Co-precipitation synthesis, Characterization and Electrical analysis of Copper Oxide Nanoparticles

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Abstract : Nano copper oxide attracts more and more people's awareness and has become one of the most extensively used inorganic materials. Compared with the ordinary copper oxide, nano CuO has unusual physical and chemical properties. Copper oxide nanoparticles synthesized using the aqueous precipitation method. In this method, copper acetate is used as a precursor and sodium hydroxide as a stabilizing agent. The dielectric constant is one of the basic electrical properties of solids and the measurement of it and dielectric loss as a function of frequency and temperature is of great interest both from theoretical point of view and from the applied physics**.**

IndexTerms **- :** copper oxide nanoparticles, Co-Precipitation synthesis, dielectric analysis.

I. INTRODUCTION

The oxides of transition metals are an important class of semiconductors having applications in multiple technical fields like solar energy transformation, magnetic storage media, electronics and catalysis [1-3]. Among the oxides of transition metals, copper oxide nanoparticles are of special interest because of their efficiency as nanofluids in heat transfer application [4], secondly it is the basis of several high-Tc superconductors [5]. CuO is a semiconducting material with a narrow band gap and is used for photoconductive and photothermal applications [6]. Opposite to n-type semiconducting metal oxides, copper oxide (CuO) is a p-type semiconductor with a band gap of 1.2-1.9 eV. Its applications also include catalysis, lithium-copper oxide electrochemical cells, solar cells and gas sensors [7-9].

Copper oxide is widely used in the field of superconductors and ceramics as a kind of important inorganic materials. Dielectric constant can be measured by determining the change in the capacitance of specially designed condenser when the dielectric material is inserted between plates of that condenser. Practically the presence of a dielectric material between the plates of a condenser enhances the capacitance provides the basic experimental method for the measurement of dielectric constant. Various polarization mechanisms in solids such as atomic polarization of the lattice, orientational polarization of dipoles and space charge polarization can be understood very easily by studying the dielectric properties as a function of frequency and temperature for crystalline solids [10-11]. Dielectric properties for all the prepared samples in the present study using the conventional parallel plate capacitor method using an LCR meter (Agilent 4284 A) with various frequencies with various temperature ranging from 30-100ºC in a similar way followed by Mahadevan and his co-workers [12-14].

II. **Experimental**

To synthesis Copper Oxide nanoparticles, a standard procedure was followed. During the synthesis of Copper Oxide nanoparticles, appropriate amount of copper acetate is dissolved in appropriate amount of double distilled water. Then the solution of NaOH is added drop by drop with the solution. The drop wise addition of NaOH solution was carried out with the constant stirring of the room temperature. Then add to acetic acid small drop by drop. The color of the mixture is turned from blue and black as the reaction proceeded. The black precipitate was copper oxide. The precipitate was filtered by a centrifuge process. Then washed with acetone and removed organic impurities it any. Then the sample was allowed to get dried. The dried sample was heated at temperature at 60°C for 6 hrs to obtain dry powder Copper Oxide nanoparticles. Then the annealed sample was grinded to get the powdered nanoparticles. The powdered Copper Oxide nanoparticle was allowed to different characterization techniques. The prepared sample was characterized using PXRD, UV-VIS, and Dielectric analysis metods. The nanocrystals were pelletised and used for the dielectric measurements.

III. RESULTS AND DISCUSSIONS

X-ray diffraction is obviously the most common tool to study the crystal structure of nanoparticles. The grain size and the structure of the nanoparticles are investigated with a powder diffractometer with radiation at a diffraction angle between 20º to 80 º. The powder X- ray diffraction of pure CuO nanoparticles is performed using automated powder X-ray diffractometer of operating at wavelength 0.15405 nm. From the XRD pattern the particle size D be calculated using scherrer formula $D = K\lambda / \beta \cos\theta$,

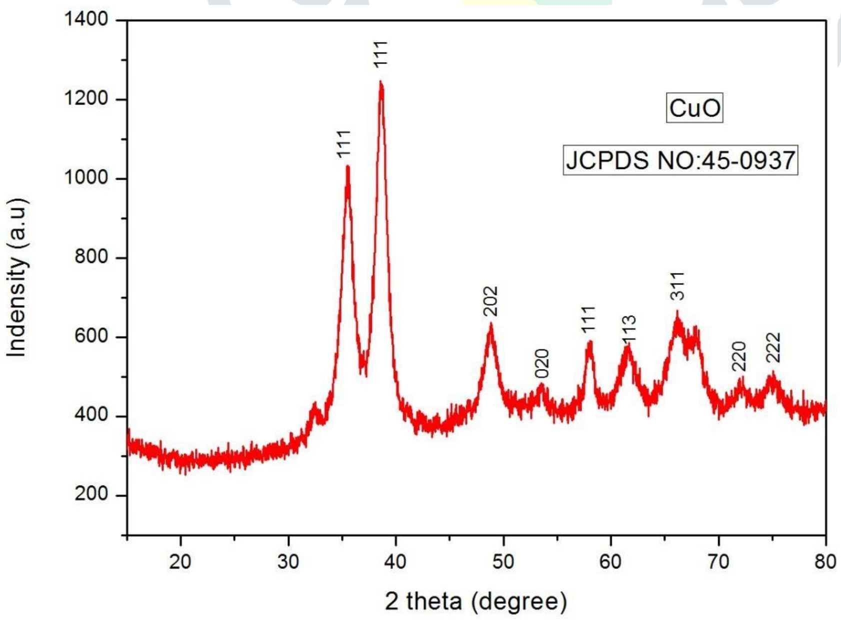
Where K is a shape factor, λ is the wavelength of the incident X-ray and θ is diffraction angle and β is the Full width half maximum. From the value of the particle size (D) we can calculate the dislocation density (δ) of the nanoparticles, which is a measure of the number of dislocation in a unit volume of a crystalline material by the formula

$$\delta = 1/D^2.$$

From XRD analysis we can obtain the microstrain value, which is a measure of strain inside the nanoparticles due to the internal stresses using the formula,

$$\epsilon = \beta \cos\theta / 4$$

where is ϵ the microstrain, β is the full width half maximum value and θ is the angle ofdiffraction. The figure shows the obtained Powder XRD spectra of Pure CuO nanoparticles.

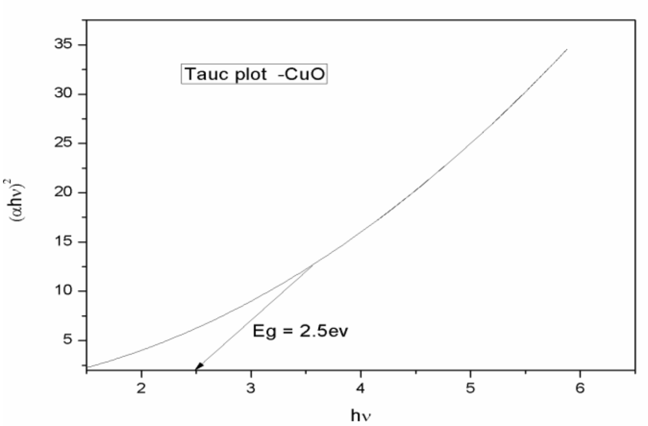


From the figure it is shown that sharp peaks are observed, which shows the crystallinity perfection of CuO nanoparticles. For pure CuO nanoparticles, the peaks 35.53- [111], 38.59- [111], 48.79- [202], 53.47- [020], 58.17- [111], 61.63- [113], 66.18- [311], 68.05- [220], 72.20-[222], The peaks of the diffraction patterns can be compared with standard available data for the confirmation of the structure, with the use of JCPDS Card no; 45-

0937. The XRD patterns agree well with the monoclinic phase of the CuO and it is confirmed that both pure CuO nanoparticles are of monoclinic crystalline structure. There is no change in the crystalline structure of CuO nanoparticles. From the XRD spectrum the particle size of the prepared samples are calculated by scherrer formula. The values of the particle size in table

Sample	Particle size 'D' (nm)	Dislocation density 'δ' (m^{-2})	Microstrain
Pure CuO	**29**	**$8.39*10^{15}$**	**0.009381**

To study the optical properties of the CuO nanoparticles, optical asorption spectrum is utilized. From the absorption spectrum, the band gap and the type of transitions can also be determined. The optical properties of pure CuO nanoparticles are studied based on the effect of the optical and band gap energies using Perker Elmer Lamda 25 UV-vis diffuse reflectance spectroscopy. The room temperature absorption spectra of both pure CuO nanoparticles in the range of 200 to 900 nm are shown in the figure . For the pure CuO nanoparticles, the absorption peak is about 370 nm. The optical band gap of the nanoparticles can be calculated from the absorption spectra using Tauc's . The band gap energies Eg of pure CuO were obtained from the wavelength value corresponding to the intercept point of the straight line a=0.



Tauc's plots are drawn between the values of photon energy hv and $(\alpha h\nu)^2$ are shown in figure ,From the Tauc's plot, the calculated band gap energies of pure CuOs are 2.5 eV respectively.

Dielectric constant, dielectric loss and AC electrical conductivity of the prepared pure and zinc doped CuO nanoparticles were observed in the present study are shown in figures. The dielectric parameters are observed to increase with increase in temperature for all the samples. Also doping leads to reduction in the dielectric parameters.

The (σ_{ac}) values observed in the present study are very small which increases with increasing temperature. Thus the space charge contribution plays an important role in the charge transport process and polarizability in the present study. All the three parameters increase with increase in temperature for the entire prepared sample considered for this study. From the dielectric studies it is also seen that the dielectric constant increases with decreasing frequency and increases in temperature.

It is evident from the figures that tan δ also increases with increase of temperature and has a decreasing trend at elevated frequencies. This can be attributed to the fact that the electric relaxation is a thermally activated process in the materials under study. The decrease in loss factor may be attributed to the space charge polarization which arises due to the accumulation of charge carriers at grain boundaries under the application of external electric field.

From the AC conductivity graph, it is seen that as frequency increases the conductivity remains more or less constant at low frequencies, but at higher frequencies, as the frequency increases the conductivity also increases. The variations are similar for other temperatures, but the values are shifted upwards as the temperature rises.This increase in dielectric constant as a result of increase in temperature can be explained on the basis of the phenomenon that as the temperature increases, the dipoles relatively become free and they respond to the applied electric field. Consequently the polarization increased and hence dielectric constant also increases with the increase in temperature [15,16].

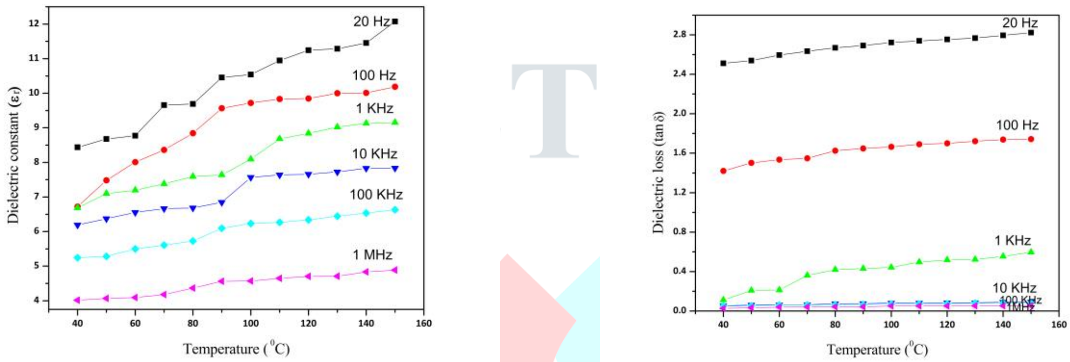


Fig: Dielectric constant and Dielectric loss plot for pure CuO

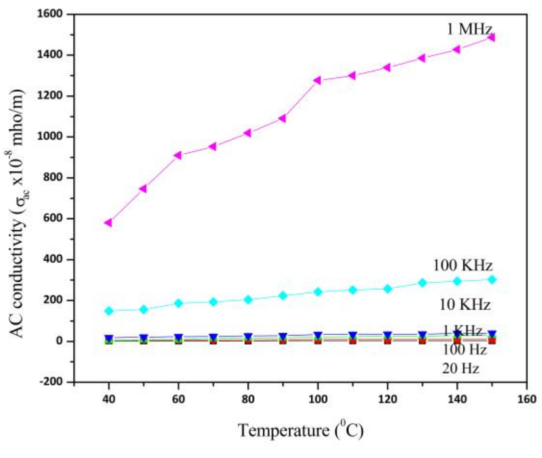


Fig: AC conductivity plot for pure CuO

IV .Summary and Conclusion:

Copper oxide nanoparticles was prepapred using co-precipitate metod. Dielectric constant, dielectric loss, and the AC electrical conductivity presented in the figures show that all the three parameters increase with increase in temperature for the entire prepared sample considered for this study. This increase in dielectric constant as a result of increase in temperature can be explained on the basis of the phenomenon that as the temperature increases, the dipoles relatively become free and they respond to the applied electric field. AC conductivity increases with the increase in temperature and frequency.

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