Synthesis and Characterization of Structural and Optical Properties of Al_2O_3 Dopped SnO_2 Nano Composites

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Abstract: - The structural and optical properties of Al_2O_3dopped SnO_2 Nano Composites nano particles of metal oxides are studied here. The subjected nano composites nano particles of metaloxides were synthesized using chemical route method i.e., microwave assisted chemical co- precipitation method. The synthesized samples were characterized by the methods of X-Ray Diffraction, FTIR Spectroscopy and UV-VIS Spectroscopy for the structural and optical properties of the samples. The result suggests that samples are of nano size and are wide band gap semiconductors in nature. The X-Rays Spectrum a, UV-Visible Spectrum and Tauc Plots of the samples results were analyzed and size, absorption peaks and band gaps of the samples were calculated and compared. The comparative study suggests the applications of the samples as per their properties of wide band gap semiconductors behavior.

Keywords: Band Gap, Wide Band Gap, Nano-Materials, Nano-Composites,

1. INTRODUCTION:-

Nano-composite and nano materials have long been the subject of interest and extensive study. The interest in the heterogeneous systems made of nanoparticles due to their current and future utility applications to the thrust zone/s. The field is. That these nanoparticles and nano composites are basically related to the high surface-to-volume ratio and the high total interfacial surface area of the embedded nanoparticles/nanocomposites. In addition, many size-dependent functional properties can be enriched by nanoparticles and hosting materials with interesting multifunctional utilities (Bashir & Liu, 2015).Structural and semiconducting properties of the nanocomposites and nanoparticles are the most popular functional nano fillers (Bousiakou et al., 2022; Chavali & Nikolova, 2019) for the thrust area. The structural and semiconductor's band gap properties of the resultant nano-composites are affected and sometimes are limited by various factors, such as the degree of dispersion/aggregation of nanoparticles, the strength of inter particle interactions, and the effect of the surface on the nanoparticle'sstructures and band gap(Allia et al., 2014; Joschko et al., 2021). Whereas some aspects are still perplexing, such as the extent to which the interface between nanocomposites and nanoparticles will affect the structural and semiconducting properties and the given enclosure influences their properties (Bagheri-Mohagheghi et al., 2008; Gnanaprakasam Dhinakar et al., 2016). The density of holes and electrons in metal oxides can be adjusted and controlled to a large extent by doping small amounts of impurities. Atoms that intentionally replace atoms to any degree in a crystal are called dopants and the cognitive process is called doping. Therefore, by doping, we can create intermediate states in the bandgap of metal oxide nanomaterials. In this way, doping will significantly increase the imperfection of the surface and cause a change in the electrical properties of the metal oxide. The dopant atoms presented can be interstitially dissolved or ionized or replaced in crystalline sites, resulting in deformation in the lattice, affecting the neutrality of the charge and the properties of the parent compound. The ions and cations that are doped have a unique effect on the network of metal oxide nanomaterials (MONS). Metal oxide nanomaterials (MONS) which generally act as a recombination center for excited electrons, while anionic doping results in cationic doping in the localized D states in the bandgap of deepening the donor levels in the P states near the valence band. Therefore, during doping, specific behaviors such as the ionization energy of impurities, absorption edge, state density and fundamental energy differences of metal oxide nanomaterials change due to the high concentration of impurity or due to the high concentration of charge carriers.The metal oxide semiconductors are widely used in various sensors (Wang et al., 2010). Nanocomposites are formed by mixing oxides that depend on the concentration of the material (Shaba et al., 2021; Zhu et al., 2020). Nanocomposites are very important for a variety of applications, such as– gas sensors, photovoltaic devices and solar cells (Ates et al., 2020; Doagou-Rad et al., 2020). Nickel oxide is one of the P-type semiconductors (Egbo et al., 2020). SnO**2** is an N-type semiconductor widely used in electronics. Solar cells and gas sensors (Hashim & Hamad, 2020; Li et al., 2001; Mahmood et al., 2020), nano-campsites and the optimal properties, which are significantly superior to simple oxides, improve properties in nanocomposite electrical and electronic applications, where the physical properties of nanocomposites are mainly influenced by the chemical composition of materials used in nanoscale and applications (El-Sharkawy et al., 1997; Mahmood et al., 2020). The commonly used oxides are tin oxide, nickel oxide, cadmium dioxide, Aluminium oxide, and tungsten oxide. These materials have been successfully used to detect a range as low cost, simple manufacturing, small size and good detection properties (Du et al., 2018; H. Xu et al., 2022). Furthermore, this approach provides reproducible films that have a well-defined nanostructure with grain and grain boundaries that can be easily studied (Mariano et al., 2020; B. Xu et al., 2018).In this work, we prepared Al_2O_3-SnO_2 nano composite nano structures by micro wave assisted chemical co-precipitation method. The goal of this work is to synthesize Al_2O_3- SnO_2 nanocomposites with different concentration at different calcination temperatures. The effect of different reports on the nano composites nano structures for the most part focusing on the resulting structural and optical properties were studied and the results obtained were compared and discussed here. The properties will be shown here which critically depends upon the types of the host enclosure and on the preparation proficiency.

2. Research Methodology

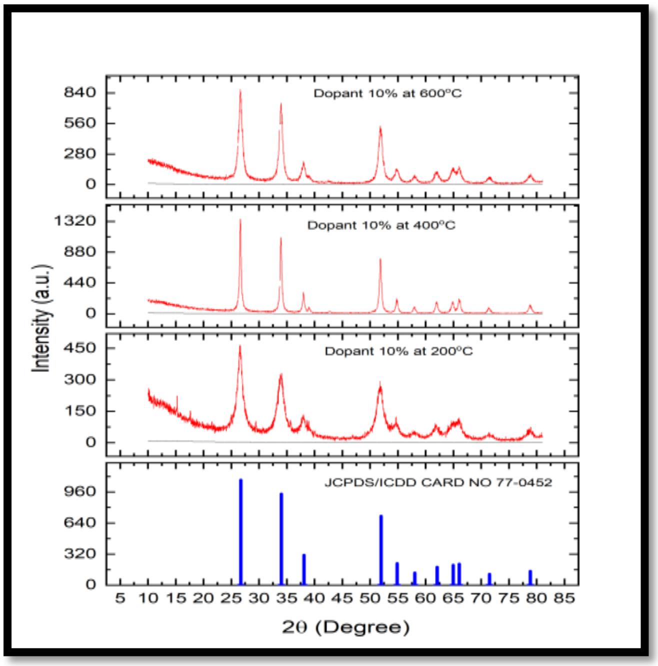
Experimental Synthesis Techniques:-The Fe-doped SnO_2 nano composites formation was carried out using microwave-assisted chemical coprecipitation method in which $SnCl_2.5H_2O$ and $Fe(NO_3)2$ were dissolved in 100 ml of deionized water with a suitable 10% molar concentration. The resulting solution was flexed again using magnetic stirrer for 1 hour at room temperature to obtain a clear solution of an acidic nature continuously and regularly. Then, an ammonium solution (NH_4OH) was added drop-drop with constant stirring to the solution so that its pH remained at a value between 8 and 9, which was confirmed using the electrode pH meter (the pH meter was calibrated using the buffer solution). The resulting precipitated solution was maintained for the aging process to stabilize the same size of the crystal for about 24 hours. Now the precipitate is filtered using qualitative Whatman filter paper which has a pore size (20-25 micrometers). The resulting precipitate was washed using distilled water and ethanol to release impurities such as nitrate and chloride. The precipitated cake was heated from 4 hours to 6 hours at 100 °C using a hot plate to remove the water contents. Now, part of the resulting sample is grinded in the agate mortar and pastel and samples the "synthesized samples" and another part was then calcined to 200°C, 400 °C and 600°C, respectively and as powder form samples using the agate mortar and pestle. The samples as synthesized, calcined sample and various calcined samples were placed in an airtight container and used for structural, optical and other characterization techniques.

Sample Characterization: -The synthesized samples are characterized and the additional methods were used to elucidate the composition and phase of the heat-treated samples. The XRD of the samples was recorded by Philips PW/1710 X-ray diffractometer; With the Ni filter, the monochromatic radiation with Cu Kα wavelengths 1.5418 Å at 50 KV and 40 mA, in the range of $2\theta \sim 20^{o}$- 80 °. The particle size, size and distribution of the samples were studied at 100 kV using a transmission electron microscope (Hitachi-H7500). For this purpose, the dispersion of sample nanoparticles was piped onto a carbon-coated copper grid. Infrared spectra were recorded on pellets obtained from dispersing the samples in sodium bromide using a Fourier transform infrared spectrometer (Perkin Elmer 1600) ranging from 2500 cm^{-1} to 400 cm^{-1}. The UV visible spectrum was recorded for nanoparticles using the Lambda 365 Perkin Elmer UV-Visible Spectrophotometer.

3. RESULTS AND DISCUSSION

XRD Analysis: - In Powder X-ray diffraction investigation, the crystalline phase of samples was calculated at room temperature using Rigaku Mini flex diffractometer with wavelength of radiation 1.54 Angstrom. In the x ray analysis, one matched Phases was obtained for the 10% doping of $Al2O_3$ with the SnO_2. the corresponding spectra shows the well-matched peaks as tin oxide which is indexed for the different calcination temperatures. the observed XRD pattern revealed the formation of nano-composites of tin oxide with Aluminium oxide, further with no change in phase of tin oxide suggests that tin is replaced by the Al ions. The experimental and calculated peaks are well matched which signifies the formation of single phase nano-composites. The figure 5.1 shows the comparative study of Aluminium oxide nano-composites.

Optical Properties:-The optical properties are an important property of the nano particles and for the nano composites are very useful for gas sensors, electronics and in optoelectronics. These properties include absorbance and energy deviation of the targeted samples.



Absorbance Properties:-In the figure number 5.2, which shows pure Al2O$_3$ dopped with SnO_2: and nano composites are synthesized. According to figure number 5.2 and 5.3, the valueof the absorbance at a wavelength of 250 nm to 310 nm is having peak in UV region, and these decreases with increasing calcination temperatures, the decrement are in very small amount. This is due to the effect of an increase in the density of oxygen voids, crystal defects/voids and strain as it affects the crystal structure of the nano composites and causes changes in the nature of the surfaces

Electronic Band Gap Properties: -The optical energy difference is of great importance in determining the possibility of using nano composites in the application of sensors and optoelectronics as it gives a clear idea of the optical absorption, since the nano composites are transparent to radiation whose energy is less than the band gap energy i.e. Eg> hυ and an absorptive radiation whose energy is greater than that Eg< hυ. The value of the energy deviation in allowing direct electronic transitions of Al_2O_3-SnO_2: The band gap energy differences are calculated by drawing the graphical relation between $(\alpha h\nu)^{1/2}$ and the energy of the photons, so we get the value of the energy difference for the allowed indirect transition. Which are shown in figure number 1 shows the permissible indirect energy deviation of the nano composites, it wasfound that the band gap differences are shown in the figure number 1

4. FIGURES AND TABLES

Figure 1 XRD Pattern of Al_2O_3 Doped SnO_2 Nano Composites with 10% Dopant Concentration on Different Calcination Temperatures Calcined for 2 Hours. (a) 200°C (b) 400°C (c) 600°C and Compared with its JCPDS/ICDD data of SnO_2 Nanoparticles.

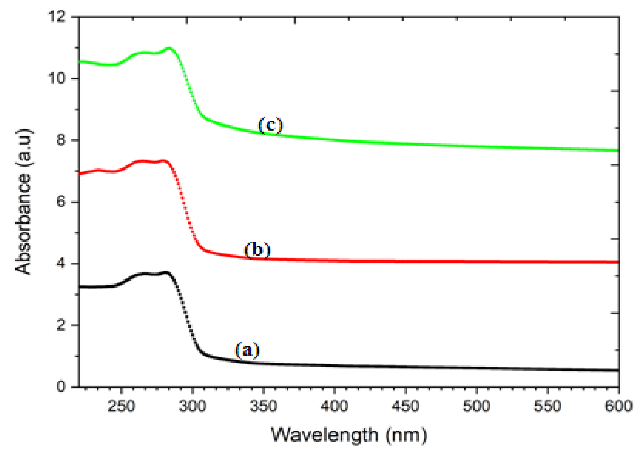


Figure 2 UV-Visible Spectra of Al_2O_3 Doped SnO_2 Nano Composites with 10% Dopant Concentration on DifferentCalcination Temperatures and Calcinated for 2 Hours. (a) 200°C (b) 400°C (c) 600°

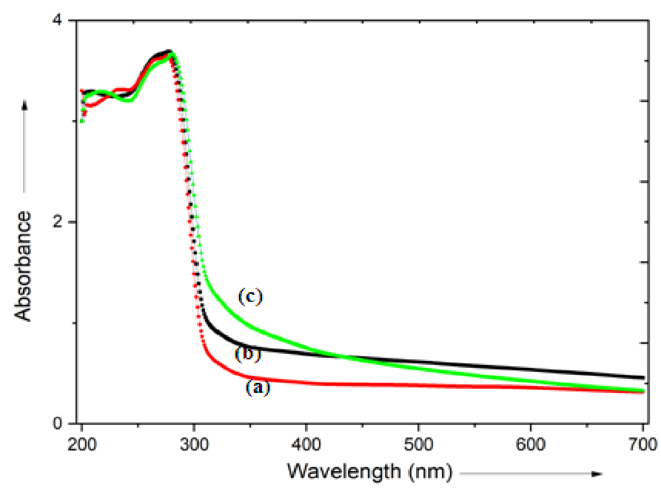


Figure 3 UV-Visible Spectra of Al_2O_3 Doped SnO_2 Nano Composites with 10% Dopant Concentration on Different Calcination Temperatures and Calcinatedfor 2 Hours. (a) 200°C (b) 400°C (c) 600°C.

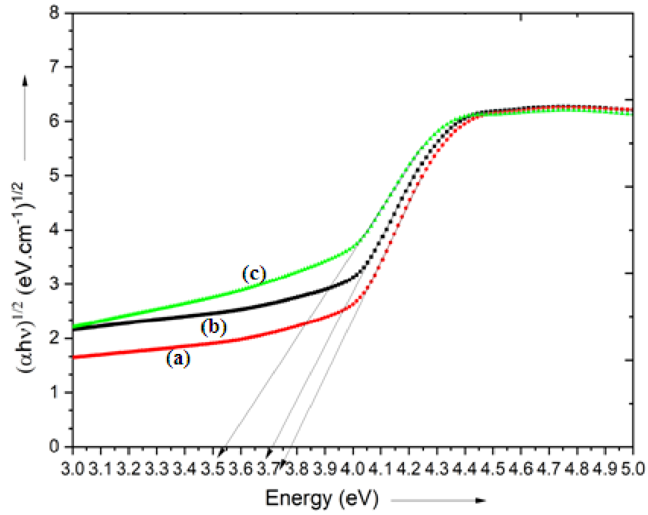


Figure 4 Tauc Plots of Al2O_3 Doped SnO_2 Nano Composites with 10% Dopant Concentration on Different Calcination Temperatures and Calcinated for 2 Hours. (a) 200°C (b) 400°C (c) 600°C.

5. CONCLUSION:

The experimental and calculated peaks x-ray diffraction results are well matched and signifies the formation of nano-composites. The figure 1 shows that x ray analysis, one matched Phases was obtained for the 10% doping of Al_2O_3 with the SnO_2. the corresponding spectra shows the well-matched peaks as tin oxide which is indexed for the different calcination temperatures. According to figure number 2, the value of the absorbance at a wavelength of250 nm to 310 nm is having peak in UV region, and these decreases with increasing calcination temperatures, the decrement are in very small amount. The figure number 4 shows the permissible indirect energy deviation of the nano composites, it was found that the band gap differences are shown in the figure number 3 are 3.71 eV, 3.77 eV and 3.53 eV for the calcinated temperatures.

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