_2 have such a big impact on their transmission **(Akgul, F et al.,2013)**

From the transmittance it is clear that SnO_2 can transmit more amount of energy than CdTO, CdO, ZnO thin films)]. Basically, the energy conversion is depending on how much the solar radiation can transmit through the coating material. Also, this transmittance of SnO_2 has good agreements with results of **(T. Serin et al. (2006), A.R. Babar et al (2011))**.

- ***ABSORBANCE GRAPH***

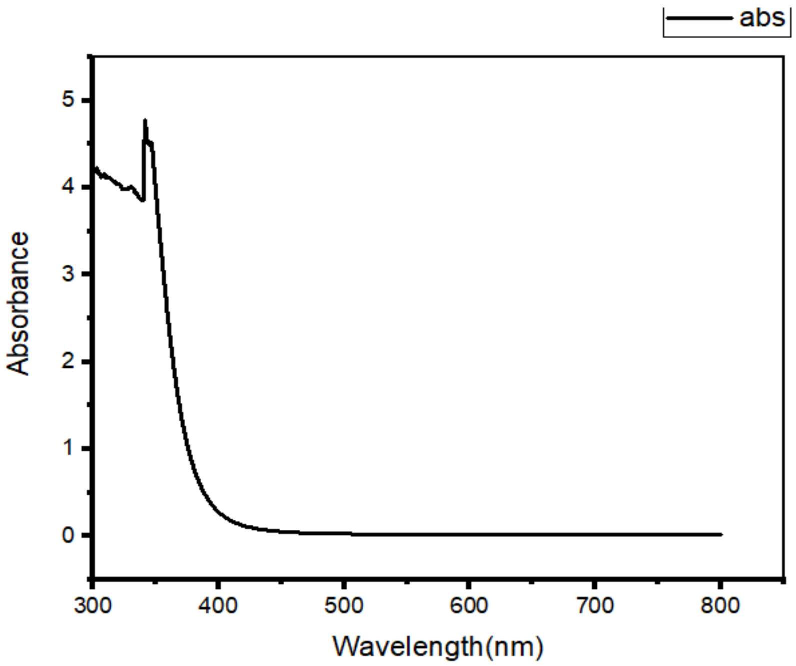


Fig 6.4 Absorbance graph for SnO_2 solution

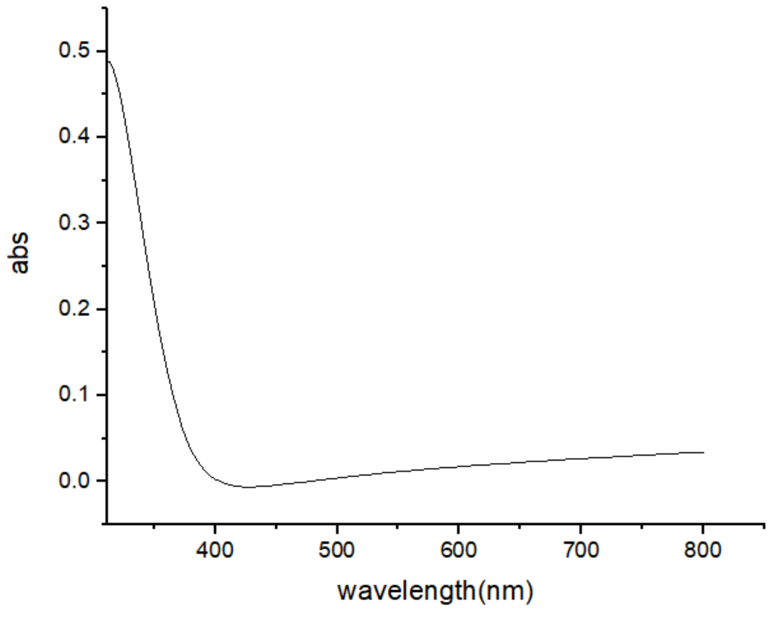


Fig 6.5 Absorbance graph for SnO_2 thin film

The absorbance spectrum of SnO_2 solution and Thin Film has been obtained by using UV-Vis Spectroscopy technique. The figure 6.4 illustrates that that maximum absorbance of pure SnO_2 solution is about between 4-5 a.u. The figure 6.5 illustrates that that maximum absorbance of pure SnO_2 thin film is about between 0.4-0.5 a.u. SnO_2 solution has maximum at 312 nm cut-off frequency. SnO_2 thin film has maximum at 320nm cut-off frequency, which indicates that both samples absorb maximum radiation in the UV region and decrease gradually in the visible region. We know that in the day time, the Earth's surface receives more UV radiation from the sun than the night (receive IR radiation). Therefore, SnO_2 Thin film suitable for Solar Cell Application. Also, it has good agreements **(C. Agashe et al (2009)**.

- ***BAND GAP***

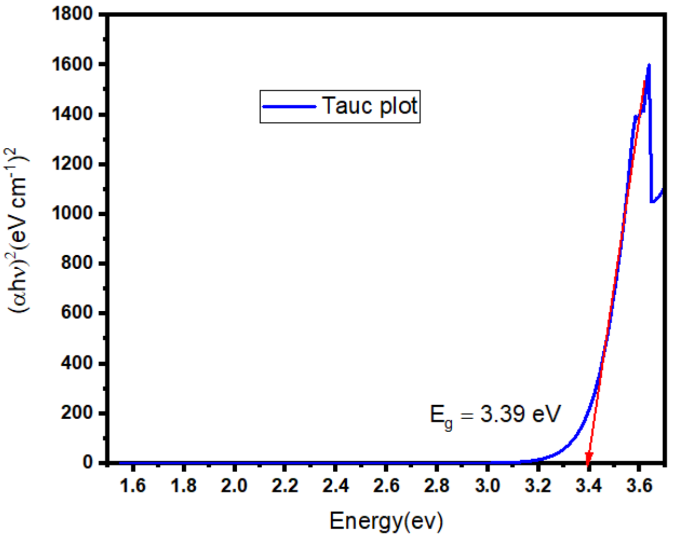


Fig 6.6 band gap graph for SnO_2 solution

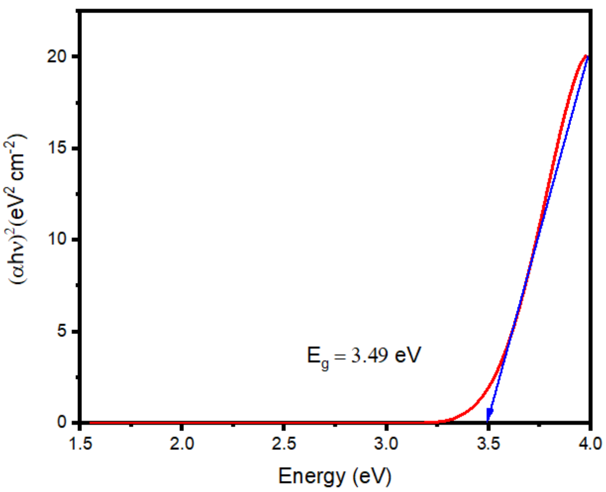


Fig 6.7 band gap graph for SnO_2 thin film

To determine the possible transitions, $(ahv)^{1/n}$ vs. hv was plotted and corresponding band gap was obtained from extrapolating the straight portion of the graph on hv samples.

Fig 6.6 shows the band gap of pure SnO_2 solution. Fig 6.7 shows the band gap of pure SnO_2 thin film.

The optical energy band gap was obtained axis at a = 0 The plot of (ahv) versus hv is plotted for both undoped solution and thin film by extrapolating the linear portion of $(ahv)^2$ versus hv plot to $(ahv)^2$ gives 3.39-3.6eV for undoped SnO2 solution and gives 3.49-3.52eV for undoped SnO_2 thin film **(Rameshkumar. C et al.,2021)**

6.3 ELECTRICAL PROPERTY

6.3.1 HALL EFFECT

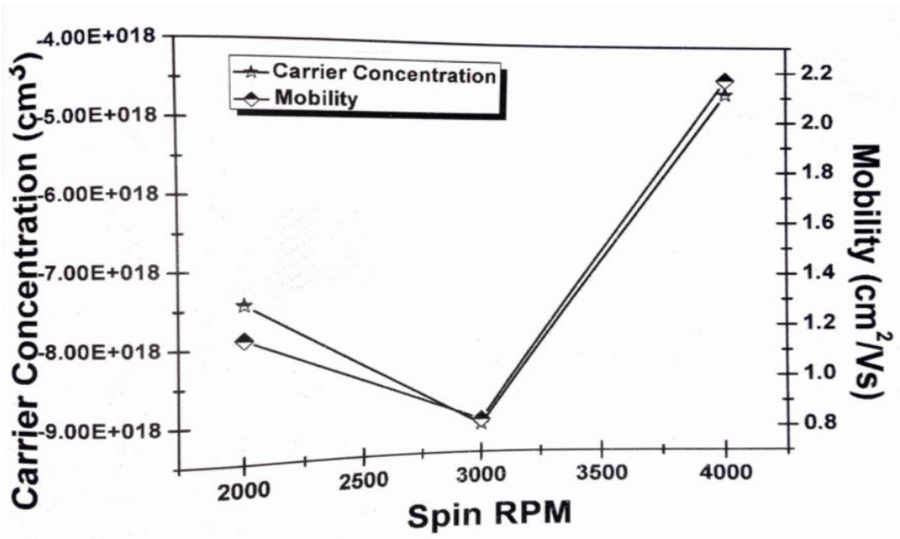


Fig 6.8 Variations in the carrier concentration and Hall mobility of the SnO_2 films as a function of the spin RPM

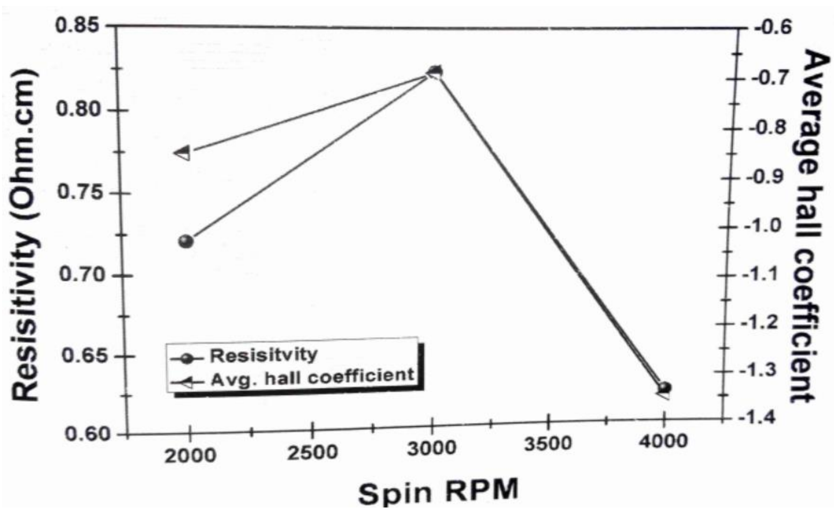


Fig 6.9 Variations in the resistivity and average hall coefficient of the SnO_2 film as a function of the spin RPM

No significant changes in the electrical properties of the film were observed in terms of the spin RPM. The carrier concentration 7.0E+018 cm^3 and the mobility is 2.2cm^2/s. The Resistivity value is 0.62 Ω-cm or the undoped sample. Thus, the carrier concentration and resistivity values show the good conductivity nature of undoped tin oxide thin film. Fig 6.8 and 6.9 shows that variation in the carrier concentration and mobility of SnO_2 thin film as a function of the spin RPM and the variation in the resistivity and the average hall coefficient of the SnO_2 film as a function of spin RPM respectively.

CHAPTER 7

CONCLUSION

SnO_2 thin film can be successfully deposited on the glass substrate by sol gel spin coating method. We investigated the structural, optical and electrical properties of pure SnO_2 thin film. Structural characteristics were determined by XRD and Raman shift. The x-ray diffraction pattern revealed that the as deposited film had tetragonal crystal structure with preferable orientation along (110) plane. The tetragonal structure of all prepared samples was confirmed by X-ray diffraction spectra and the Raman scattering. Optical characteristics was investigated using a UV visible spectrometer. The optical band gap of tin oxide is calculated using Tauc's plot. The value is found is about 3.39-3.49 for solution and thin film samples. The transmittance of pure SnO_2 sample is about above 90. Therefore, it is found suitable for photo voltaic devices. The carrier concentration 7.0E+018 cm^3 and the mobility is 2.2cm^2/s. The Resistivity value is 0.62 Ω-cm or the undoped sample. Thus, the carrier concentration and resistivity values show the good conductivity nature of undoped tin oxide thin film. In future research work, addition of dopant to these base SnO_2 and characterized the film for solar cell application.it is high response against the incident light.

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Deposition, s., film, t., sulfide, C., sulfide, c., treatment, h., telluride, C., process, m., reaction, a., deposition, c., dioxide, T., process, d. and deposition, r., 2022.

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