

PRIMARY RESEARCH

Investigation of the morphology and optical properteis of CuAlO₂ thin film

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Index Terms

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Abstract— The search for p-type Transparent Conducting Oxides (TCO) has been pursued vigorously to complement current advances in n-type TCOs to develop heterojunctions for various electronic devices. One of the promising p-type TCOs is CuAlO₂. Thin films of CuAlO₂ were deposited on a clean glass substrate using the chemical solution deposition (sol-gel) method of deposition with CuCl and AlCl₃ taken as the starting materials. CuCl was dissolved in HCl while AlCl₃ in distilled water, pH value of the mixture was controlled by the addition of NaOH. The samples were annealed at different temperatures in order to determine the effect of annealing temperatures on the morphological and optical properties of the deposited CuAlO₂ thin film. The surface morphology reveals an improved crystalline nature as annealing temperature increases. The UV-vis and FT-IR spectrophotometry results indicate that the absorbance for all the samples decreases sharply from a common value of about 89% at about 329nm to a range of values of 56.2%-35.2%. The extinction coefficients for all the samples decrease from 133.89×10^{-3} , 111.76×10^{-3} , 93.45×10^{-3} and 89.44×10^{-3} in the infrared region to about 81.11×10^{-3} , 82.22×10^{-3} , 83.35×10^{-3} and 84.42×10^{-3} at about 4.05eV in the visible region. And the absorption coefficients of three samples decrease with increase in annealing temperature from 1.58×10^{-6} , 1.29×10^{-6} and 1.08×10^{-6} at about 1.14eV in the infrared region to about 1.93×10^{-6} , 1.58×10^{-6} and 1.29×10^{-6} at about 3.62eV in the visible region. Transmittance and band gaps vary directly with annealing temperature; the deposited films were found to be suitable in optoelectronic applications.

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I. INTRODUCTION

This work provides an introduction to the basic physics of TCO films and surveys the various topics and challenges in the field and the technology behind the fabrications. TCOs are very useful materials to transparent optoelectronics because they have unique features of optical properties in the visible light region such as the transparency over 85%, optical band gap greater than 3eV and controllable electrical conductivity such as carrier concentration of at least 10^{20}cm^{-3} and resistivity of about $10^{-4} \Omega \text{cm}$ [1]. Transparent Conducting Oxides (TCO) thin films of In-2O₃, ZnO, SnO₂, CuAlO₂ etc. and their mixtures have been extensively used in optoelectronic applications

such as transparent electrodes in touch panels, Flat Panel Displays (FPDs), infrared detectors solar cells, gas detectors and many other applications. The search for p-type Transparent Conducting Oxides (TCOs) has been pursued vigorously in order to compliment current advances in n-type TCOs with a view to develop heterojunctions for various electronic devices. One of the promising p-type TCOs is CuAlO₂.

[2] reported the synthesis of phase impure copper aluminium oxide films by solution method using metal alkalooids and nitrates as metal sources in the precursor solutions. [3] used similar solution process to synthesize CuAlO₂ thin film using copper acetate and aluminium nitrate as metal sources. [4] used organometallic compounds

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to fabricate both phase pure and phase impure copper aluminium oxide using sol-gel process at different Cu/Al ratios. [5] conducted a research on the annealing effects on the structural, optical and electrical properties of CuAlO_2 thin film deposited by magnetron sputtering. He found that the crystallinity of CuAlO_2 is improved with increasing annealing temperature in N_2 ambience and the film annealed at 900°C presents the excellent preferred (001) orientation in x-ray diffraction.

[6] conducted another research on optical and electrical properties of p-type transparent conducting oxide CuAlO_2 thin film. In the work p-type transparent conducting CuAlO_2 thin film was prepared by e-beam evaporation and wet oxidation technique. In the work transmittance varied from 20-85% and the resistivity from 5×10^{-3} to $4 \Omega\text{cm}$ with wet oxidation conditions. The nature of the p-type film was confirmed by the positive Hall Effect technique. Optical band gap was estimated to be in the range 3.96-4.20eV.

[7] conducted a research on wet chemical dip coating preparation on highly oriented copper aluminium oxide thin film and its opto-electrical characterization. In the work transparent p-type semiconducting copper aluminium oxide thin film was synthesized by wet chemical route. The films were deposited by dip coating on Si and glass substrates. XRD pattern confirms the crystalline CuAlO_2 phase formation with strong (006) orientation while UV-Vis measurement shows a high transparency of the film in the region with direct band gap of 3.94eV.

[8] conducted another research on the size dependent optical properties of sputter-deposited nanocrystalline p-type transparent CuAlO_2 thin film. He deposited nanocrystalline p-type semiconducting transparent CuAlO_2 thin films by direct current sputtering of a prefabricated polycrystalline CuAlO_2 target with deposition time as a variable parameter. Transmission electron micrographs reveal the formation of CuAlO_2 nanoparticles. X-ray diffraction shows some diffraction peaks depicting rhombohedral crystal structure. The band gap values obtained from the optical transmission and reflection data for the films deposited in 3 and 9 mins are 3.94 and 3.84eV respectively.

In this work thin film of CuAlO_2 was deposited on glass substrate, five samples were produced, four of which were annealed at temperatures of 400°C , 500°C , 600°C and 700°C for 2hrs each. Surface morphology of the deposited and annealed samples was studied using the Scanning electron microscope and the optical properties of the samples such as transmittance, absorbance, absorption coefficient,

extinction coefficient and the band gaps were studied with respect to an increase in annealing temperature though UV Vis and Fourier Transform infrared (FT-IR) spectrometry.

A. P-type TCO

Since the discovery of p-type conductivity in CuAlO_2 , many Cu (I) based delafossites having transparency and p-type conductivity have been synthesized. After the report of p-type semiconducting transparent CuAlO_2 thin film, a new field in device technology called the 'transparent electronics' in which a combination of the two types of TCOs in the form of a p-n junction is studied, has emerged [9]. This leads to a 'functional' window which would transmit visible portion of solar radiation yet generates electricity by the absorption of UV part of it. Also CuAlO_2 has good thermoelectric field-emission, ozone sensing, photochemical and photo-catalytic hydrogen evolution properties as well as ferromagnetic characteristics and capability of refrigeration of electronic devices [10], [19] and [20]. Also keeping an eye on the tremendous progress in Nanotechnology, fabrication and characterization of Nano-structure p- CuAlO_2 as well as other p-TCO thin films have become an important field of work, because of new and interesting properties exhibited by these Nano materials [8].

B. CuAlO_2 as P-Type TCO

[11] first reported synthesis of CuAlO_2 as a p-type TCO material based on the copper I Oxides such as CuAlO_2 , CuGaO_2 , and SrCuO_2 with chemical modulation of valence band, in spite of several merits of CuAlO_2 as a P-type TCO, the main hurdle is its low electrical conductivity compared to the n-type TCO. Therefore, different methods such as high temperature solid state reaction, hydrothermal method ion exchanges and sol-gel methods etc. have been proposed to prepare CuAlO_2 [12], [21] and [22]. Each copper atom in CuAlO_2 is linearly coordinated with two oxygen atoms to form an O-Cu-O dumbbell unit placed parallel to the c-axis. Oxygen atoms of the O-Cu-O dumbbell link Cu layers with the AlO_2 layers. For the synthesis of CuAlO_2 thin films, the groups of Hosono, Gong and Chattopadhyay used a pulsed laser deposition, plasma-enhanced metalorganic chemical vapor deposition and dc sputtering, respectively.

[13] The electronic structures of CuAlO_2 were experimentally probed by normal /inverse photoemission spectroscopy. The Fermi energy determined experimentally was set to zero in the energy scale in the three spectra. A band gap was observed between the valence band edge in the

photoemission spectroscopy and the conduction band edge in the Inverse photoemission spectroscopy; the band gap estimated was about 3.5eV. The Fermi energy lies around the top of the valence band. The origin of the Fermi level was determined using Au electrode deposited on sample. These results mean that CuAlO_2 is a transparent p-type semiconducting material, which has excellent potential for use in optoelectronics device technology.

II. EXPERIMENTAL DETAILS

A. Sol Preparation

A sol was prepared by adding concentrated hydrochloric acid to cuprous oxide and the solution was stirred with a magnetic stirrer, during the stirring process. Further addition of hydrochloric acid to the solution was done until all the salts were dissolved in it. Another solution was prepared by adding distilled water drop by drop to Aluminium chloride salts to dissolve it completely. The two solutions were mixed together and some excess distilled water added to the mixture. The solution was further stirred at an elevated temperature of about 80°C for 2hrs. Now during this stirring process, some amount of sodium hydroxide pellets was added to the solution to control the pH value to around 2 (acidic medium). This makes the mixed solution appear darker and gel-like. The solution was then aged for 3hrs to get the required sol which was used for the dipping process in the second stage.

B. Substrate Preparation

Ordinary microscopic slides were used as substrates, the choice of which is because it is transparent, flat, thin enough and also able to adequately adhere the Cu-Al films to it; not only at normal temperature but also during relatively large temperature changes during the annealing process.

Before the dipping process these glass substrates were cleaned with mild soap solution, then washed thoroughly in deionized water and also in boiling water. Finally they are ultrasonically cleaned in acetone for 20 minutes.

C. Coating Process

During this process, the substrates were completely dipped one by one into the jelly sol and withdrawn vertically slowly at a rate of 10cm /min 8 times. Between two successive dipping, the substrate along with the carried sol was dried at $100\text{-}120^\circ\text{C}$ so as to have a quick gelation. After

the dipping and withdrawing procedure, the resulting four CuAlO_2 thin film samples were prepared and ready for annealing.

D. Annealing Process

The four samples of CuAlO_2 thin films deposited using the sol-gel technique were annealed at temperatures of 400°C , 500°C , 600°C and 700°C for 3hrs each and the annealed thin films are kept ready for structural and optical analysis.

E. Study of the Surface Morphology

This study of the surface morphology of the as-synthesized and annealed samples of thin films of CuAlO_2 was carried out using the SEM Hitachi S-1100 Model scanning electron microscope.

F. Samples Preparation for SEM Measurements

All the five samples were cut and made appropriate sizes of one square centimeter each to fit into the specimen chamber and were generally mounted rigidly on a specimen holder called a specimen stub. Carbon coating was applied to the film surface to enhance the imaging.

G. Study of the Optical Characteristics

This study was carried out in two stages: i-By UV-Visible spectrophotometry and ii-By Fourier Transform Infrared FT-IR. The purpose of this study is to determine the properties exhibited by the CuAlO_2 Thin film in the presence of light and annealed at a temperature range of $400\text{-}700^\circ\text{C}$ in the intervals of 100°C each. The optical properties studied are the Transmittance (T), Absorbance (A) and Absorption coefficient (α). Others are the extinction coefficient (k) and the band gaps.

H. Samples Preparation for SEM Measurements

The UV-visible spectrophotometer used for this work is Varian Cary 50Bio UV-Vis spectrophotometer. Samples for UV-Vis spectrophotometry using the Varian Cary 50 Bio mode are most often liquids, and typically placed in a transparent cell, known as cuvette. The cuvette is typically rectangular in shape commonly with an internal width of 1cm, this width becomes the path length L in the Beer Lambert law. It allows radiation to pass over the spectral region of interest. The most widely applicable cuvette is made of high quality fused silica or quartz glass because they are

transparent throughout the UV-Vis and near infrared regions [14]. In this work small portions of all the six samples of the prepared CuAlO_2 thin films were scrapped and the powder diluted with distilled water and placed in two separate cuvettes for UV-Vis spectrophotometry.

I. Sample Preparation for FT-IR Spectrometer Measurement

Small portions of all the four coated samples of CuAlO_2 thin film were scrapped using a sterile blade to obtain the powdered samples, these were placed on FT-IR spectrometer stage for FT-IR analysis.

III. RESULTS AND DISCUSSION

Figures 4a-4e show the SEM micrographs of the as synthesized and annealed samples of the deposited CuAlO_2 thin film on glass substrate using the chemical solution (sol gel) method of deposition. From the micrograph of fig 1 (as deposited CuAlO_2 sample) it will be observed that the film had loose structure with small particle size and a fine and well defined grain boundaries and size, the grain size appears smaller compared with those annealed at different temperatures, also the film color is black and uniformly covering the substrate with good adherence.

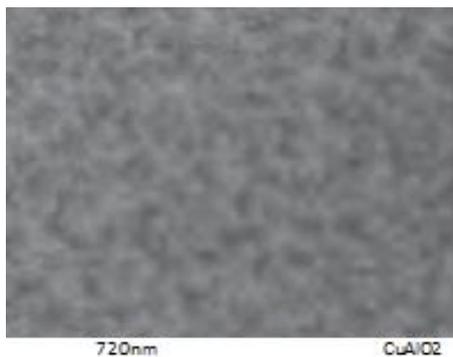


Fig. 2 . SEM micrograph of CuAlO_2 annealed at 400°C

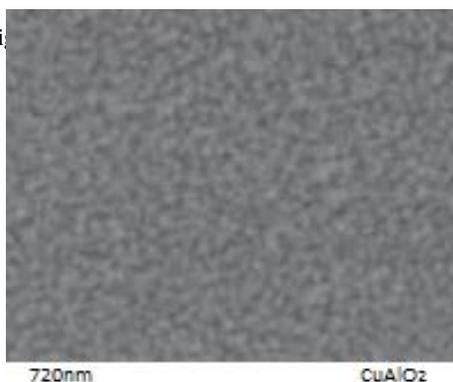


Fig. 2 . SEM micrograph of CuAlO_2 annealed at 400°C

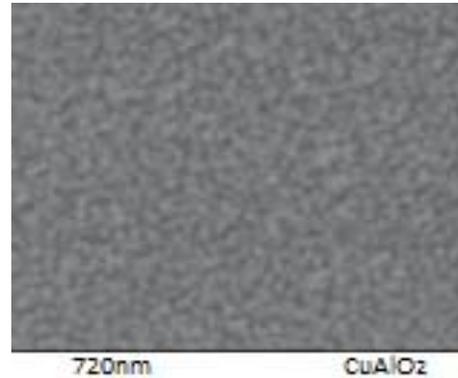


Fig. 3 . SEM micrograph of CuAlO_2 thin film annealed at 500°C

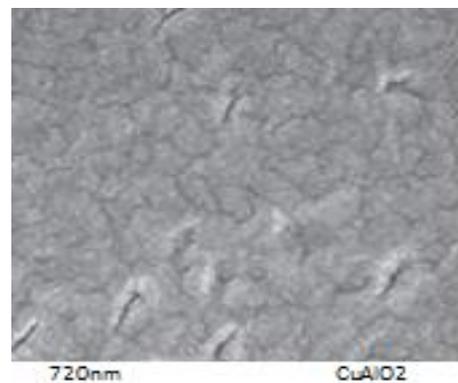


Fig. 4 . SEM micrograph of CuAlO_2 thin film annealed at 600°C

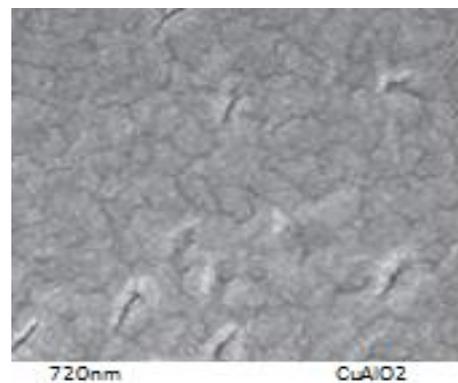


Fig. 5 . SEM micrograph of CuAlO_2 thin film annealed at 700°C

The micrographs of figs. 2 to 5 showed a similar structure with larger particles size and at these temperatures the film looked more compact. There is the existence of a smooth surface with finer grain. Again some bigger clusters are also shown to be dispersed on the surface which resulted due to agglomeration of finer grains. It is apparent that the grain size of the films increases as the

annealing temperature increases which can be understood by high mobility of atoms at high annealing temperatures. This result agrees with the work of [15] who found similar results of the structure of Cu-Al-O film deposited at a temperature of 750oC with larger particle size of about 40-50nm. Dense granular structures are also observed in the images with some voids visible at the middle of the structure. This agrees with the work of [5] and [6]. It is also worth to notice that the micrographs of figs. 1, and 4b are having similar type of crystallinity due to the annealing temperature range of 400oC to 500oC, it now appears that due to the annealing temperatures of the micrographs of figs. 1 and 2, the densification of the films has not fully taken place. However a further elevated thermal treatment as in micrographs of figs. 4 - 4e reduces the voids in the micrographs. It is also to be observed that the overall surface of the micrograph of fig. 5 is seen to have finer grain boundaries covering the substrate which is attributed to the elevated thermal treatment of 700°C.

A. Study of the Optical Properties

The optical properties of CuAlO₂ thin films in terms of absorbance, transmittance, absorption coefficient, extinction coefficient and band gaps have been studied in detail. The four samples S1, S2, S3 and S4 of the deposited CuAlO₂ film with different annealing temperatures of 400°C, 500°C, 600°C and 700°C respectively with 2hrs annealing time each were studied and analyzed.

B. Absorbance

Absorbance is expressed as logarithm (base10) of the reciprocal of the transmittance:

$$A = \text{Log}_{10} \frac{1}{T} \quad (1)$$

Also, Beer Lambert's Law below gives the concentration of an absorbed specimen given by:

$$A = \text{Log}_{10} \frac{I_0}{I} \epsilon c l \quad (2)$$

Where, A is the measured absorbance:

I_0 is the intensity of the incident light at a given wavelength

I is the transmitted intensity

c is the concentration of absorbing specimen

In fig. 1, the absorbance decreases with increasing annealing temperature, the absorbance of all the samples decreases sharply from common value of about 1.5au at

about 329nm to about 0.81au, 0.63au, 0.52au and 0.45au for samples S1, S2, S3and S4 respectively in the wavelength region of about 400nm.

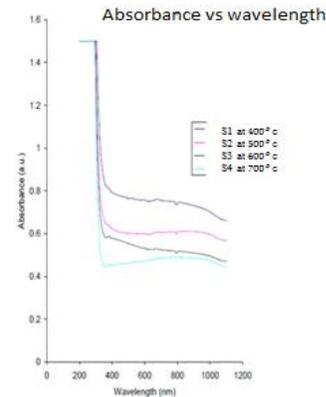


Fig. 6. Absorbance vs wavelength spectra for CuAlO₂ thin film at different annealing temperatures

Within the visible range the absorbance value of samples S1, S2 and S3 decreases from about 0.81au to 0.75au, 0.63au to 0.62au and 0.59au to 0.52au respectively. However the absorbance of sample S4 increases slowly from about 0.45au to about 0.48au within the visible range. Between 700nm and 900nm, the absorbance values of the samples are fairly constant. While the absorbance values of samples S1 and S2 are about 0.75au and 0.62 within this range the values for samples S3 and S4 are about 0.52au and 0.45au respectively. Beyond 900nm, absorbance value of all samples decreases slowly with increase in wavelength.

C. Transmittance

The ratio of radiant power (P) transmitted by a sample to the radiant power incident (P₀) on the sample is called transmittance:

$$T = \frac{P}{P_0} \quad (3)$$

And from:

$$A = \text{Log}_{10} \frac{1}{T} \quad (4)$$

so that:

$$A = \frac{1}{10^A} \quad (5)$$

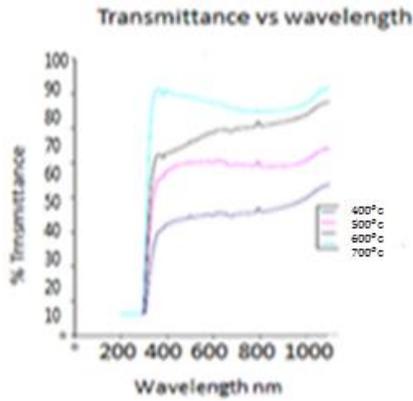


Fig. 7. Transmittance vs wavelength spectra for CuAlO₂ thin film at different annealing temperatures

D. Absorption Coefficient

The absorption coefficients (α) are calculated from the absorbance data using the Beer Lambert equation given as:

$$a = \frac{2.203A}{d} \tag{6}$$

Where,

A is the absorbance and d is the thickness of the film

The absorption coefficient α decreases with increasing annealing temperature. The absorption coefficient of three samples S1, S2 and S3 increases according to fig. 4 from 1.58×10^{-6} , 1.29×10^{-6} and 1.08×10^{-6} at about 1.14eV in the infrared region to about 1.93×10^{-6} , 1.58×10^{-6} and 1.29×10^{-6} at about 3.62eV in the visible region and this agrees with the work of [6]. And between 3.62eV and 4.00eV, the absorption coefficient of the samples rises sharply and attains different peak values which decrease with increasing annealing temperature.

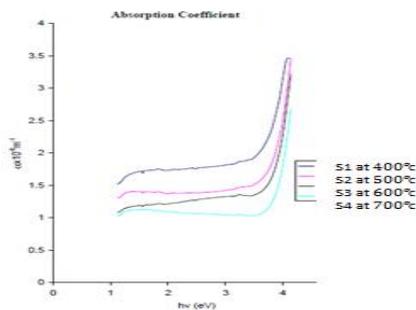


Fig. 8. Absorption coefficient vs photon energy for CuAlO₂ thin film at different annealing temperatures

E. Energy Band Gap

The energy in electron volt (eV) is obtained using:

$$E = hv \frac{hc}{\lambda} \tag{7}$$

h is a Planck’s constant given as 6.62×10^{-34} Js

c is the speed of light and

λ is the wavelength

The direct band gap for all the samples is calculated using Tauc’s relation from the values obtained for absorption coefficient (α) and energy gap (E). The direct band gap according to the plot in fig. 6 for sample S1 is about 3.55eV while that of S2 and S3 is about 3.80eV and the sample S4 has a direct band gap of about 3.85eV. This value agrees with the values of the band gaps estimated by [5] as 3.0, 3.15, 3.50 and 3.75 and the work of [7] who extrapolate the linear portions of the graphs of $(\alpha hv)^{1/n} = A(hv-E)$ to the hv axes and obtained a direct band gap of CuAlO₂ to be 3.94 and 2.42 for indirect band gap.

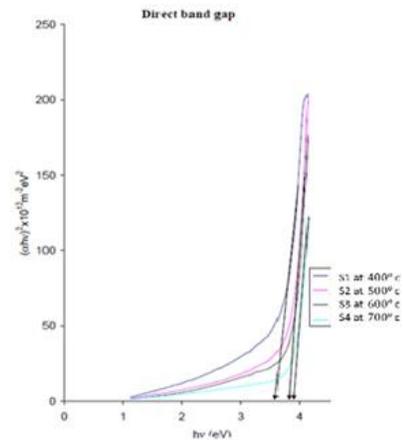


Fig. 9. Direct band gap vs photon energy for CuAlO₂ thin film at different annealing temperatures

F. The Extinction Coefficient

The extinction coefficient (k) of all the samples is calculated from the values of absorption coefficient (α) from the equation:

$$k = \frac{\lambda a}{4\pi} \tag{8}$$

From the plot of fig. 5, the extinction coefficient of the samples S1, S2, S3, and S4 decreases parabolically from 133.89×10^{-3} , 11.76×10^{-3} , 93.45×10^{-3} and 89.44×10^{-3} respectively in the infrared region to about 81.11×10^{-3} ,

82.22×10^{-3} , 83.35×10^{-3} and 84.42×10^{-3} at about 4.05 eV in the visible region respectively. The minimum values of the extinction coefficient are 57.78×10^{-3} and 29.44×10^{-3} for samples S2 and S1 respectively and it occurs at about 3.54 eV . Now the extinction coefficient values of the samples at 2 eV are approximately 94.32×10^{-3} , 72.58×10^{-3} , and 64.44×10^{-3} and 59.46×10^{-3} for samples S1, S2, S3, and S4 respectively and these values are comparable with those in the work of [7] whose values of the extinction coefficients vary from 22.00×10^{-3} to 65.32×10^{-3} in the wavelength region of $300\text{-}800 \text{ nm}$.

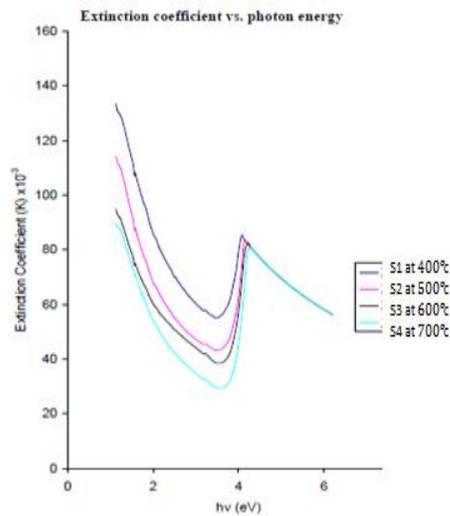


Fig. 10 . Extinction coefficient vs photon energy of CuAlO_2 thin film at different annealing temperatures

G. Fourier Transform Analysis of the CuAlO_2 thin Film

Fourier transform changes a given function to a new function:

$$F(\omega) = \int_{-\infty}^{\infty} f(t)e^{-i\omega x} dt \quad (9)$$

Where:

$$f(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(\omega)e^{i\omega x} d\omega \quad (10)$$

Fourier transform infrared spectroscopy (FT-IR) performed on the CuAlO_2 thin film deposited on microscope slide (glass slide) as substrate was only carried out on sample S4 annealed at temperature 700°C , this is because in the UV-Visible spectrophotometry all the samples of the deposited CuAlO_2 thin film annealed at 400°C , 500°C , 600°C and 700°C were analyzed for all parameters and the results were discussed.

H. Absorbance in FT-IR Spectroscopy

The absorbance for all the samples annealed at different temperatures decreases with increasing annealing temperature as found in the UV- Vis spectrophotometry of fig. 1. For this sample S4 annealed at 700°C , the FT-IR spectra of absorbance vs wavenumber cm^{-1} are given in fig. 1.

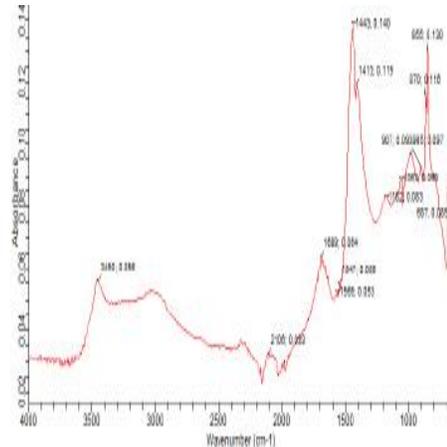


Fig. 11 . Spectra for absorption vs wavenumber cm^{-1} for sample S4 CuAlO_2 thin film annealed at 700°C temperature

The wave number varied from 700 to 400 cm^{-1} in the spectra, the absorbance decreases with an increase in temperature, the absorbance is at its lowest value of about 0.031 au at a wave number of 2106 cm^{-1} and a peak value of 0.14 au at a wave number of 1443 cm^{-1} . Between the wavenumbers of 3600 cm^{-1} and 4000 cm^{-1} there is almost no change in the absorbance value of the given sample. However there appears a sudden rise in the absorbance values from 0.031 au to 0.055 au at a region between 3450 cm^{-1} and 3570 cm^{-1} wavenumber. The two highest peaks at 0.140 au (1443 cm^{-1}) and 0.130 au (855 cm^{-1}) may be attributed to the Al-O and CuO stretching and bending vibration change in surface structure taking place after calcination. And between the wavenumbers of about 1480 nm (0.140 au) and 1547 nm (0.055 au), there appears a very sharp decrease in the absorbance of the sample. [17] in his infrared spectral interpretation observes the decrease in his spectra of CuAl_2O_4 Nanopowder.

I. Transmittance in FT-IR Spectroscopy

Transmittance generally increases with an increase in the annealing temperature [18]. This was also previously reached in the uv-vis transmittance spectra of all the sam-

ples of CuAlO_2 produced at different annealing temperatures of fig. 2 above. For the FT-IR transmittance of the sample annealed at 700°C temperature, the spectrum of the film is produced in fig. 2.

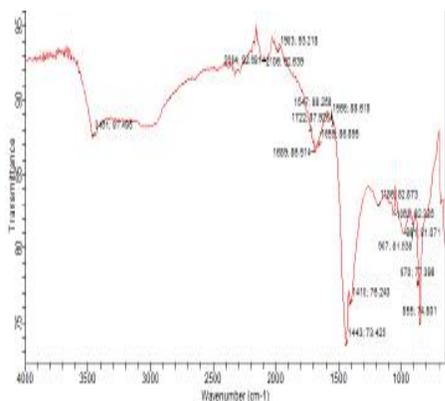


Fig. 12 . FT-IR spectra for transmittance vs wavenumber cm^{-1} for sample S4 annealed at 700°C temperature

The wave number varies from about 700cm^{-1} to 400cm^{-1} in the above spectra, there appears almost constant transmittances of about 85% and 95% at the wave number regions of about 2980cm^{-1} to 3900cm^{-1} and 3645cm^{-1} to 4000cm^{-1} . The two lowest peaks at the wavenumber region of 700cm^{-1} to 1443cm^{-1} with transmittances of 73.425% and 74.801% may be attributed to Cu-O stretching vibration. And the other peak at 1185cm^{-1} wavenumber equivalent to 82.873% transmittance may be due to short Al-O stretching vibration in distorted AlO_6 octahedra. The peak at 1689cm^{-1} equivalent to 86.51% transmittance may be due to OH stretching vibration which may be incorporated from the atmospheric contaminations, other similar peaks in 2084cm^{-1} equivalent to 92.681% and 1983cm^{-1} equivalent to 93.218% may be attributed to O-Al vibration which occurs due to the nature of the CuAlO_2 film in the sample. Lastly a peak at 3461cm^{-1} (87.495% transmittance) may be a CO_2 peak. This is comparable with the work of [16] who found similar results in optical properties of mechanochemical synthesis of nanocrystalline delafosites CuAlO_2 . Hence the assignment of the peaks for differ-

ent modes of CuAlO_2 is a simplification of the vibrational treatment of different inorganic aluminates as well as copper complexes in organic solvents.

IV. CONCLUSION

Chemical solution deposition of transparent CuAlO_2 thin film on clean glass microscope slide CuAlO_2 substrate was successfully carried out; five samples of the CuAlO_2 thin films were produced, four samples were annealed at temperatures of 400°C, 500°C, 600°C and 700°C respectively. The surface morphology of the annealed samples was studied with the aid of a scanning electron microscope (SEM Hitachi S-1100). The micrographs also revealed the portion of the samples studied at 720nm each. A smooth surface with finer grains and well defined grain boundaries were observed in all the four samples, some bigger clusters were also observed on the micrographs of samples S3 and S4 which resulted due to the agglomeration of finer grains and some voids are visible on the surface of micrographs of figs. 1 and 2, it was also observed that the crystallinity of samples S3 and S4 has been improved. It will now be concluded that annealing at higher temperature improves crystallinity of CuAlO_2 thin film. For the UV-Vis and FT-IR Spectroscopy the findings indicate that while absorbance and absorption coefficient/extinction coefficients of the deposited films decrease with increasing annealing temperature, transmittance spectra exhibit that CuAlO_2 is transparent (37%-87%) in the visible range, reflectance and direct band gaps of the films increase with increasing annealing temperature. And also there is an improvement in crystallinity of the deposited films as annealing temperature increases. The high direct band gap for samples S1 and S2 is about 3.55 each, while that of S3 and S4 are approximately 3.80eV and 3.85eV respectively. It can therefore be concluded that while the absorbance, absorption/extinction coefficients of CuAlO_2 thin film are inversely proportional to annealing temperature the transmittance and direct band gaps are directly proportional to the annealing temperature. This therefore indicates the suitability of CuAlO_2 for optoelectronic technology.

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