

Characterization of CdO:Cu Nano Thin Films Prepared Using Dual Solution Synthesis for possible Photonic Devices and Optoelectronic Applications

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Abstract- CdO:Cu thin films were successfully deposited on glass substrates by Successive Ionic layer adsorption Reaction method. The chemical compositions and thickness were obtained by Rutherford backscattering spectrometer. Samples C1 and C2 have elemental compositions of Cu:1.64%, O:56.00%, Cd:6.35% and Cu:1.57%, O:53.00%, Cd:7.50% respectively. The films optical properties were characterized using UV double beam spectrophotometer series 1800, for transmittance measurements and other optical properties such as Absorbance, reflectance, absorption coefficient, refractive index, were determined using appropriate equations. The transmittance spectrum shows that the films of samples C1(black)) and C2(red) have good transparency in the UV (16%-60%) for sample C1 and good transmittance (27%-70%) for sample C2 in the wavelength range (320nm-400nm). The high transmittance (61%-59%) for sample C1 from the visible region(400nm-700nm), becomes almost linear through the near infrared region of electromagnetic spectrum. The transmittance of sample C2 increases as wavelength increases up to the near infrared region of electromagnetic. In the near-infrared region, sample C2 has high transmittance (81%-85%) within the wavelength of 700nm- 1000nm of the region of electromagnetic spectrum. This makes these alloyed films good materials for UV filter and transparent electrode. The energy band gaps of samples C1 and C2 are evaluated by extrapolating the linear portion of the plot $(\alpha h\nu)^2$ against photon energy $h\nu$ at $(\alpha h\nu)^2 = 0$ where α is the absorption coefficient. The direct band gap values of 3.80eV and 3.75eV are obtained for samples C1 and C2 respectively. The average band gap value 3.78eV. The wide band gap obtained in this work makes the alloy of CdO:Cu a good material for the production of laser diodes and light emitting diodes (LEDs) used to produce field effect transistors where P-n junction may not be required if produced for solar applications. It can also be used to produce field effect transistors where P-n junction may not be required if produced for solar applications.

Keywords: Transmittance, Band gap, Spectrophotometer, Absorbance, Reflectance

I. INTRODUCTION

A thin film is a layer of material ranging from fractions of a nanometer (monolayer) to several micrometers in thickness. The controlled synthesis of materials as thin films (a process referred to as deposition) is a fundamental step in many applications. A familiar example is the household mirror, which typically has a thin metal coating on the back of a sheet of glass to form a reflective interface. The process of silvering was once commonly used to produce mirrors, while more recently the metal layer is deposited using techniques such as sputtering. Advances in thin film deposition techniques during the 20th century have enabled a wide range of technological breakthroughs in areas such as magnetic recording media, electronic semiconductor devices, integrated passive devices, LEDs, optical coatings such as antireflective coatings, hard coatings on cutting tools, and for both energy generation e.g. thin-film solar cells and storage (thin-film batteries). It is also being applied to pharmaceuticals, via thin-film drug delivery (Johari et al., 2012).

Cadmium oxide doped with copper has been studied extensively in recent years. Copper doping has been found to improve the optical, electrical, and structural properties of cadmium oxide thin films (Jana et al, 2020). Copper is a suitable dopant for the cadmium oxide lattice because its ionic radii is smaller than that of Cd²⁺, which prevents deformation of the CdO lattice. CdO:Cu nanomaterial have been synthesized using sol-gel method. CdO:Cu thin films have been

prepared using spray pyrolysis techniques. CdO:Cu has also been studied for its potential use in optoelectronic applications such as solar cells and smart windows. The role of dopants in improving the morphology and emission of CdO:Cu powder has also been investigated, with copper doping found to increase transparency and electronic properties. Overall, copper doping has been found to have a positive effect on the properties of cadmium oxide.

CdO is an important semiconductor material for the development of various technologies of solid state devices (panel display, optoelectronic components, thermally insulating glass. CdO finds its potential applications in the field optoelectronics devices such as solar cells (Janari and Shenoy, 2019; Taşdemirci, 2025) Preparation, phototransistors, photodiodes, transparent electrodes, catalysts and gas sensor. In this study, cadmium oxide thin films have been prepared onto glass substrate using dual solution synthesis (DSS). The production of semiconductor nano thin films, have been carried out mostly on binary compounds such as Cu_xO (Onwuemeka and Nwulu, 2017), CdO (Onwuemeka and Nwulu, 2017) which were useful in the area of passive and active applications (Onwuemeka et al., 2017). Alloys of semiconductors have also been prepared using dual solution synthesis (DSS) such as $ZnSnO_4$ (Onwuemeka et al, 2019), $CuSnO_4$, (Onwuemeka, 2020), $CdSnO_4$ (Onwuemeka and Ekpunobi, 2018) and $PbCuSO_4$, (Onwuemeka, 2020). In this work,

dual solution synthesis (DSS) was adopted, which involved simultaneous application of successive ionic layer adsorption and reaction (SILAR) and solution growth technique (SGT).

II. MATERIALS AND METHODS

In dual solution method, the deposition of CdO:Cu, two methods are involved which are: successive ionic layer adsorption and reaction (SILAR) and the solution growth technique (SGT). 0.5M solution of $CdCl_2$ was made to react with the solution of triethanolamine (TEA) forming complex Cd ion as given in Eqn. (2.1). In order to remove the unadsorbed ions on the substrates, the glass substrates were carefully cleaned and inserted into the solution in beaker (a) containing Cd complex ion as given in Eqn (2.2) and was removed and immersed in de-ionized H_2O in beaker (b) for 5 seconds in constant 20 cycles and was subsequently immersed in the third beaker (c) containing solution of hydrogen peroxide (H_2O_2) which is the anionic precursor as given in Eqn (2.3) and then immersed into the fourth beaker labeled beaker (d) containing de-ionized H_2O as given in Figure 2.1 which completes the SILAR approach. The substrates were dipped into complex solution of copper ion as given in Eqn (2.4), the solution growth method as shown in Figure 2.2 and was pulled out after 5 seconds and was allowed to dry in air.

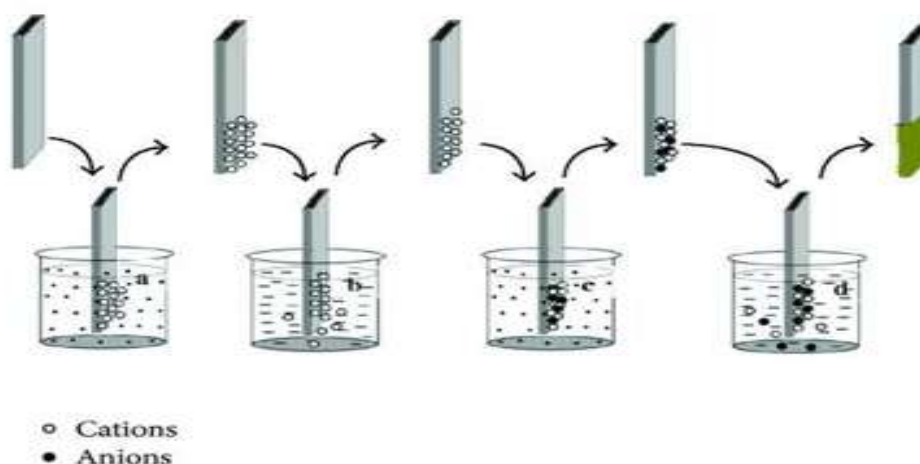


Figure 2.1 SILAR Method

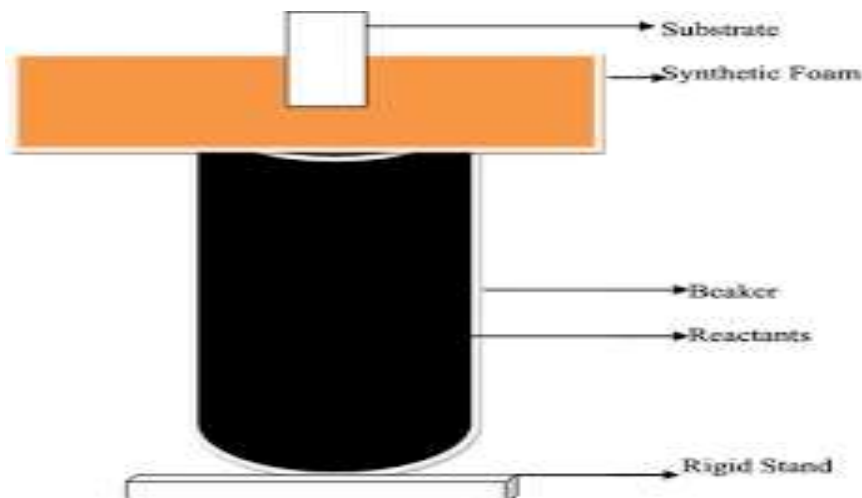
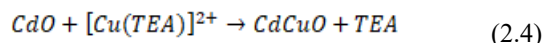
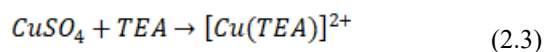
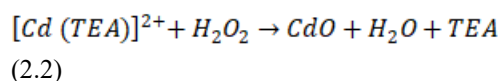
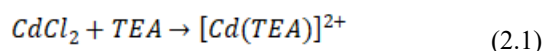


Figure 2.2 Solution Growth Method (Onwuemeka et al, 2018)



The suitable pH value for this work is 11 as detected by the pH meter.

III. RESULTS AND DISCUSSION

The deposited films of different parametric conditions were subjected to heat treatment from 150°C-250°C. using Master Chef Annealing Machine.

3.1 Composition and Thickness Characterizations

There is need to determine the elements and the thicknesses of the film samples. In this work,

elemental compositions and the thicknesses of the samples were determined using Rutherford Back Scattering equipment: 2.2MeV alpha beam, obtained from CERD Ion Beam Analysis (IBA) Facility With Model: NEC 5SDH 1.7 MV Pelletron Tandem Accelerator equipped with a Radio Frequency Charge Exchange Ion Source Alphasron.

Table 3.1 The elements in sample C1 of CdO:Cu

Elements	Layer(1)%Comp.	Layer(2)%Comp.
O	93.05	56.00
Ca	-	1.83
Fe	-	0.52
Na	-	12.60
Al	-	0.53
Si	-	28.00
Cd	6.35	-
Cu	1.64	-

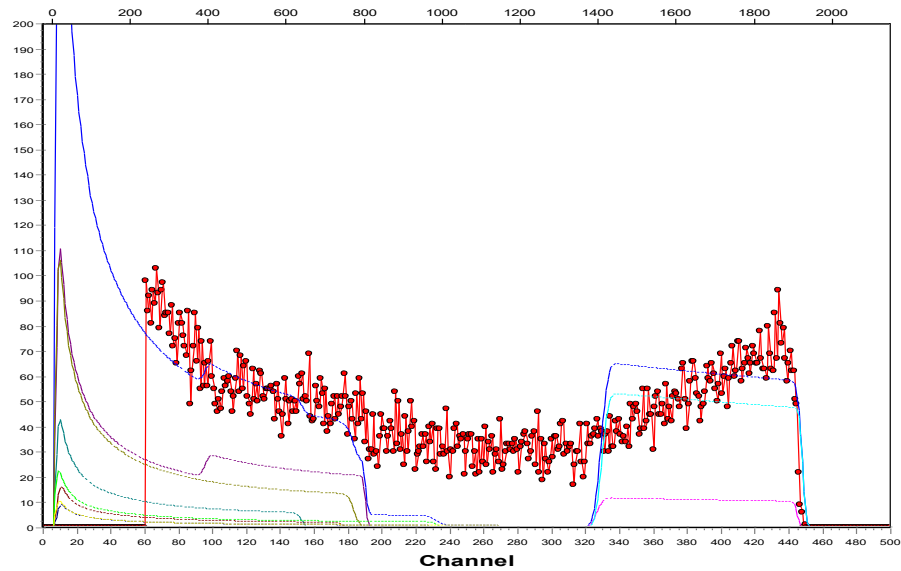


Figure 3.1 The composition of sample C1 of CdO:Cu of thickness, 100.64nm as measured by Rutherford backscattering spectroscopy

Table 3.2 The elements in sample C2 of CdO:Cu

Elements	Layer(1)%Comp.	Layer(2)%Comp.
O	93.17	53.00
Ca	-	1.83
Fe	-	0.52
Na	-	12.60
Al	-	0.53
Si	-	28.00
Cd	7.50	-
Cu	1.57	-

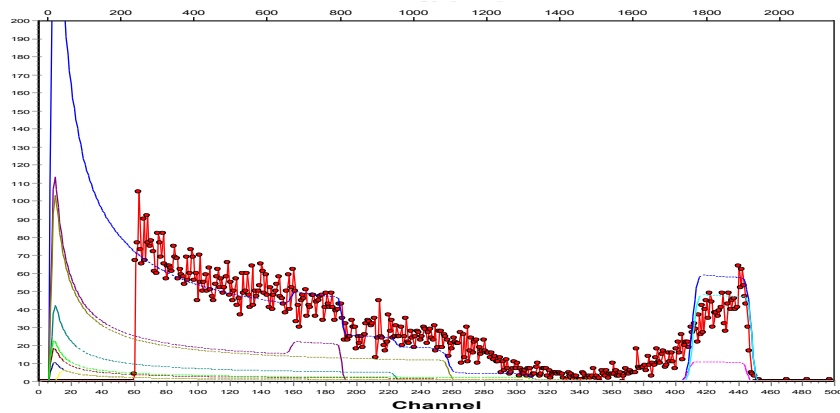


Figure 3.2 The composition of sample C2 of CdO:Cu with thickness, 101.31nm as measured by Rutherford backscattering spectroscopy

3.2 Transmittance

The transmittance spectrum shows that the films of samples C1(black)) and C2(red) have good transparency in the UV (16%-60%) for sample C1 and good transmittance (27%-70%) for sample C2 in the wavelength range (320nm-400nm). The high transmittance (61%-59%) for sample C1 from the visible region(400nm-700nm), becomes almost linear through the near infrared region of electromagnetic

spectrum. The transmittance of sample C2 increases as wavelength increases up to the near infrared region of electromagnetic. In the near-infrared region, sample C2 has high transmittance (81%-85%) within the wavelength of 700nm- 1000nm of the region of electromagnetic spectrum as shown in Figure3.3. This makes these alloyed films good materials for UV filter and transparent electrode.

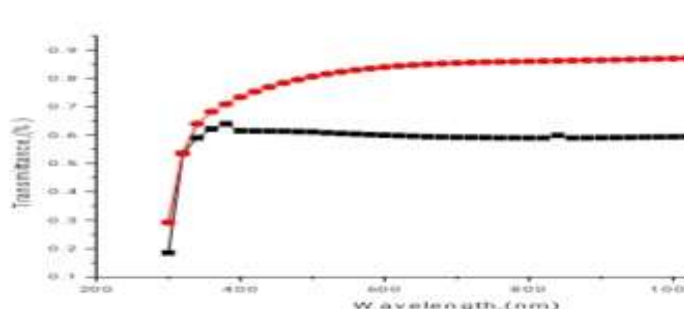


Figure 3.3 Graph of transmittance against wavelength of CdO:Cu

The optical energy band gap is obtained in k space.

The energy band gaps of samples C1 and C2 are evaluated by extrapolating the linear portion of the plot $(\alpha h\nu)^2$ against photon energy $h\nu$ at $(\alpha h\nu)^2 = 0$ where α is the absorption coefficient as shown in Figure 2.6

The direct band gap values of 3.80eV and 3.75eV are obtained for samples C1 and C2 respectively. The average band gap value 3.78eV.

The wide band gap obtained in this work makes the alloy of CdO:Cu a good material for the production of laser diodes and light emitting diodes (LEDs) used to produce field effect transistors where P-n junction may not be required if produced for solar applications (Look, 2001).

It can also be used to produce field effect transistors where P-n junction may not be required if produced for solar applications (Kasinathan et al., 2019; Onwumeka et al., 2017).

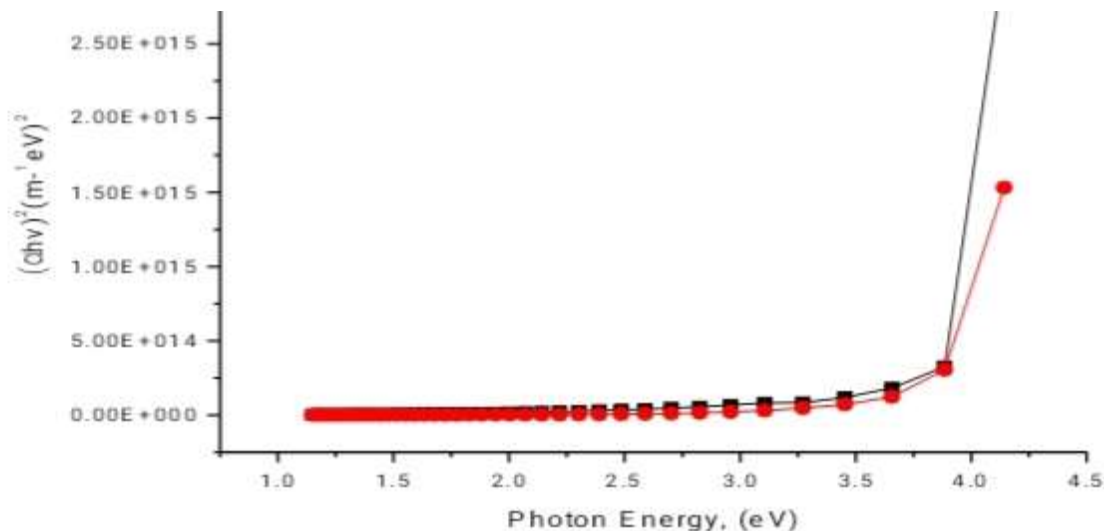


Figure 3.4 The Graph of $(\alpha h\nu)^2$ against photon energy $h\nu$ for CdO:Cu

IV. CONCLUSION

The CdO:Cu thin films have successfully been deposited on glass substrates. This was achieved using dual solution synthesis (DSS) which employs two different methods simultaneously. The two methods adopted are successive ionic layer adsorption and reaction (SILAR) and solution growth technique (SGT). The method is cheap, effective, accurate and easy to execute.

The substrates were prepared in aqua regia before being used for the fabrication. The complexing agent used is triethanolamine (TEA). The precursor materials used as the sources of cation are solutions of hydrated CuSO₄, CdCl₂ and H₂O₂ as the source of anion.

The deposition of CdO:Cu was carried out at room temperature of 20°C. The samples were annealed at 2000C and 2500C for 1hour. The compositions and thickness measurements were determined using Rutherford Backscattering Spectroscopy (RBS).

The graphs of the optical characterization were plotted against wavelength for the samples produced. The energy band gaps of the samples were determined from the graph of $(\alpha h\nu)^2$ against $h\nu$ by extrapolation of straight portion of the curves to $h\nu$

axis where $(\alpha h\nu)^2 = 0$. The average band gap of the four samples is 3.78eV. As a material with wide energy band gap, it can be found useful as photovoltaic and photoconductive thin films for optoelectronic applications, solar cell production, sensor devices, chemical detectors in oil and gas productions and as material for solar control coatings and good material for photonic and flat panel displays.

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