© 2015 IJSRST | Volume 1 | Issue 5 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

Investigation of the Optical Properties of Liquid Deposition $CuSO_4$ Thin Film

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ABSTRACT

Liquid Deposition was used to fabricate $CuSO_4$ thin films on glass substrate. The thickness of the thin films was controlled via the interference fringes of diode laser (532 nm) transmitted from the thin films. The interference was used to calculate the thickness of the fabricated film. The transmission spectrum of the film with 266 nm thickness was recorded using different monochromatic light sources by measuring their intensities before and after deposition. The refractive indices and the absorption coefficients were calculated and plotted as functions of wavelengths.
Keywords: thin films, interference fringes, liquid phase deposition (LPD), laser assisted deposition, optical properties of $CuSO_4$.

I. INTRODUCTION

A material is said to be a thin film when it is build up as a thin layer on a substrate by controlled condensation of the individual atomic, molecular or ionic species either directly by a physical process or through a chemical/electrochemical reaction [1]. Thin solid films are both functional and intrinsically interesting. Their most familiar use is as coatings on the lenses of optical instruments, where they reduce reflections inside the instrument and produce sharper image [2]. The deposition of thin films on a glass substrate can change physical properties of the specimen. Optical properties of a material change or affect the characteristics of light passing through it by modifying its propagation vector or intensity. Two of the most important optical properties are the refractive index and the extinction coefficient, which are generically called optical constants [3]. One important factor that has a principal effect on the characteristics of a work piece is the thickness of the fabricated film. Optical techniques for film-thickness determinations are widely used because they are applicable to both opaque and transparent films and generally yield thickness values of high accuracy [4]. A.V. Valiulis and Silickas P. in 2007, tried to elucidate the role of the substrate during LPD (Liquid phase deposition) of TiO_2 films by using Kapton with different types of surface treatments, SEM analysis showed that the deposited, LPD used for Titania deposition and characterization, given their relatively low acidity and low temperature, LPD methods are ideally suited to polymer substrates [5]. The low-cost and convenience of LPD coatings and their lack of line-of-site limitations strongly recommend their being considered as a general strategy. Moreover, the relatively mild conditions for ceramic film formation using LPD methodology makes them prime candidates for application on polymer substrates. The thickness of the Titania coating was determined by cross-sectional SEM.

In interference by thin films as light strikes the surface of a film it is either transmitted or reflected at the upper surface. Light that is transmitted reaches the bottom surface and may once again be transmitted or reflected. The light reflected from the upper and lower surfaces will interfere. In general, the condition for constructive interference in thin films is: $2\mu t = (2n+1)\frac{\lambda}{2}$ (maxima)

Where μ is the refractive index of the film, t represent the thickness of the film, n is the interference fringes order and λ is the wavelength of the light passing through the film [6]. The general equation for destructive interference in thin films is: $2\mu t = n\lambda$ (minima).

In our case the path length between the two rays reflected from the upper and bottom surface of the thin film is three times the wavelength of the light source, using this and assuming the index of refraction is unity, from the first interference fringe (n=1) (maxima), quater wave (λ/4) of the intensity pattern monitored indicate a thickness of the film equal half of the wavelength of the light source used. In this work we utilize diode Laser (532 nm) to assit the LPD process to fabricate $CuSO_4$ thin films and some of its optical properties were studied.

II. METHODS AND MATERIAL

MATERIALS:

The material used in this work was Cupper (II) Sulphate (pentahydrate). It was dissolved in distilled water.

EQUIPMENT'S, TOOLS AND SETUP:

The light sources used in this work are listed in table (1) below [7], [8], [9] and [10].

Table 1: The monochromatic light sources and their wavelengths

Light Source	Wavelength (nm)
Diode Laser	532
Sodium Vapor Lamp	589.2
He-Ne Laser	632.8
Diode laser	660
Omega XP Laser (red probe)	675
Omega XP Laser (IR 820 nm probe)	820
Omega XP Laser (IR 915 nm probe)	915

THE PHOTODETECTOR:

A silicon pin photodiode was used in this work for detecting the intensity of light sources.

THE DIGITAL OSCILLOSCOPE (CRO):

C.R.O. that was used in this work was manufactured by Tektronix Company [11].

The setup used in this work to fabricate the thin films and measuring its thickness is shown schematically in Fig. (1).

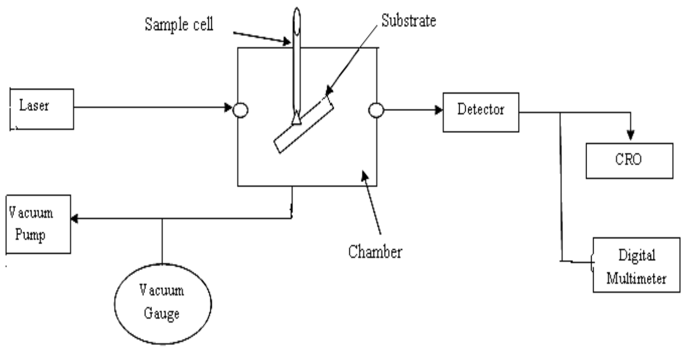

Figure 1 : Schematic diagram of the experimental setup

METHOD:

The procedure was done according to the following sequences:

- The experimental setup was arranged as shown in figure (1).
- The sample holder was inserted in the vacuum chamber which holds the glass substrate at an angle of 45^o, and was closed carefully after that.
- The vacuum pump was turned ON to evacuate the chamber and the pressure was measured inside the chamber after 10 minutes by the vacuum gauge.
- Diode laser (532 nm) was turned ON and then ($\mathbf{I_o}$) was measured and the signal was detected by C.R.O.
- The sample was deposited slowly from the burrete on the glass substrate, and then the laser intensity was detected by the C.R.O. during deposition until the appearance of the interference fringes, which indicate the desired thickness. The transmitted intensity of laser (I) was measured.

- Thickness of thin film was calculated from the interference fringes, that equal half multiple of the wavelength of the laser wavelength.
- The transmission spectrum of the fabricated thin film for this thickness was recorded using different monochromatic light sources.
- The refractive index of the thin films was calculated using the measured reflectivity **R** and the glass refractive index μ according to: [12], [13].

$$\mu = (\frac{\mu_s[1+\sqrt{R}]}{1-\sqrt{R}})^{\frac{1}{2}} \qquad (1)$$

$$\mu_s = \frac{1}{T_s}(\frac{1}{T_s{}^2}-1)^{\frac{1}{2}}$$

where T_s represents the transmission of glass substrate.

- The absorption coefficient was deduced from the measured value of reflectivity R, transmittance T, refractive index μ_s, and thickness t according to : [12],[13]

$$\alpha = \frac{1}{t}\mu\frac{(1-R)^2}{T} \qquad (2)$$

III. RESULT AND DISCUSSION

First of all the intensity of diode laser 532 nm was monitored by CRO before deposition, the obtained intensity pattern is shown in figure (2-a).

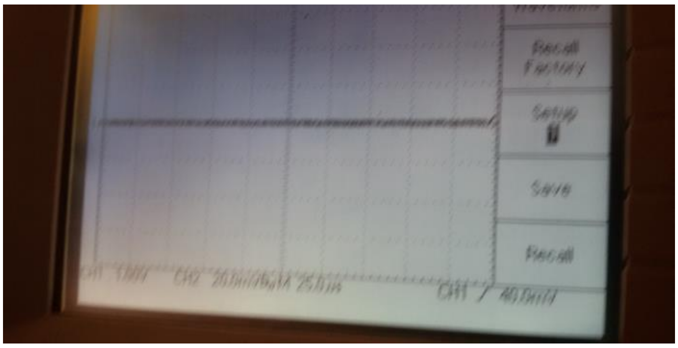

Figure 2-a: The detected signal Diode laser 532 nm l before deposition

During deposition when an interference fringes reach maximum intensity, this means that a thin film of thickness equal half of the wavelength of the laser source was fabricated. At this point the deposition was quickly stopped and the fringe was photographed as shown in figure (2-b).

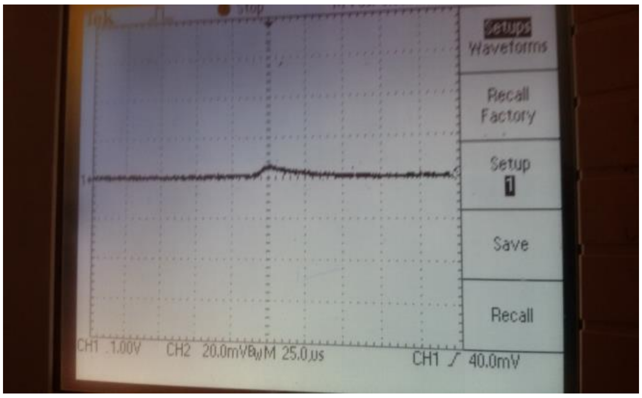

Figure 2-b : Interference fringe indicates the deposition of thin film with thickness =266 nm

This means that the thickness of the fabricated thin film = 266 nm.

Then the transmission intensities of different monochromatic light sources were detected after deposition and the results are tabulated in table (2).

Table 2 : Intensities before and after the deposition of thin films with thickness = 266 nm:

Wavelength (nm)	Intensity before deposition Io± 0.001 (V)	Intensity after deposition I ± 0.001 (V)
532	0.295	0.293
589.2	0.144	0.138
632.8	0.275	0.268
660	0.347	0.327
675	0.380	0.371
820	0.388	0.371
915	0.420	0.414

The data in table (2) above was used to calculate the T% ($T = I/I_0$) of the thin film. The calculated values are plotted in figure (3) as a function of wavelength.

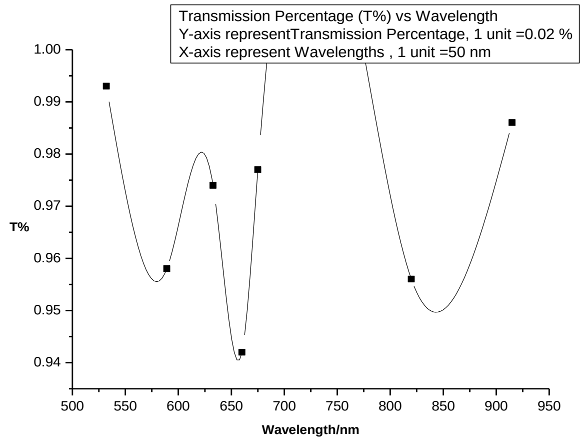

Figure 3 : Transmission spectrum of a 266 nm thickness $CuSO_4$ thin film

The relation between the calculated refractive indices using equation (1) and the wavelengths is plotted in figure (4)

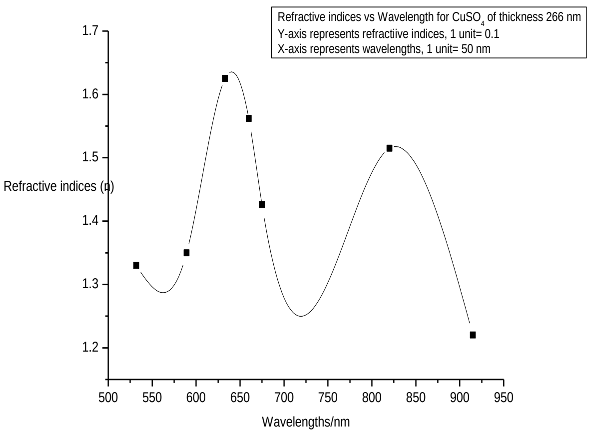

Figure 4 : The refractive index of $CuSO_4$ thin film (266 nm) versus wavelengths

The refractive index of any material in thin film profile is usually deviates from that of the bulk of the same material [14]. This is due to the void fraction typical of the thin film microstructure.

The absorption coefficients calculated from equation (2) versus wavelengths using equation (2) is plotted in figure (5) below:

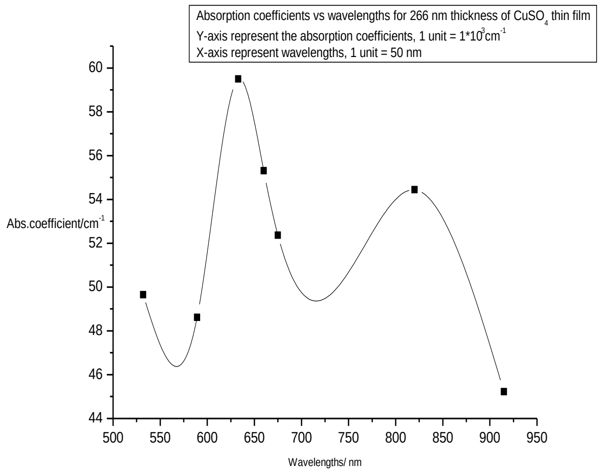

Figure 5 : Absorption coefficients versus wavelengths for the 266 nm thin film $CuSO_4$

Figures (4) and (5) support the idea of using such film as an optical filter or as a reflector in specific wavelengths deduced from the transmission spectrum. The refractive indices and absorption coefficients of the fabricated thin film $CuSO_4$ varies with wavelength, and they exhibit similarity in shape when plotted as functions of wavelengths. Optical measurement constitutes the most important means of determining the band structure of the materials. And the optical constants of thin films provide us with information concerning microscopic characteristics of the material and its determination is very important for using it in any of such devices**.**

IV. CONCLUSION

From the results obtained, the followings can be concluded:

- Thin films of $CuSO_4$ of different thicknesses can be obtained by evacuation method.
- The thickness of the deposited liquid sample can be controlled and measured via interference fringes of the transmitted laser light.
- The $CuSO_4$ can be used to produce optical components in the range from visible to IR regions it can be used to produce an optical filter in (532 nm) and as partial reflector at (660 nm).

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