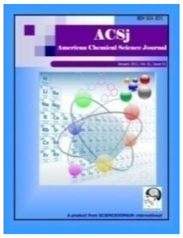

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A Study of the Optical Conductivity, Extinction Coefficient and Dielectric Function of CdO by Sucessive Ionic Layer Adsorption and Reaction (SILAR) Techniques

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AO and MDF designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors RUO and BAE managed the analyses of the study. Authors NAN and TOJ managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: The research is to study the Optical Conductivity, Extinction Coefficient and Dielectric function using deposited CdO films
Place and Duration of Study: The research place is at the Material Science and Nanotechnology Unit, Department of Physics and Astronomy, University of Nigeria Nsukka, between of August 2012 to June 2013.
Methodology: The approach used in the deposition of CdO is the Solution Method, known as the Successive Ionic Layer Adsorption and Reaction techniques (SILAR) Technique and the UV-VIS-NIR spectroscopy was used for film characterization.
Results: The deposited CdO thin film has a low and high transmittance in the UV and visible region respectively. The band gap of the deposited CdO decreases with an increase in No. of cycles films and ranges from 1.45eV – 2.35eV, this was attributed to the increase in the thickness of films. Also studied is the variation of the film optical conductivity with the band gap, which was observed to decrease with an increase in band gap. Lastly, the

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relationship between the film band gap and the dielectric function of the materials was consider, the dielectric constant varies exponentially with the band gap and also increases with the number of cycles (film thickness).

Keywords: CdO; SILAR; extinction coefficients; bandgap.

1. INTRODUCTION

The sun releases an estimated 10^{17} Joules of energy, which it delivers to earth in one second [1]. The approximated 3 trillion barrels of the recoverable earth's ultimate of oil, has 1.7×10^{22} joules of energy, and this is supplied by the sun to earth in one and half days. Every year the sum total of about 4.6×10^{20} Joules is consummated by humans, and this is the approximated amount which gets to earth from the sun in 1 hour. The enormous power that the sun continuously supplies the renewable or non-renewable earth is 1.2×10^{5} terawatts dwarfs every other energy source [2]. It is obvious that this exceeds the rate at which human social advancement produces and uses energy, which is about 13TW [2].

The fascinating thing about the solar energy supply is complemented by its worldwide uses. Solar energy can be converted into electricity by photovoltaic cell. Natural photosynthesis in green plants or artificial photosynthesis in human-engineered system has the ability of yielding chemical fuel [3, 4]. Concentrated or non-concentrated thermal collectors have been used to collect solar energy, to produce heat for direct use. Amidst the sufficiency and availability of solar energy, only very little amount of it has being used directly to power human activities. Photovoltaic accounts for a minuscule 0.015% of global electricity production, and solar thermal for 0.3% of the world heating of water and space. Biomass created by natural photosynthesis is the greatest use of solar energy; its combustion or gasification records for about 11% of human energy consumptions [5–7].

On the other hand, over two-third of that is gathered unsustainably, this means, with no replacement plan in mind and burned in small, inefficient area where combustion is not completed and the resultant pollution are uncontrollable.

Mohaboob et al. deposited CdO using the SILAR approach, Cadmium acetate was used as a source of CdO and ammonium hydroxide was the complexing agent. The study determined the effect of molarity of solution on the optical, morphological, and structural properties of deposited films. XRD shows that the crystal size of the deposited CdO film is increased with molarity of the precursor solution. UV/VIS spectrum of the films revealed that the optical band gap energy increases as the cadmium acetate's concentration in the precursor solution [8].

Balu et al. also, deposited CdO using the SILAR technique, noticed the effect of solution concentration on the electrical, structural, optical, and morphological properties of the deposited sample. The XRD revealed that the films were polycrystalline and with orientation preferred along the 200 plane. The lattice parameter was found to be equal to 4.690A, grain size increased from 15.96nm to 21nm as the solution concentration increased. The measurements of optical absorption showed that the films coated with 0.05M had a highest transmittance of 84%, band gap energy of the coated films decreased with the increase in solution concentration. It was recorded that the sheet resistance increased from

$14\times10^2\Omega/m^2$to $17.5\times10^2\Omega/m^2$ as the concentration of the samples increases from 0.05M to 0.2M. Film coated with 0.1M had low temperature coefficient of resistance -1.75×10^{-3}/K [9].

2. EXPERIMENTAL DETAILS

7.72g of cadmium acetate dehydrate of atomic weight of 308.48g was dissolved in 100cm^3 of distilled water in a beaker, the resulting mixture was stirred. In another beaker 20cm^3 of analytical ammonia was dissolved in 80cm^3 of distilled water.

Four (4) beakers were set up, the first one was filled with cadmium acetate dihydrate solution, the second was filled with distilled water, and the third was filled with ammonia solution and the fourth with distilled water. A prepared substrate was first dipped in the first beaker for 10seconds then rinsed in the second beaker for 5seconds, and then it was dipped in the third beaker for 10seconds and finally rinsed in the fourth beaker for 5 seconds. This constituted one cycle. The same process was repeated for 25, 30, 35 and 40 cycles. These substrates were label A, B, C and D respectively. Whitish films were observed to deposit on the substrates.

These films were heated at 623K (350ºC) for 3hrs which helps in the decrease of dislocations, inhomogeneities and stresses. Finally, to confirm the formation of CdO the whitish films were changed to brown. The deposited CdO films were characterized using UV – Vis absorption spectrophotometer.

The mechanism of CdO film formation by the SILAR method shown as follows:

$$Cd(C_2H_3O_2)_2 + 2NH_4OH \longrightarrow CdO + 2NH_4(C_2H_3O_2) + H_2O$$

3. RESULT AND DISCUSSIONS

3.1 Optical Studies of the Deposited CdO Films

The optical properties studied in this research include the transmittance, reflectance, optical conductivity, refractive index, extinction coefficient and dielectric function.

3.2 Transmittance of Films

The optical transmittance of the films in the UV–Vis-NIR wavelength range for deposited CdO using NH_3 as the complexing agents is presented in Fig. 1.In the Visible region, it can be seen that the films have high transparency (>50%) for the films with 25 number of cycles. The films with number of cycles of 25 and 30 have slightly high transmittance at the NIR region and this suggest that it could be possibly used as material for poultry roofs and walls, which has greater efficiency than using the conventional methods of heating [10].

3.3 Reflectance of Film

Fig. 2 shows the reflectance curves for the deposited CdO thin films for different numbers of cycles using NH_3 as complexing agent. The plots show that the samples with fewer number of cycles (25 and 30) show high reflectance in IR region of the electromagnetic spectrum. A careful observation of Fig. 2 shows that the reflectance of the film increases as wavelength increases with the highest reflectance value of about 75% at approximate wavelength of

1000nm for film with 25 cycles. The high reflectance exhibited by this material makes it useful in the manufacture of highly reflectance mirrors commonly found in desktop scanners, photocopy machines, astronomical telescope, car head lamps and halogen lamps [11].

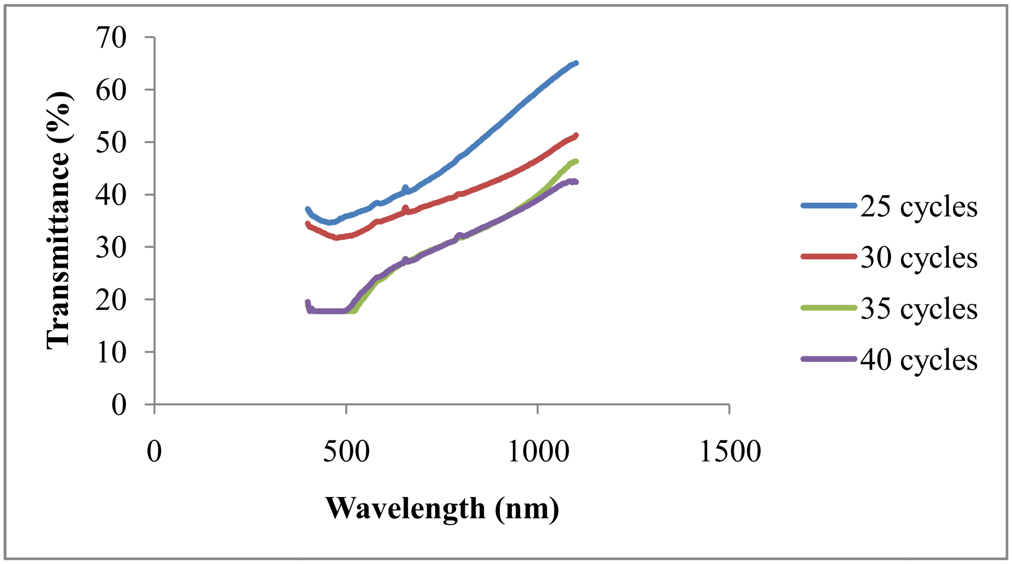

Fig. 1. The transmittance spectra of deposited CdO films using NH_3 as complexing agent

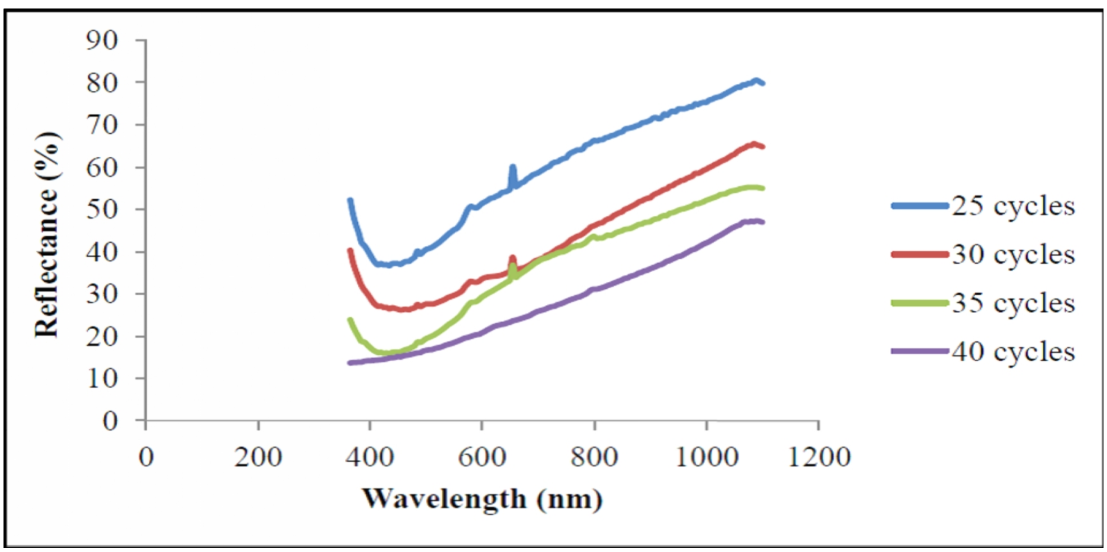

Fig. 2. Reflectance of deposited CdO thin films using NH3 as complexing agent

3.4 Optical Band Gap Studies

For the determination of the type of optical transition of the material, the absorption coefficient (α) dependence on the photon energy (hυ) has to be understood. The value of the energy bandgap can be determined from the fundamental absorption of the material which corresponds to the excitation of electrons from the valence band to the conduction band. The absorption coefficient was determined from transmittance values using the expression:

$$\alpha = \frac{[-InT]}{t} \quad - \quad - \quad - \quad - \quad - \quad - \qquad (1)$$

Where, α = Absorption coefficient
T = Transmittance values
t = Thickness of the film.

The relation between absorption coefficient (α), and the incident photon energy (hυ), can be expressed as:

$$(\alpha hv) = K(hv - E_g)^n \quad - \quad - \quad - \quad - \quad - \quad - \qquad (2)$$

Where K is a constant and n is a number which characterizes the transition process and is theoretically equal to 1/2 and 2 for direct and indirect transition, Eg is the optical band gap energy of the material.

The plot for the optical band gap of the deposited CdO thin film is shown in Fig. 3. The direct band gap energy for the deposited CdO thin films was obtained from the plot of $(\alpha h\upsilon)^2$ versus the photon energy, hυ, for different No. of cycles and extrapolating the curve to $(\alpha h\upsilon)^2 = 0$ as shown in Fig. 3. Table 1 also shows the values of these band gaps which ranges from 1.45eV to 2.35eV. A good observation of this plot reveals that the deposited CdO band gaps decreases with increasing number of cycles. The reason for the decrease in band gap energy is attributed to quantum size effect.

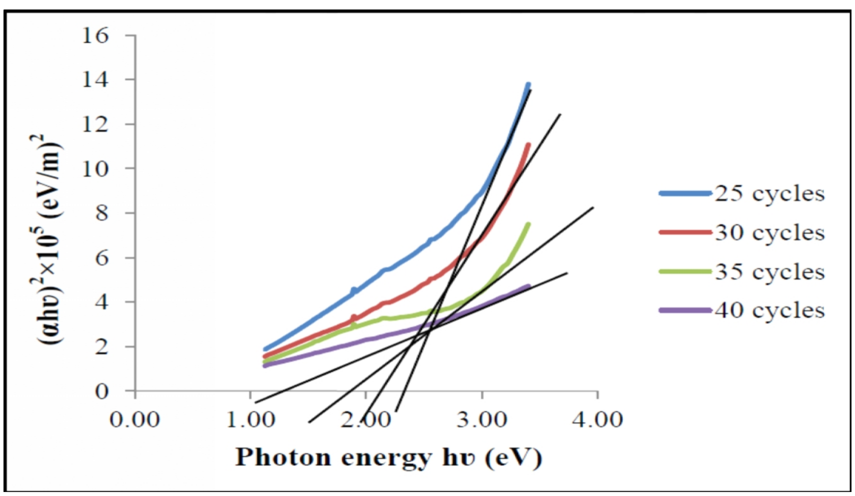

Fig. 3. Plots of photon band gap for the deposited CdO thin film.

Table 1. Nos. of cycles and respective band gaps

No. of cycles	25	30	35	40
Band gap (eV)	2.35	2.10	1.80	1.45

3.5 Extinction Coefficient of Deposited CdO Thin Films

The extinction coefficient of the films was calculated using the expression:

$$k = \alpha\lambda/4\pi \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad (3)$$

The plot of extinction coefficient versus photon energy for the CdO films deposited at different No. of cycles is shown in Fig. 4. We observe that the extinction coefficient decreases with increase in photon energy for all the samples. The extinction coefficient obtained for these materials lie within the range of 0.4 to 3.8. Also noticeable is a decrease in the extinction coefficient of the deposited CdO thin film with increasing No. of cycles.

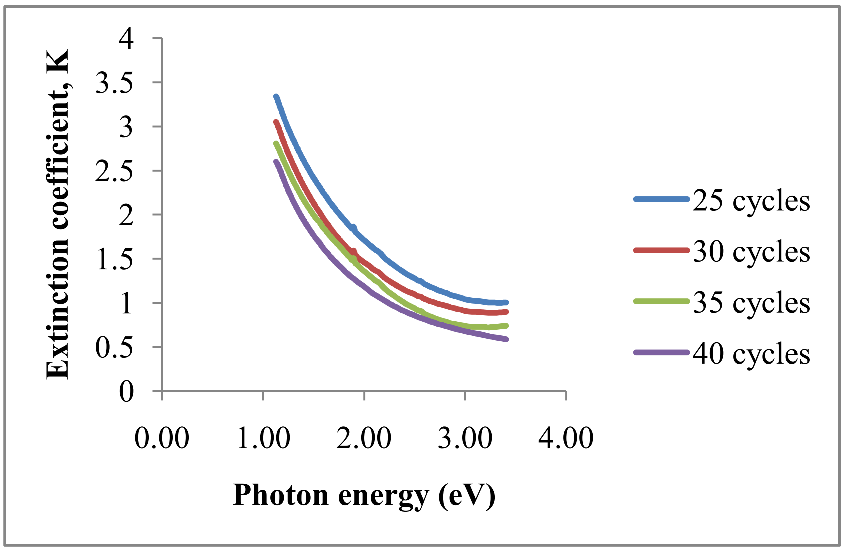

Fig. 4. The extinction coefficient versus photon energy for deposited CdO

3.6 Refractive Index of Deposited CdO Films

Fig. 5 shows the plot of the refractive index against the photon energy of the deposited CdO thin film. The refractive index of the material was calculated from reflectance value using the expression:

$$\eta = (1 + R^{1/2})/(1- R^{1/2}) \quad - \quad - \quad - \quad - \quad - \quad (4)$$

The refractive index of the material is seen to increase exponentially with increase in photon energy and also increased with No. of cycles. The refractive index obtained lies within therange of 1.0 to 1.3 for NH_3, with the highest 1.3 at 40 revolutions.

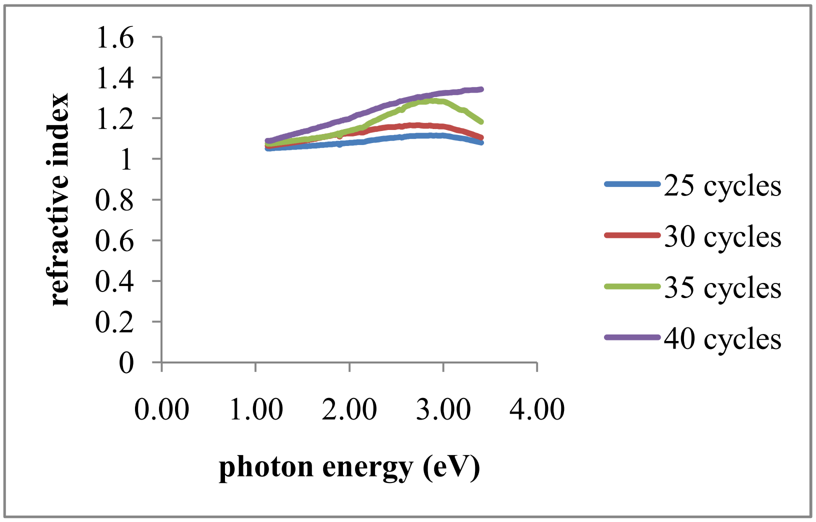

Fig. 5. Variation of refractive index with photon energy

3.7 Optical Conductivity of CdO Films

The optical conductivity of the material was calculated using the equation below;

$$\sigma = \frac{\alpha n c}{4\pi} \quad - \quad - \quad - \quad - \quad - \quad - \qquad (5)$$

Variation of optical conductivity of the material versus photon energy deposited at different No. of cycles for NH_3 as complexing agents are shown in Fig. 6. The optical conductivity decreases exponentially with photon energy and the number of cycles.

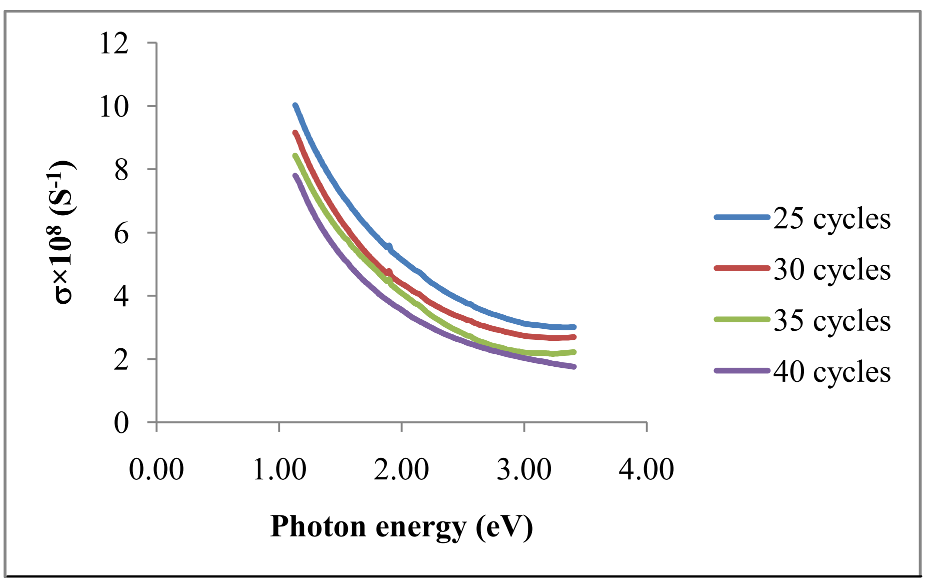

Fig. 6. Optical conductivity as a function of photon energy for CdO thin films at different number of cycles

3.8 Dielectric Function of the Deposited CdO Films

The dielectric function is a complex quantity and a fundamental intrinsic property of the material which consists of both the real and imaginary parts. The real part indicates how the speed of light in the material can be slowed down while the imaginary part deals with the absorption of energy by a dielectric from electric field due to dipole motion.

The dielectric function of the deposited CdO thin films grown in this research was calculated from the expression:

$$\varepsilon_T = \varepsilon_r + \varepsilon_i \qquad (6)$$

Where, we have used ε_r to represent the real part and ε_i to represent the imaginary part and they are given by the relation:

$$\varepsilon_r = \eta^2 - k^2 \qquad (7)$$

$$\varepsilon_i = 2\eta k, \qquad (8)$$

Where η and k represents the refractive index and extinction coefficient of the films respectively.

The dielectric function varies exponentially with the bandgap and also increases with the number of cycles as shown in Fig. 7.

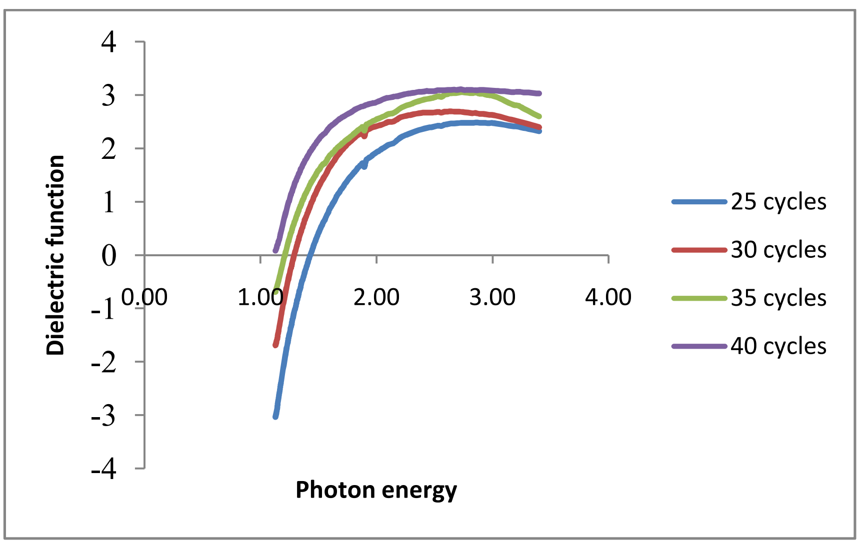

Fig. 7. Dielectric constant as a function of photon energy for CdO thin films at different number of cycles

4. CONCLUSIONS

The deposited CdO thin films were prepared using NH_3 as complexing agent by Successive Ionic Layer Adsorption and Reaction techniques. The characterization technique of UV-VIS-NIR spectroscopy was used for the films. The deposited CdO thin films conversely have low and high transmittance in the UV and visible region respectively. The band gap of the deposited CdO decreases with an increase in No. of cycles, this was attributed to the increase in the thickness of films. Also studied is the relationship between the film optical conductivity and the energy band gap, which was observed to decrease with an increase in band gap.

Lastly, the dependence of the film band gap and the dielectric function of the materials was consider, the dielectric constant varies exponentially with the band gap and also increases with the number of cycles (film thickness).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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