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Study the Effect of Temperature on Structural and Optical properties of CuO thin films Prepared by Chemical Spray Pyrolysis

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ABSTRACT

In this study, CuO thin films were deposited on glass substrates at (200, 250, and 300 ºC) using the chemical spray pyrolysis method. CuO thin films are polycrystalline, according to the X-ray diffraction test, and have a monoclinic crystal structure. The size of the crystallites reduces as the temperature rises, with the primary growth trend being (200).

The Field Emission Scanning Electron Microscope (FE-SEM) was used to analyze the surface morphology of the thin films that were deposited. The CuO surface shape was seen to change somewhat with temperature, and it was discovered that the surface was densely packed with crystallites. The CuO thin film's FE-SEM micrographs revealed spherical and tube-shaped grains. The pictures showed a thick layer of grains covering the whole surface, free of flaws like pinholes or fissures. The CuO thin films show direct energy band gap transitions, according to optical measurements made with a UV-Vis spectrophotometer. The higher temperature, the lower the films' absorbance. Furthermore, the energy band gap decreases with increasing temperature.

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1. INTRODUCTION

In recent research, many scientists have become interested in nanostructured semiconductors due to their structural, morphological, and optical properties that set them apart from traditional structures. ZnO, or zinc oxide. Metal oxide nanoparticle semiconductors, such as titanium dioxide (TiO2), cadmium oxide (CdO), and zirconium oxide (ZrO), are recognized as scientific advances for a range of applications. In recent decades, a number of researchers have become interested in semiconductor nanomaterials because of their infinite potential applications. With a narrow bandgap of about 1.2–1.9 eV, copper oxide (CuO) is a promising p-type semiconductor that is ideal for a variety of energy harvesting applications, especially solar cells and photoluminescence. Its low cost, non-toxic nature, and wide availability all contribute to its allure for eco-friendly solutions. To increase the effectiveness of CuO thin films in various applications, research has recently concentrated on enhancing their structural, optical, and electrical characteristics[1]. Since CuO and Cu2O are typically regarded as p-type semiconductors, they may be useful in the production of junction devices such as pn junction diodes. Cupric oxide's constituents are abundant and non-toxic. These advantages have sparked a lot of interest in their use in a variety of industries, such as power sources and photovoltaic systems. A variety of techniques, including CVD, electrodeposition, reflux condensation, SILAR, sol-gel spin-coating, spray pyrolysis, thermal oxidation, and magnetron sputtering, are used to deposit nanostructured CuO films [2].

Because of its exceptional quality and distinct crystalline phase, CuO is therefore anticipated to see a sharp rise in demand. Energy materials, supercapacitors , magnetic storage , photodetectors [3], spintronics and superconductors [4], photocatalysis [5], nanofluids and heat transfer applications , biosensors , and the removal of inorganic pollutants are just a few of the other applications for which this material has been investigated as a potential future material due to its promising qualities. In light of these factors, CuO nanostructures also exhibit more alluring magnetic characteristics[6].

2. METHOD

The CuO thin films were produced by spraying an aqueous solution of copper acetate. A suitable quantity of Cu(CH3COO)2 powder was dissolved in distilled water to create this solution. The following formula was used to determine the proper weight (Wt) of the components Cu(CH3COO)2.

$$M = \frac{\mathrm{Wt}}{\mathrm{Mwt}} \mathrm{x} \frac{1000}{V} \ldots\ldots\ldots\ldots.(1)$$

Where W_t : weight
Mw_t : molecular weight
V: volume
M: molar weight

The solution was agitated with a magnetic stirrer and permitted to stand for 20 minutes to ensure that no residue remained and that the finished product was uniform. The resulting solution was sprayed over the glass substrate. When the solution is sprayed onto the heated substrate at varying temperatures (200, 250, and 300 ^{o}C), the reaction takes place on the surface. For a uniform spraying operation, controlling the time between sprays is essential. Ten seconds was the spray time for the study, and there was a 90-second break between two successive sprays. The distance between the capillary tube and the substrate is one of the most important variables in producing a homogenous film. In this experiment, the optimal nozzle spray height was determined to be (12) cm. As this distance increases, the atomized solution scatters away from the substrate, and as this distance decreases, the solution drops gather at a single spot. This result will affect the homogeneity of the final thin film.

3. RESULTS AND DISCUSSION

Figure 1 shows the X-ray diffraction pattern of copper oxide films prepared by the chemical spray pyrolysis method on a glass substrate with (200, 250 and 300 oC). The X-ray diffraction peaks corresponding to the International Centre for Diffraction Data (ICDD) reference number (00-048-1548) and the position of peaks for films prepared at 200C are (32.5, 38.9 and 66.2) and Miller indices (110), (200) and (31-1) , and after increases the temperature of deposition lead to increase the number and intensity of peaks for second film prepared at 250oC and the Miller indices for this peaks was (110), (11-1), (200), (020), (310), (31-2) and (002) . When temperature of deposition increases to 300 oC the third film prepared at 300 oC leads to an increase in the intensity of peaks because increase in the crystal growth and the Miller indices became (110), (11-1), (200), (020) and (022) and the trend of growth was (200) . The crystallite size of films was calculated by Debye sherrer equation where the crystallite size of the film prepared at 200C was 95 nm but the crystallite size of the films prepared at 250 and 300C was 35 and 26.3 nm, this decreases in crystallite size with increasing temperature because Increased crystal growth. It can be seen that the temperature affects the XRD pattern of copper oxide films i.e. the intensities of the observed peaks hence crystallinity of the thin films increases with the annealing temperature [7].

$$\mathbf{D= K\lambda /\beta \cos \Theta \quad \ldots\ldots\ldots\ldots.(2)}$$

Where K=0.9 and λ = 0.154060 nm

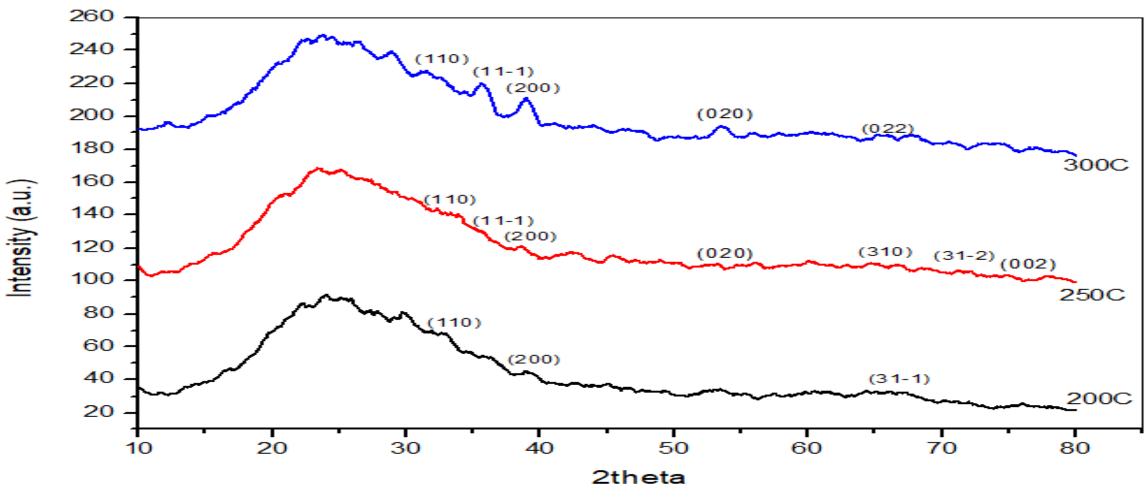
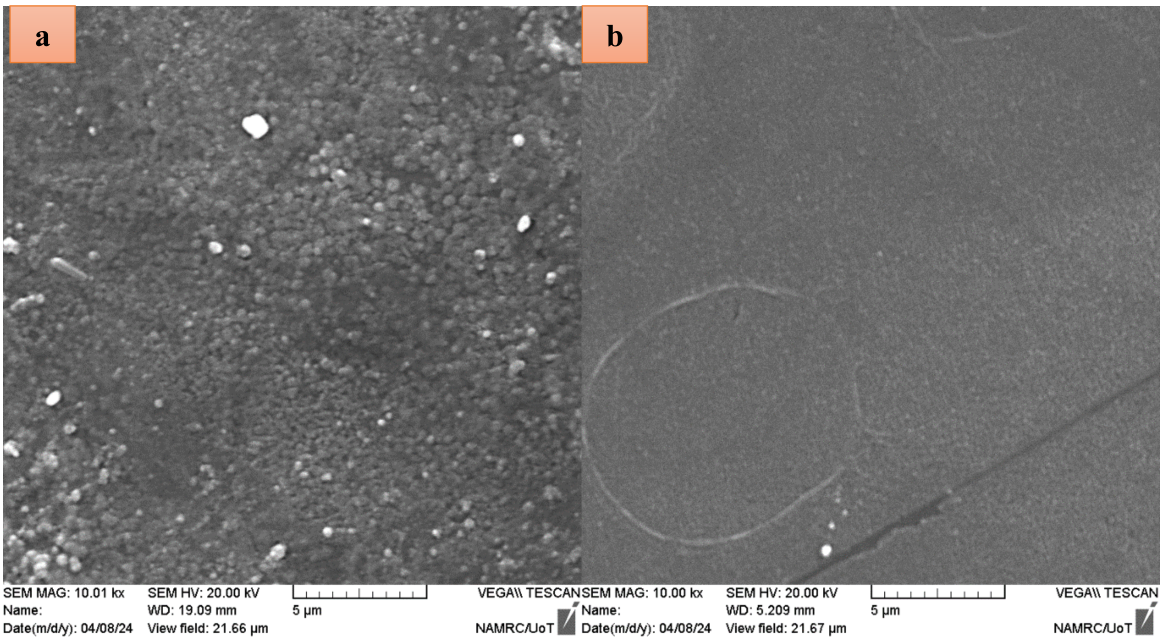


Figure 1. Shows the X-ray diffraction pattern of CuO thin films prepared at (200, 250, 300) oC

SEM of CuO thin film

A scanning electron microscope (SEM) was used to analyze the surface morphology of CuO thin films that were formed on a glass substrate using a chemical spray pyrolysis process at 200, 250, and 300 oC. Figure 2 shows SEM micrographs of CuO films produced on glass substrates at magnifications of 10 KX. The surface morphology of CuO produced at 200 oC is densely packed with crystallites in Figure (2.a), indicating that the film is smooth and free of pinholes. Additionally, the grains come in a variety of sizes and resemble spheres. Furthermore, the pictures showed a compact of the grains that covered the whole surface without any flaws like pinholes or fissures. The surface morphology of the CuO formed at 250 oC is smooth and free of pinholes in Figure (2.b). The grains are spherical in shape and vary in size, and there are no cracks or pinholes. The surface morphology of CuO produced at 300 oC is seen in Figure 2.c to be densely packed with crystallites. The outcome demonstrates how fluid the movie is. Additionally, the grains are free of flaws like cracks and have a blend of spherical and nanotube forms [8].



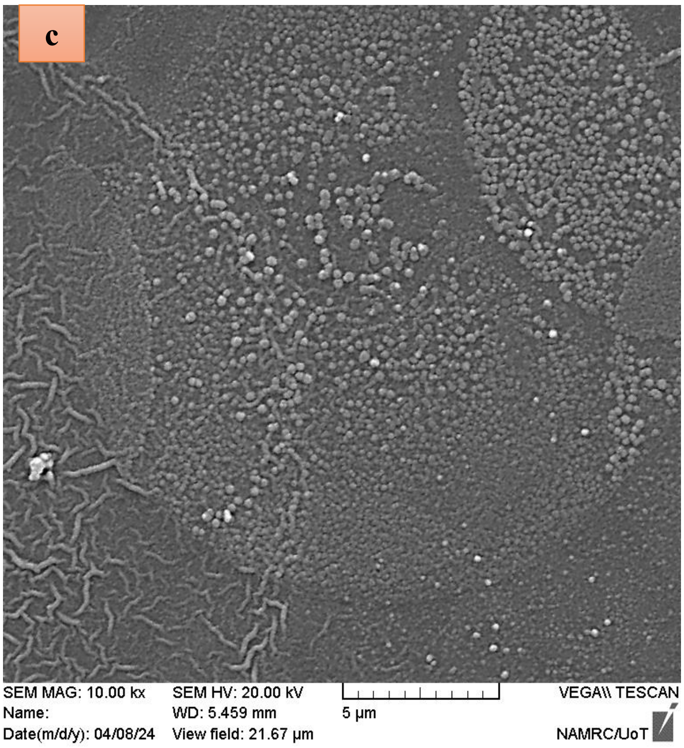


Figure 2. Shows SEM of CuO thin films prepared at (200, 250, 300) oC

The optical properties of CuO

There are wavelength-dependent patterns in the absorbance spectrum. The 400–1100 nm absorbance range was examined. The relationship between absorbance (A) and wavelength of CuO with varying temperatures (200, 250, and 300 oC) thin films is shown in Figure 3. When the energy of the incoming photon is equal to or less than the energy gap value, the absorbance falls at long wavelengths (low energies) that correspond to the films' energy gap. The electron was physically agitated by the incident photon and migrated from the valence band to the conduction band because its value was greater than the energy gap. This figure illustrates how the absorbance drops as the temperature rises.

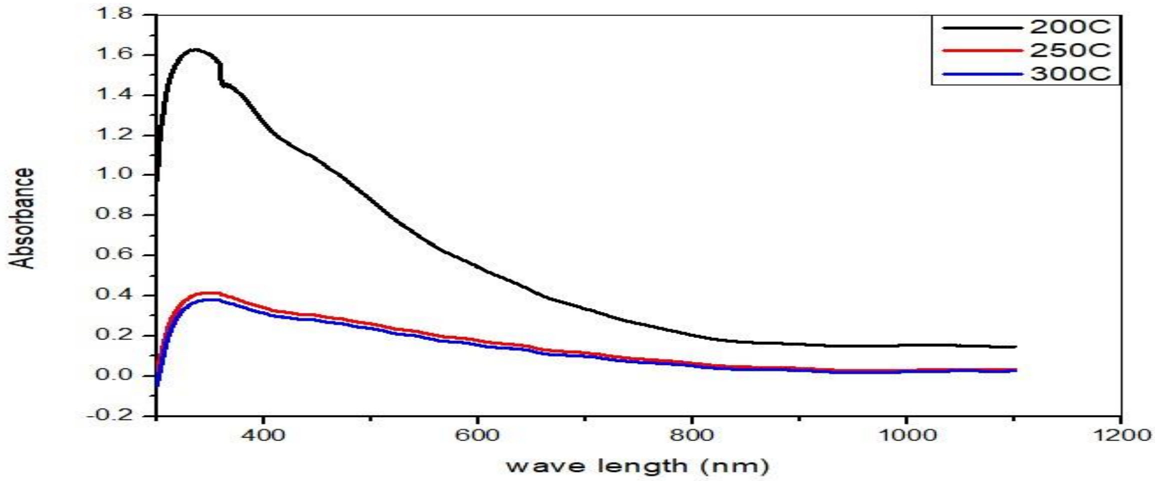


Figure 3. Absorbance of CuO with different temperature (200, 250 and 300 oC) Thin Films.

Optical energy band gap

When the straight line is extrapolated to (αhυ)2=0, as in Figure 4, the value of the direct band gap is obtained from Tauc's plot graph between (αhυ)2 and (hυ) in eV. It is clear from figure (4) that energy band gap values was (2.75, 2.65 and 2.62 e.V) where decreased with temperature rises, indicating an improvement in the film's quality as a result of the structural flaws being annealed out. The presence of an amorphous phase in films and the quantum size effect were the primary causes of a shift in the energy gap. As the annealing temperature rises, the amorphous phase in films might decrease. The atoms have more energy to grow when the temperature rises [9].

(α•hν)1/n = A(hν - Eg)…………….(3)

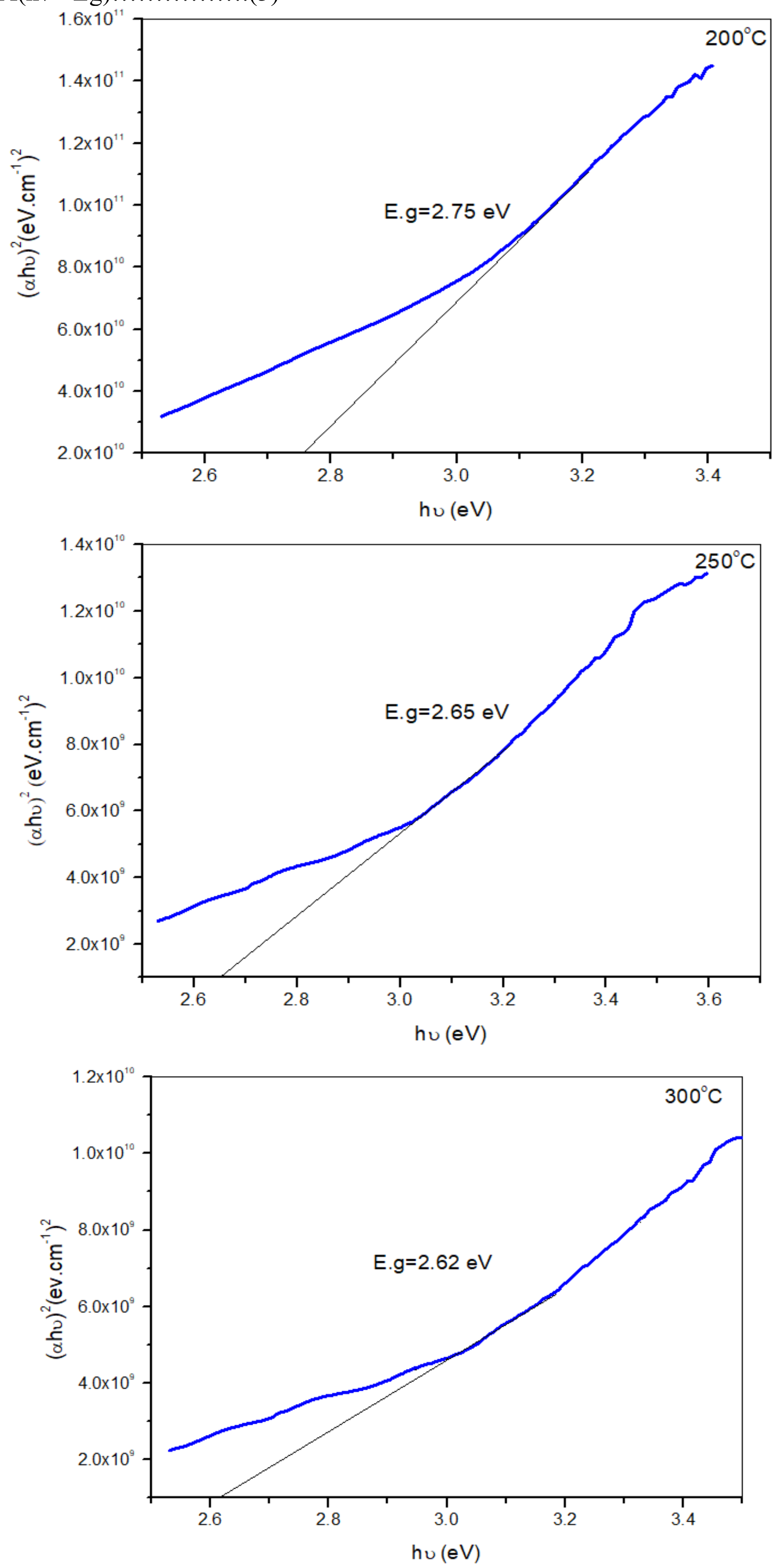


Figure 4. Optical energy band gap of CuO thin films at (200, 250 and 300oC)

4. CONCLUSION

The ability of prepare CuO thin film at different temperature by chemical spray pyrolysis method. The crystallite size of films in X-ray diffraction was decreased with increasing temperature. The best absorbance in UV measurement was at temperature 200oC and the energy band gap decreases with increasing temperature.

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