Comparative Study in the Optical Bandgaps of Cadmium Copper Oxide and Strontium Copper Oxide Nanocomposites

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Abstract. Nanoparticles of Cadmium Oxide (CdO), Copper Oxide (CuO), Strontium Oxide (SrO) along with the nanocomposites of Cadmium Copper Oxide (CdO/CuO) as well as Strontium Copper Oxide (SrO/CuO) were synthesized by chemical co-precipitation method. The samples annealed at 800ºC were used for structural and optical studies. Scherrer equation was used to calculate the average particle size of the synthesized nano samples. The optical characterizations of the metal oxide nano samples were carried out by UV/Visible analysis. From the analysis of the absorption spectra, the optical bandgap of the nano samples were calculated in detail. Copper oxide planes are found to be common for both Cadmium Copper Oxide and Strontium Copper Oxide nanocomposites.

INTRODUCTION

Nanomaterials generated through chemical methods have proved to be more effective, providing better control as well as enable different sizes, shapes and functionalization than those generated with other physical methods such as laser ablation, arc-discharge and evaporation. Metal oxide nanoparticles can be produced by soft chemical methods such as co-precipitation, sol-gel and hydrothermal synthesis. Among different chemical methods, co-precipitation has chosen in this work for the synthesis of the nanoparticles of Cadmium Oxide, Copper Oxide, Strontium Oxide and the nanocomposites of Cadmium Copper Oxide as well as Strontium Copper Oxide.

Copper oxide is a potential field emitter that can be used as an effective catalytic agent as well as a good gas sensing material. It is an efficient semiconducting compound with a narrow bandgap and can be used for photoconductive and photo thermal applications. Copper oxide plays an important role in the field of optoelectronics and solar cell applications[1-2]. Recently considerable interest has been focused on copper oxide nanoparticles mainly due to their optical, catalytic, antimicrobial, mechanical and electrical properties[3].

Cadmium oxide nanoparticles are highly reactive and they can be used in energy storage systems, electro chromic thin films, magneto resistive devices and heterogeneous catalysis. Metal nanoparticles with high specific surface area and a high fraction of surface atoms have been studied extensively due to their unique physicochemical characteristics such as catalytic activity, optical properties, electronic properties, antimicrobial activity and magnetic properties[4]. Cadmium oxide has not only the unique optical and optoelectrical characteristics but also has the selective catalytic properties that can be used to photo degrade some of the organic compounds, dyes, pigments and many environmental pollutants.

The recent enzyme-free biosensor is unique and noble research work for ultra-sensitive recognition of BLR with CuO/CdO nanocomposites onto glassy carbon electrode in short response time[5].

About 8% by weight of cathode ray tubes is strontium oxide, which has been one of the major uses of strontium oxide nanoparticles. Lead nano oxide can be used in the neck and funnel, but causes discoloration when used in the faceplate[6].

Cadmium Copper Oxide and Strontium Copper Oxide nanocomposites exhibit unique UV absorbing ability, high stability at high temperatures and reactivity as catalyst.

MATERIAL AND METHODS

Synthesis of CdO/CuO and SrO/CuO nanocomposites

Nanocomposite of Cadmium Copper Oxide (CdO/CuO) was prepared by arrested precipitation using analytical grade 0.1M Cadmium Nitrate, 0.1M Copper Nitrate, 0.02M Citric acid and 0.5M sodium hydroxide as the reagents. Among the reagents, citric acid was used as the stabilizer to prevent agglomeration. The precipitates so formed by stirring were separated from the reaction combination and were washed many times with distilled water to remove all impurities. The dried precipitates at room temperature were thoroughly grounded using an agate mortar to obtain its fine powder. On heating at 800ºC, CdO/CuO nanocomposite was formed. The same procedure was also be used for the synthesis of CdO, CuO and SrO nanoparticles. However, in the synthesis of SrO/CuO nanocomposite, 0.1M Strontium Nitrate was used instead of 0.1M cadmium nitrate solution.

RESULTS AND DISCUSSION

Analysis of XRD Patterns of nanoparticles and nanocomposites

X-Ray Diffraction (XRD) is one of the most commonly used methods for crystal structure determination of materials[7]. XRD pattern reveal that the particles are nanosized and crystalline. The sharp peaks obtained from the XRD patterns indicate the crystalline nature of the samples. The XRD patterns are drawn by using angle (2Θ) along the X-axis and intensity (counts) along the Y-axis. There is a definite line broadening of the XRD peaks which indicates the synthesized materials consist of particles in nanometer scale.

XRD patterns of the nanoparticles of CuO, CdO, SrO and the nanocomposite of CdO/CuO as well as SrO/CuO annealed at 800^0C are shown in figures 1(a), 1(b), 1(c), 2(a) and 2(b) respectively. Particle sizes are calculated using Debye-Scherrer equation[8], $t = k\lambda/ (\beta\cos\theta)$; where k is the Scherrer constant and its value is taken as 0.9, β is the full width at half maximum of XRD peaks, θ is the Bragg diffraction angle and λ is wavelength of X-rays used in XRD analysis. The broadening of the peaks in the XRD pattern may be due to the micro straining of the crystal structures arising from the defects like dislocations and twinning. The particle sizes are found to be 27nm for both CuO and CdO nanoparticles. But SrO exhibit the highest particle size of 65nms. However it is found to be 46nms for both CdO/CuO and SrO/CuO nanocomposites.

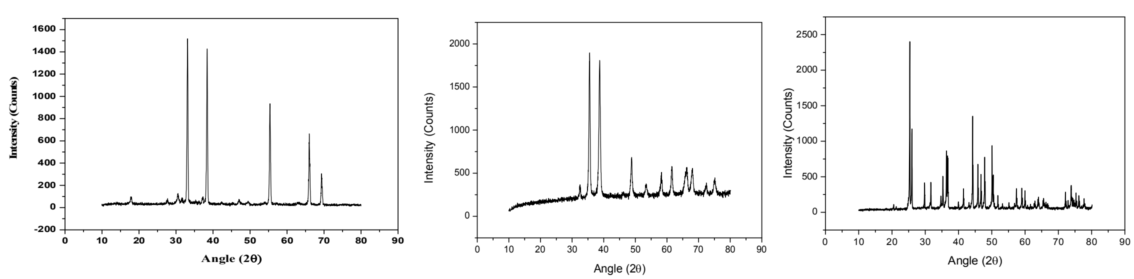

FIGURE 1(a), 1(b) and 1(c). XRD Pattern of CuO, CdO and SrO nanoparticles

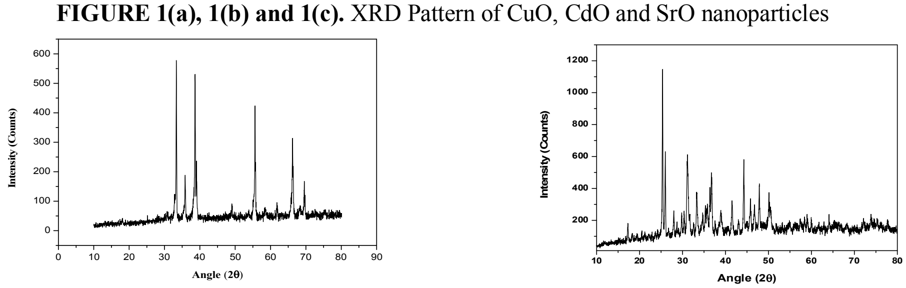

FIGURE 2(a) and 2(b). XRD Pattern of CdO/CuO and SrO/CuO nanocomposites

UV SPECTRAL STUDIES

Ultraviolet-Visible (UV-Vis) spectroscopy is extensively utilized to quantitatively characterize organic and inorganic nanosized molecules[9]. UV spectra of the nanoparticles of CuO, CdO, SrO along with the nanocomposites of CdO/CuO and SrO/CuO annealed at 800ºC are taken in the wavelength range of 200 to 870 nm with 1 nm resolution are shown in figures 3(a) to 3(e) respectively. UV spectra provide important information about the details related with optical bandgaps of the material. The decrease in absorption indicates the presence of optical bandgaps in the material. This corresponds to the excitation of surface plasmons in the composite nanoparticles. The energy band of the material is related to the absorption coefficient α by the Tauc's relation[10], $\alpha h\upsilon = A(h\upsilon - Eg)^n$, where A is a constant, hυ is the photon energy, Eg is the bandgap and n=1/2 for an allowed direct transition. Plot $(\alpha h\upsilon)^2$- hυ graph of the samples heated at 800ºC and extrapolation of the straight line to $(\alpha h\upsilon)^2 = 0$, gives the value of the optical bandgap. The direct optical bandgaps of the nanoparticles of CuO, CdO, SrO along with the nanocomposites of CdO/CuO and SrO/CuO are shown in figures 4(a) to 4(e) respectively. The values of direct bandgaps are found to be 3.77eV for CuO nanoparticles, 3.78eV for CdO nanoparticles and 3.85eV for CdO/CuO nanocomposite. However, the value of bandgap of SrO nanoparticle is 2.33eV and SrO/CuO nanocomposite is 3.88eV. Figures 4(a) to 4(e) represents the Tauc's plots of CuO, CdO, SrO, CdO/CuO and SrO/CuO.

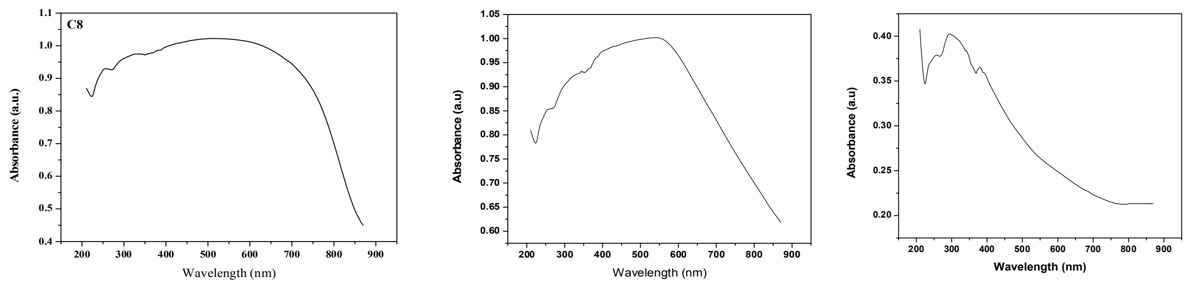

FIGURE 3(a), 3(b) and 3(c). UV spectra of CuO, CdO and SrO nanoparticles

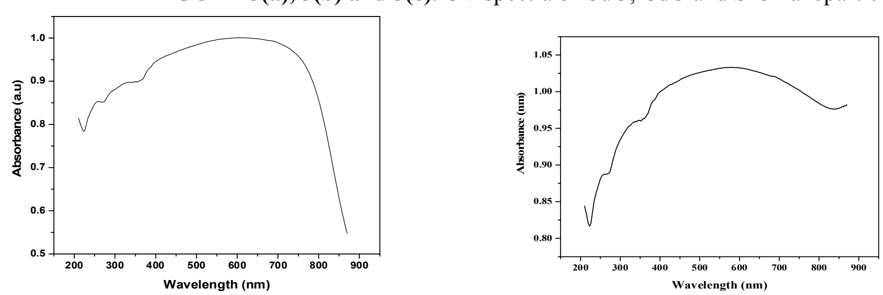

FIGURE 3(d) and 3(e). UV spectra of CdO/CuO and SrO/CuO nanocomposites

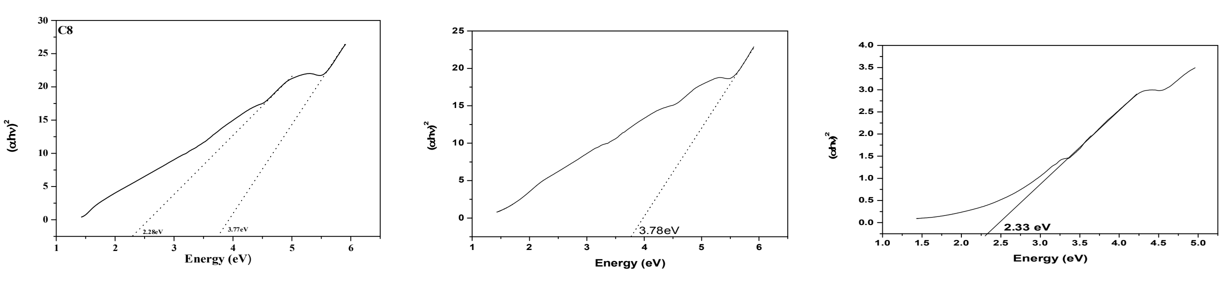

FIGURE 4(a), 4(b) and 4(c). Bandgap energy of CuO, CdO and SrO nanoparticles

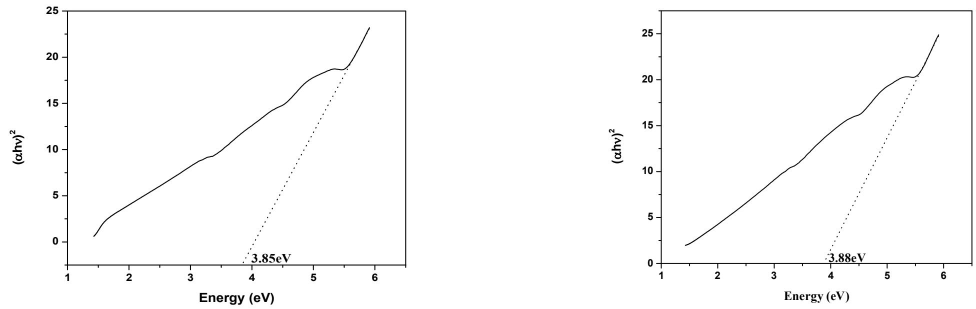

FIGURE 4(d) and 4(e). Bandgap energy of CdO/CuO and SrO/CuO nanocomposites

CONCLUSION

Nanoparticles of Copper Oxide, Cadmium Oxide, Strontium oxide along with the nanocomposites of Cadmium Copper Oxide and Strontium copper oxide have been synthesized by chemical co-precipitation method. XRD patterns reveal that the samples synthesized are nanocrystalline in nature. The broad peaks are the characteristics of the nanocrystalline nature of the samples. The particle size is found to be 27nm for both CuO and CdO nanoparticles. However it is found to be 46nm for both CdO/CuO and SrO/CuO nanocomposites. Direct optical bandgap values of the nanoparticles/nanocomposites of CuO, CdO, SrO, CdO/CuO and SrO/CuO using Tauc's relation are found to be 3.77, 3.78, 2.33, 3.85 and 3.88eV respectively.

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