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Investigation of Morphology, Structure and Optical properties of Cu doped SnO_2 via Chemical Precipitation Method for Optical Ethanol Sensing

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***Abstract:** Cu doped SnO_2 were prepared via low cost and simple Chemical Precipitation Method for optical ethanol sensing. Morphology, structure and optical properties were characterized by Scanning Electron Microscope (SEM), Energy Dispersive X-ray Spectroscopy (EDS), X-Ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), and Ultraviolet Visible Spectroscopy (UVS). 3 wt% of Cu is present in SnO_2 confirm by EDX, Cu doping does not affect the structure of SnO_2 and also decreases the size of SnO_2 confirm by the XRD, the average size of Cu doped SnO_2 was found 6.97 nm. Light Transmittance and absorbance of the material are high, that means it has optical property. Cu doped SnO_2 exhibit good sensitivity towards ethanol sensing. The average ethanol sensitivity was found to be 0.31 µW / ppm.*

***Index Terms:** Cu, SnO_2, Characterizations, Properties and Ethanol Sensing*

I. INTRODUCTION

In those days gas sensors play a very important role in many areas such as own protection, environmental safety, medical diagnosis, revealing of pollutants and transportation industries. Semiconductors such as zinc oxide, tin oxide, titanium di-oxide and many more are used for gas sensing, because they have high sensitivity to target gases and simplicity in preparation. Among them tin oxide is an n-type wide band gap (E_g = 3.6 eV at 300 K) semiconductor, and shows special properties like transparency, chemical, physical and thermal strength, which used in photodetectors, catalysts, gas sensors, solar cells, LCDs, protective coating. SnO_2 widely used in gas sensors due to its low cost, high gas sensitivity, fast gas response and high stability. The sensing properties of the gas sensors are well known that highly related to the morphology, size and dispersibility [1, 2].

SnO_2 has attracted doping with transition metal ions such as Fe, Ni, and Cu etc. due to their electronic, optical and magnetic properties resulting from large sp-d exchange interaction between the magnetic ions and band electrons [2].

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Many synthesis processes have been developed to synthesize the SnO_2 nanoparticles for example: hydrothermal precipitation method, sol-gel method, spray pyrolysis, chemical vapor deposition etc. but chemical precipitation method is a simple, cheap and ecofriendly method. Doping with Cu has been showing high sensitivity and selectivity of SnO_2 towards ethanol, because SnO_2 is n-type and Cu is p-type which form p-n heterojunctions. Many researchers show that several metals (Al, Co, Fe, Cu, Ni, and Pb etc.) increase in surface area of SnO_2 due to this decreases the size of SnO_2 [3]. After literature survey, in the present work we have synthesized Cu doped SnO_2 nanoparticles with 3 wt% of Cu doping using chemical precipitation method.

II. PREPARETION

Synthesis of Cu doped SnO_2 nanoparticles was successfully synthesized by chemical precipitation method. This method is a cheap, easy and ecofriendly method. For this, initially 0.1M of $SnCl_2.2H_2O$ dissolve in 25 ml of ethanol and 25 ml of distilled water. 3 wt% of $CuCl_2.2H_2O$ was dissolve in 50 ml of distilled water, both solution are separately Stirring for several hours, to make solution of a Cu doped SnO_2, start doping of Cu solution in to SnO_2 during stirring process. After the doping process, we will go for the adding the 10-12 drops of PVP to reduce the grain size. To form the precipitate of the prepared solution, we adding sufficient amount of ammonia to the solution, during stirring and dropping rate must be well controlled. The resulting precipitate was collected, washed with distilled water, and then dried in an oven at 120°C for 2:30 hrs, after that put on Furnace for cancelation process at 500°C for 3 hrs, and then go for crushing process of prepared material for several hours. Finally got Cu doped SnO_2 nanoparticles.

III. CHARACTERIZATIONS

JSM-6490LV, JEOL, Japan Scanning Electron Microscope is using for morphological study. To confirm the existence of chemicals in the prepared sample are confirmed by EDX. Crystal structure of prepared sample was obtained by the PANalytical X'Pert Powder XRD and Nicolet^{TM}6700, Thermo Scientific, U.S.A. Fourier Transform Infrared Spectrometer is recorded infrared data. Agilent Technologies, Cary Series UV-Vis Spectrophotometer is used for obtaining the absorbance spectra [4].

IV. RESULT AND DISCUSSION

A. Scanning Electron Microscope

Figure 1 shows the morphology of prepared sample. These images confirmed that Cu does not change the structure of tin oxide which is tetragonal structure. These images are taken on 10,000 and 27,000 magnifications and cover 1 µm and 0.5 µm areas. Application of this type of morphology is Sensors, Solar Cells, and Photodiode etc.

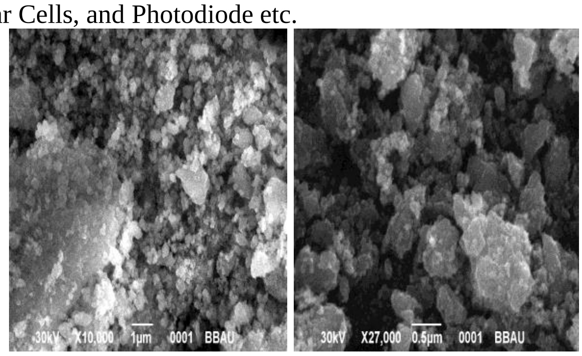

Figure 1: Morphology of Cu doped SnO_2

B. Energy Dispersive X-ray Spectroscopy

EDX stands for the Energy Dispersive X-ray Spectroscopy, which confirms the Cu, Sn and O are present in the prepared sample. No other chemical compound or dust particle is present in the prepared sample. We can see in Figure 2 one peaks of Sn, three peaks of Cu, one peak of O and One peak of C. Weight % of Sn, Cu, O and C are found as 37.51, 5.31, 31.44 and 25.74 respectively. Their carbon peak is present because sample was mounted on carbon tape; otherwise no other peak of any dust particle or unwanted chemical compound is present [5].

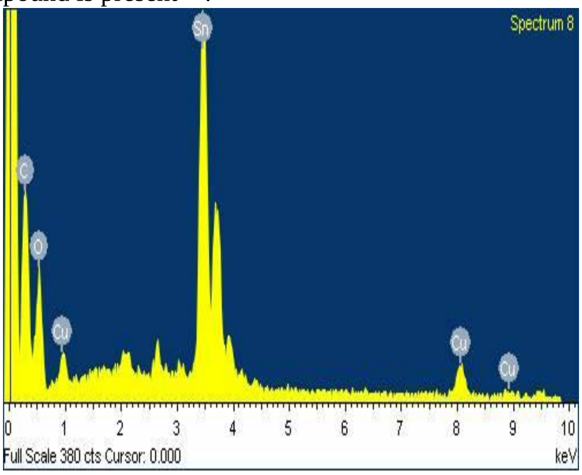

Figure 2: Confirmation of Cu, Sn and O compound

C. X-ray Diffraction

XRD is used for the structural analysis, which helps to examine the crystalline and structure of the particle. This technique is very useful to examine the crystalline size, structure and type of material etc. To obtain the size from the XRD results by applying the Scherrer formula ($D=K\lambda/\beta\cos\theta$). Where K is constant which value taken as 0.89, λ is wavelength, β is FWHM and θ is the angle. XRD data was shown in figure 3 which is calculated the average size 6.97 nm of the prepared sample [6].

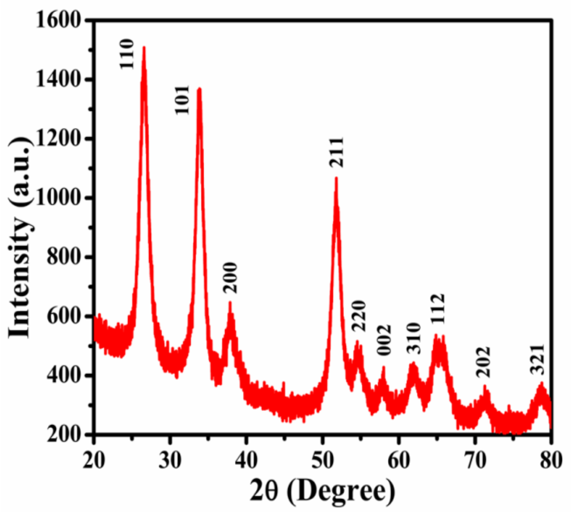

Figure 3: XRD pattern

D. Fourier Transform Infrared Spectroscopy

For the infrared analysis, we are using Fourier Transform Infrared Spectroscopy. Figure 4 shows the IR spectra of Cu doped SnO_2 nanoparticles. From figure 4 we clearly saw the IR spectra in which changes of position, size and shapes are indicated that Cu has included in SnO_2 lattice. The particle exhibits wide IR peaks which raging from 3000 to 4000 cm^{-1} for the synthesized particles which could be ascribed to stretching vibration of surface hydroxyl groups. 632.6 cm^{-1} may be related to bending vibration of Sn-O-Sn. 1628.6 cm^{-1} may be recognized to the bending mode O-H bond [6].

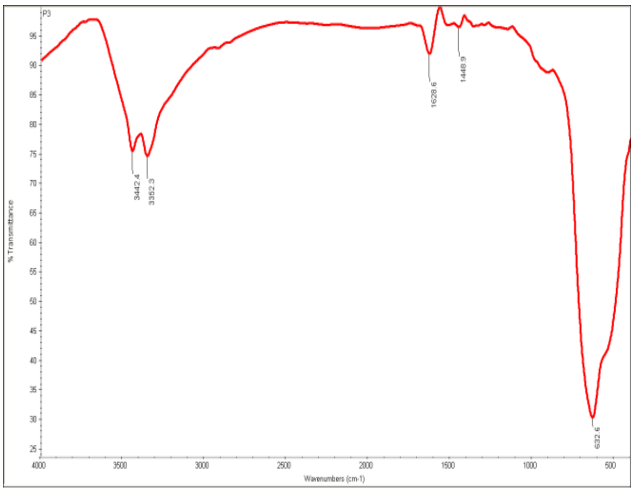

Figure 4: analysis of IR Spectra

E. UV – Visible Spectroscopy

Figure 5 shows the UV absorbance graph and the bandgap of Cu doped SnO_2. The light absorbance recorded from 200 nm to 600 nm wavelengths. Higher pick of optical absorbance was noticeable from the figure 5 [3]. The energy band gap of Cu doped SnO_2 determined by the plotting $(\alpha h\nu)^2$ versus $(h\nu)$. So here we can see that the energy band gap of Cu doped SnO_2 is 4.81 eV. This prepared sample has a wide bandgap that is confirmed from figure 5. Cu doping is beneficial for the SnO_2 in the terms of optical property.

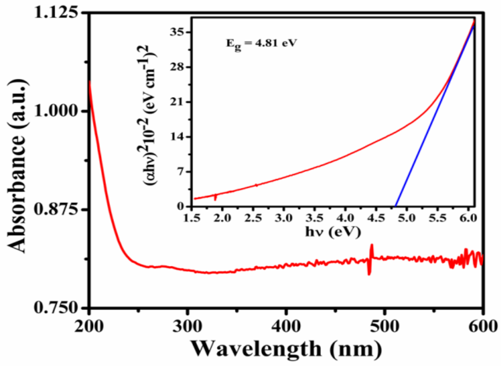

Figure 5: UV absorbance and energy band gap

F. *Optical Ethanol Sensing*

Figure 6 shows the optical ethanol sensing setup. The prepared thin film of Cu doped SnO_2 placed inside the glass chamber. Flow different ppm solution of ethanol in the glass chamber. 1 mW and 630 nm wavelength Laser was used as a light source.

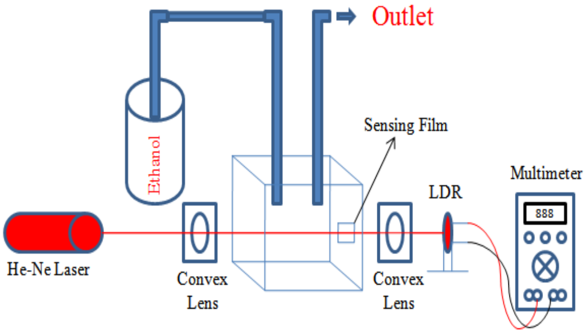

Figure 6: Setup of Optical Ethanol Sensing

Optical Ethanol sensing of Cu doped SnO_2 film was prepared by using spin coater. Variation in output power with different ppm was recorded by a multimeter and plotted as Figure 7. The change in the power of sensing materials depends upon the number of pores exist in the material. Cu doped SnO_2 at different concentration of ethanol shows a linear trend with an increase in power versus ppm value. Cu doped SnO_2 showed good ethanol sensitivity ability.

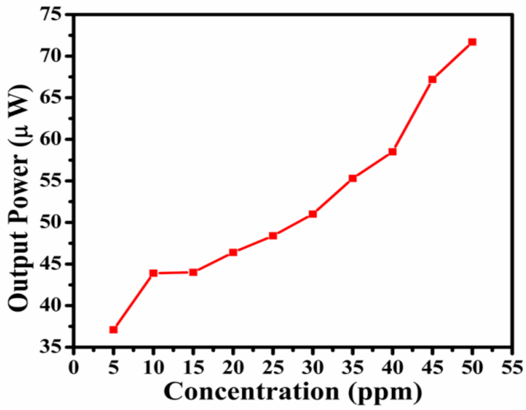

Figure 7: Ethanol Sensing graph

The variation of output power (μW) of LASER light source show concentration (ppm) of ethanol through the film of Cu doped SnO_2 was observed and corresponding data were plotted as Figure 7. The Curves show the behaviour of output power of ethanol absorption. The sensitivity calculated from curve of Figure 7, was found to be 0.31 μW/ppm.

V. CONCLUSION

Cu doped SnO_2 is successfully prepared by the chemical precipitation method, this method is very simple, reliable and ecofriendly. Cu doped SnO_2 give good result of Optical properties; the band gap of Cu doped SnO_2 is 4.81 eV. 3 wt% of Cu is present in SnO_2 confirm by EDX. Cu doping does not affect the structure of SnO_2 and also decreases the size of SnO_2 confirm by the XRD, the average size of Cu doped SnO_2 was found that 6.97 nm. Light Transmittance and absorbance of the material is high, means that it has optical property. Cu doped SnO_2 exhibit good sensitivity towards ethanol sensing. The average ethanol sensitivity was found to be 0.31 μW /ppm.

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