Nano Metal Chalcoginide Thin Film for Photosensing

Bhagyashri Dilip Patil

Department of Physics, Arts Science and P.O. Nahata Commerce College, Bhusawal, 425201 India.

Email- bhagyashripatil1989@gmail.com

Anil Ramdas Bari*

Department of Physics, Arts commerce Science college, Bodwad, 425310, India.

Email- anilbari_piyu@yahoo.com

* Corresponding Author: **Dr. Anil Ramdas Bari** (Mob. No. +91 9421523832)

Abstract:-

Some techniques allow the synthesis of various nanostructure. In Metal chalcoginide, many sulphides (ZnS, PbS, CdS) are utilised in various sensing equipments. Within the frame of this work, some nanostructures metal chalcoginide thin film synthesis using various process for solar cell, photoluminescence, and photoconductivity. Thin film prepared using various chemical methods such as sol gel method, chemical vapour deposition, colloidal method, spray pyrolysis. Some pigments and catalysts are also based on chalcogenides. At the same time paper present few examples of the use of techniques to develop advanced properties of material.

Keywords: Nano, Thin Films, Sol-gel, Metal chalcogenide, Photosensing

---

Introduction: -

A chemical molecule known as a chalcogenide is made up of at least one chalcogen anion and at least one additional electropositive element. Materials called chalcogenides include one or more chalcogen elements (such as S, Se, or Te) as a significant ingredient. They are covalently bonded materials with a band gap that typically ranges from 1-3 eV depending on composition, even though they could be amorphous or crystalline [1]. More frequently, tellurides, polonides, sulphides, and selenides are used as chalcogenides [2].

Photoconductivity is a physical phenomena that occurs both optically and electrically in which the absorption of electromagnetic radiation, such as visible light, ultraviolet light, infrared light, or gamma radiation, causes a substance to become more electrically conductive[3]. When a substance absorbs light, the number of free electrons and holes increases, resulting in improved electrical conductivity [4]. When a photoconductive material is attached to a circuit, it acts as a resistor whose resistance varies with the intensity of the light. In this context, the substance is referred to as a photoresistor (also called light-dependent resistor or photoconductor). Photoresistors are most commonly used as photodetectors, or devices which measure the intensity of light. Photoresistors are often used in photodetector applications such as camera light metres, street lights, clock radios, infrared detectors, nanophotonic systems, and low-dimensional photo-sensor devices [5]. Photoconductivity was investigated using thin films of various materials (TiO2/dopamine, TiO2, Zinc Oxide, and so on).

After photons absorption, light emission from any form of matter is called as photoluminescence [6]. The measurement of the degree of disorder in a system and the purity and crystalline quality of semiconductors like GaN and InP can both be done using photoluminescence [7]. $Ba(Co_{2x}Ti_{1-x})O_3$, $BiFeO_3$: Er-Doped, ZnS, Y_2O_3: Eu3+ thin-film phosphors with Mg2+ and Al3+ co-doping, ZnO, etc. are some of the thin films on which photoluminescence has been researched.

A solar cell, also known as a photovoltaic cell, is an electrical device that uses the photovoltaic effect, a natural physical and chemical phenomena, to convert light energy directly into electricity[8]. It is a type of photoelectric cell, which is characterised as an electrical device whose electrical properties, such as current, voltage, or resistance, change when exposed to light [9]. Solar cells were investigated using thin-film materials such as SiO2, Al-doped ZnO, Cu2ZnSnS4, CuInS2, and others.

Nanostructure synthesis method have three types such as, physical method, chemical method, biological method.

For photoconductivity, photoluminescence, solar cell, etc. used these chemical methods. Chemical methods have sol gel method, chemical vapour deposition, colloidal method, spray pyrolysis.

Chemical vapour deposition, or CVD, is the process of depositing thin layer materials from the vapour phase via a chemical reaction. This method is used to deposit a wide variety of thin film materials such as semiconductors, insulators, barrier layers, metals, silicides, superconductors, and organics. These films are used to make microelectronic and optoelectronic devices as well as optical coatings, protective coatings, and ornamental coatings. The thin films deposited can be epitaxial, polycrystalline, or amorphous in nature, and the deposition method can be selective or non-selective, or homo-heteroepitaxy [10]. For example, in the CVD creation of carbon nanotubes, a substrate is heated to high temperatures in an oven. As a result, a carbon-containing gas (such as hydrocarbons) is gradually injected into the system as a precursorDecomposition of the gas at high temperatures releases carbon atoms, which recombine to create carbon nanotubes on the substrate [11]. In general, CVD is a great technique for creating high-quality nanomaterials [12].

Spray pyrolysis is a procedure that involves spraying a solution onto a heated surface to generate a thin film, where the components react to form a chemical compound [13]. According to the type of reaction, the chemical spray deposition method can be categorised into three types: In the first group, the solution's droplets remain on the heated surface as the solvent evaporates, and the components may continue to interact once the surface is dry. The second group represents a process in which the solvent evaporates before the drops reach the heated surface and the decomposed dry solid impinges on the surface. In the third group, as the droplets approach the substrate, the solvent vaporises, resulting in a heterogeneous reaction of the solution components [14]. The substrate temperature, carrier gas flow rate, nozzle-to-substrate distance, and solution content and concentration are the most critical parameters to control in all of these processes. Among these variables, the substrate temperature has been regarded as the most essential component in creating thin films from spray pyrolysis processing since droplet drying, breakdown, crystallisation, and grain development are all strongly dependent on this parameter [15].

In colloidal method, before drop casting the wet particles onto a substrate, the particles must first be created in a solution, then the solvent, surfactants, and other ingredients must be removed. This wet synthesis process needs a lot of time and chemicals, and the final material may be contaminated with residues from the solution [16].

The sol-gel method is a more chemical way for creating different nanostructures, particularly metal oxide nanoparticles. In this method, by heating and stirring, the molecular precursor (usually metal alkoxide) is dissolved in water or alcohol and transformed to gel by hydrolysis/alcoholysis. If the gel resulting from the hydrolysis/alcoholysis process is wet or damp, it should be dried using appropriate procedures based on the desired properties and application of the gel. Advantages such as, process simplicity, extremely high output efficiency, Because of the process's solution phase, precursors have a high chemical reactivity. low initial investment while having high quality products, low temperature preparation, minimum air pollution, , large number precursor are available, less evaporation during the process as shown in Fig. 1[17].

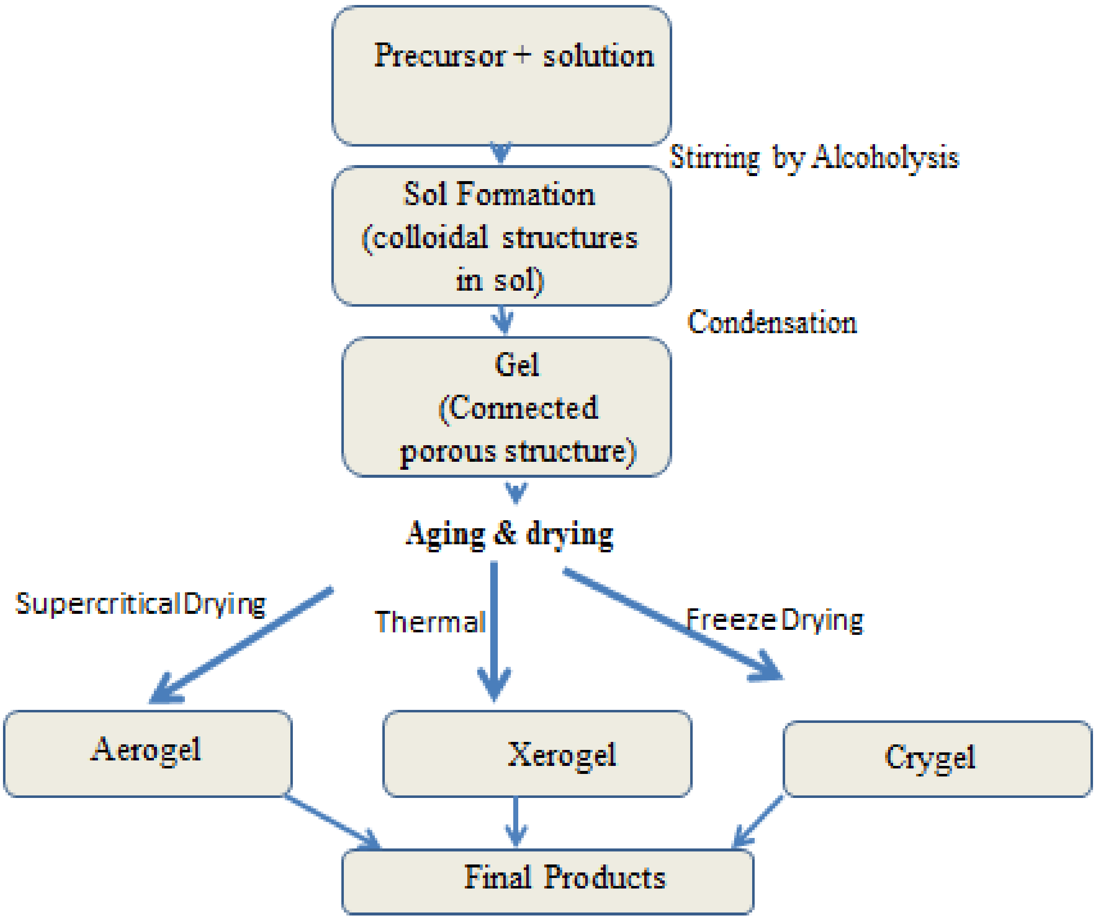

Fig. 1: Sol-Gel Method

Recent Develpoment:-

During the last two decades, researcher research the properties of solar cell, Photoconductivity, photoluminescence using various materials using various technique.

Chia Hong Huang , Chung Cheng Chang , and Jung-Hui Tsai research on MOS solar cells with oxides deposited by sol gel spin coating techniques. In this case, spin coating method was used to create SiO2 coatings on Si generated from sol gel. Such SiO2 layers have been created in MOS solar cells. Sol gel spin coating technology is a quick, easy, low-cost, and low-temperature procedure. Such a procedure is especially appropriate for production on a large scale and in huge quantities. From the above results, for MOS solar cells, it has been discovered that a sol gel SiO2 layer is an alternative to a thermally produced oxide layer. Additionally, it demonstrates that thin oxide MOS solar cells can use sol gel technology [18].

Afrina Sharmin, Samia Tabassum, M. S. Bashar & Zahid Hasan Mahmood research on depositions and characterization of sol–gel processed Al-doped ZnO (AZO) as transparent conducting oxide (TCO) for solar cell application. It can be concluded that, the best Zn concentration for AZO film as transparent conduction oxide for solar use is 0.75 mol/L. A qualitative and quantitative analysis of AZO thin films is also provided by the EDX research. With superior coverage than other films, the 1039-nm-thick film exhibits fewer voids[19].

Mehdi Ahmadi1, Sajjad Rashidi Dafeh, and Saeid Alinazmabadi research on first observation of sol-gel derived Al:CsZnO/CsZnO bilayer thin film for solar cells application. Using the spin-coating-assisted sol gel technique, CsZnO and Al:CsZnO/CsZnO bilayer thin films were grown on ITO substrates. According to the results, pure ZnO thin film optimised at 2500 RPM for 60 minutes with various spin-coating velocities. We created CsZnO and Al:CsZnO/CsZnO bilayer thin films with various dopant concentrations by optimising them. Thin films with bilayers of CsZnO and Al:CsZnO/CsZnO were studied for their optical characteristics. When comparing the effects of various doping ratios, it was discovered that 0.5% of Cs or Al displayed the greatest results in the ratios that were studied[20].

G. Valverde Aguilar, G. Prado-Prone, P. Vergara Aragón, J. Garcia Macedo, Patricia Santiago & Luis Rendón research on photoconductivity studies on nanoporous TiO_2/dopamine films prepared by sol–gel method. From photoconductivity studies, compared to TiO2/DA/15C5, amorphous TiO2/DA film has better charge transfer. The complex of TiO2/DA is affected in a number of ways by the addition of 15C5. (I) When the film is illuminated, it prevents the development of oxidation products as well as charge transmission; (II) A little red shift in the maximum peak absorption was discovered; and (III) Without calcinations, TiO2/DA/15C5 and TiO2/15C5 films developed a partial crystallisation in the TiO2 matrix[21].

G. Valverde-Aguilar , J. L. Manrı´quez Zepeda research on photoluminescence and photoconductivity studies on amorphous and crystalline ZnO thin films obtained by sol–gel method. In crystalline films as compared to amorphous ones, the luminous emission is more intense. It results from the film's crystallisation. The main transitions were at 411, 455, and 471 nm, which, in turn, corresponded to the zinc vacancies, electronic transitions of the oxygen vacancies and zinc interstitials, and transitions of unknown origin, respectively. According to photoconductivity research, the wurtzite phase formed in the ZnO matrix gives higher stability, which increases charge transfer[22].

Mohd. Mubashshir Hasan Farooqi Rajneesh Kumar Srivastava research on Effect of Annealing Temperature on Structural, Photoluminescence and Photoconductivity Properties of ZnO Thin Film Deposited on Glass Substrate by Sol–Gel Spin Coating Method. In sol-gel generated ZnO thin films formed on glass substrate, the impact of post-annealing treatment on structural and photoluminescence properties has been investigated using XRD, SEM, and photoluminescence spectroscopy. In addition, ZnO thin films' photoconductivity properties were investigated by measuring the variation of dark current and photocurrent with applied voltage and recording the rise and decay of photocurrent in air. It is observed that, three successive cycles produced a consistent photo response in the rise and decay spectra, indicating that the UV-Vis photo response capability of the synthesised films is highly reproducible[23].

Anchal Srivastava , Kamakhya Prakash Misra research on band gap control and photoluminescence properties of Ba(Co2xTi12x)O3 thin films prepared by Sol–gel method. XRD, EDS, and FTIR confirm the development of highly transparent sol-gel derived $Ba(Co_{2x}Ti_{1-x})O_3$ ($0 \le x \le 0.06$) thin films with previously unreported near-band-gap excitonic emission in the ultraviolet range about 378 nm. The presence of PL emission suggests that the band gap is 'direct' in the barium titanate-based thin films produced here. The analysis of band gap change with dopant concentration using Tauc's plot, assuming both 'direct' and 'indirect' natures, also confirms the 'direct' nature. Besides UV, in the green zone, there is a much weaker emission. As the excitation wavelength is extended to the visible range, PL emission returns to the green region, though sharper and at a higher wavelength, demonstrating the consistency of the localised states in the band gap region. The grain size of these spin-coated on fused quartz substrate films increases with dopant concentration. SEM images show the granular development transforming into flakes as the dopant Co is introduced. The AFMs reveal ribbon-like nanostructured grain development throughout the surface, which is smooth with low surface roughness values[24].

Remark:-

Considering this viewpoint, we will prepared a nanostructure metal chalcoginide thin film using deposition chemical method for photosensing. For the structural, optical, and electrical properties of thin film we will be used various characterization techniques (XRD, SEM, TEM, EDAX, AFM, UV, etc.).

References:-

[1] https://chalcogenide.wordpress.com/what-are-chalcogenides/

[2] Greenwood, N. N.; & Earnshaw, A. (1997). Chemistry of the Elements (2nd Edn.), Oxford:Butterworth-Heinemann. ISBN 0-7506-3365-4.

[3] DeWerd, L. A.; P. R. Moran (1978). "Solid-state electrophotography with Al2O3". Medical Physics. 5 (1): 23–26. Bibcode:1978MedPh...5...23D. doi:10.1118/1.594505. PMID 634229.

[4] Saghaei, Jaber; Fallahzadeh, Ali; Saghaei, Tayebeh (June 2016). "Vapor treatment as a new method for photocurrent enhancement of UV photodetectors based on ZnO nanorods". Sensors and Actuators A: Physical. 247: 150–155. doi:10.1016/j.sna.2016.05.050.

[5] Hernández-Acosta, M A; Trejo-Valdez, M; Castro-Chacón, J H; Torres-San Miguel, C R; Martínez-Gutiérrez, H; Torres-Torres, C (23 February 2018). "Chaotic signatures of photoconductive Cu ZnSnS nanostructures explored by Lorenz attractors". New Journal of Physics. 20 (2): 023048. Bibcode:2018NJPh...20b3048H. doi:10.1088/1367-2630/aaad41.

[6] Tebyetekerwa, Mike; Zhang, Jian; Xu, Zhen; Truong, Thien N.; Yin, Zongyou; Lu, Yuerui; Ramakrishna, Seeram; Macdonald, Daniel; Nguyen, Hieu T. (24 November 2020). "Mechanisms and Applications of Steady-State Photoluminescence Spectroscopy in Two-Dimensional Transition-Metal Dichalcogenides". ACS Nano. 14 (11): 14579–14604. doi:10.1021/acsnano.0c08668. PMID 33155803. S2CID 226269683.

[7] Alfaraj, N.; Mitra, S.; Wu, F. ; Ajia, A. A.; Janjua, B.; Prabaswara, A.; Aljefri, R. A.; Sun, H.; Ng, T. K.; Ooi, B. S.; Roqan, I. S.; Li, X. (2017). "Photoinduced entropy of InGaN/GaN p-i-n double-heterostructure nanowires". Applied Physics Letters 110 (16): 161110.

[8] Solar Cells. chemistryexplained.com

[9] A. C. Jones and M. L. Hitchman, in Chemical Vapour Deposition, ed. A. C. Jones and M. L. Hitchman, Royal Society of Chemistry, Cambridge, 2008, pp. 1–36.

[10] Crowell, J. E. (2003). Chemical methods of thin film deposition: Chemical vapor deposition, atomic layer deposition, and related technologies. Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films, 21(5), S88–S95. doi:10.1116/1.1600451.

[11] H. Ago, Frontiers of Graphene and Carbon Nanotubes, Springer, Japan, Tokyo, 2015, pp. 3–20.

[12] Perednis, D., & Gauckler, L. J. (2005). Thin Film Deposition Using Spray Pyrolysis. Journal of Electroceramics, 14(2), 103–111. doi:10.1007/s10832-005-0870-x

[13] J. B. Mooney, S. B. Radding. Spray pyrolysis processing. Annu. Rev. Mater. Sci. 1982; 12: 81-101.

[14] J. C. Viguié, J. Spitz. Chemical vapor deposition at low temperatures. J. Electrochem. Soc. 1975; 122(4): 585-588.

[15] G. J. Exarhos, X-D. Zhou. Discovery-based design of transparent conducting oxide films. Thin Solid Films. 2007; 515: 7025-7032.

[16]https://www.nanoscience.com/techniques/nanoparticle-synthesis/ https://www.nanoscience.com/techniques/nanoparticlesynthesis/#:~:text=%5D%20for%20example).,Colloidal%20nanoparticle%20synthesis,other%20materials%20from%20the%20particles.

[17] Dmitry Bokov, Abduladheem Turki Jalil, Supat Chupradit, Wanich Suksatan, Mohammad Javed Ansari, Iman H. Shewael, Gabdrakhman H. Valiev, Ehsan Kianfar, "Nanomaterial by Sol-Gel Method: Synthesis and Application", Advances in Materials Science and Engineering, vol. 2021, Article ID 5102014, 21 pages, 2021. A. C. Jones and M. L. Hitchman, in Chemical Vapour Deposition, ed. A. C. Jones and M. L. Hitchman, Royal Society of Chemistry, Cambridge, 2008, pp. 1–36.

[18] Huang, C.-H., Chang, C.-C., & Tsai, J.-H. (2013). MOS solar cells with oxides deposited by sol-gel spin-coating techniques. Semiconductors, 47(6), 835–837. doi:10.1134/s1063782613060092.

[19] Sharmin, A., Tabassum, S., Bashar, M.S. et al. Depositions and characterization of sol–gel processed Al-doped ZnO (AZO) as transparent conducting oxide (TCO) for solar cell application. J Theor Appl Phys 13, 123–132 (2019). https://doi.org/10.1007/s40094-019-0329-0.

[20] Ahmadi, M., Rashidi Dafeh, S. & Alinazmabadi, S. First observation of sol-gel derived Al:CsZnO/CsZnO bilayer thin film for solar cells application. Eur. Phys. J. Plus 131, 354 (2016). https://doi.org/10.1140/epjp/i2016-16354-5

[21] Valverde-Aguilar, G., Prado-Prone, G., Vergara-Aragón, P., Garcia-Macedo, J., Santiago, P., & Rendón, L. (2013). Photoconductivity studies on nanoporous TiO2/dopamine films prepared by sol–gel method. Applied Physics A, 116(3), 1075–1084. doi:10.1007/s00339-013-8187-0 .

[22]Valverde-Aguilar, G., Manríquez Zepeda, J.L. Photoluminescence and photoconductivity studies on amorphous and crystalline ZnO thin films obtained by sol–gel method. Appl. Phys. A 118, 1305–1313 (2015). https://doi.org/10.1007/s00339-014-8836-y.

[23] Farooqi, M. M. H., & Srivastava, R. K. (2019). Effect of Annealing Temperature on Structural, Photoluminescence and Photoconductivity Properties of ZnO Thin Film Deposited on Glass Substrate by Sol–Gel Spin Coating Method. Proceedings of the

National Academy of Sciences, India Section A: Physical Sciences. doi:10.1007/s40010-019-00648-x

[24] Srivastava, A., & Misra, K. P. (2014). Band gap control and photoluminescence properties of Ba(Co2x Ti1−x)O3 thin films prepared by Sol–gel method. Applied Physics A, 117(2), 917–926. doi:10.1007/s00339-014-8471-7