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Assessment of Electromagnetic Wave Propagation through Copper (Ii) Oxide, Cuo Thin Film with Dielectric perturbed Medium

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Abstract:- Electromagnetic wave propagating through homogenous copper (II) Oxide, CuO thin film, was analyzed using the general wave equation with reference to variation in dielectric constant and Refractive index. The general wave equation was solved using the method of separation of variables in conjunction with all the necessary boundary conditions. The behaviour of the wave profile within three regions of the electromagnetic spectrum viz: ultraviolet, visible and infrared regions were found to be unique as observed as displayed in the propagation profiles in accordance with the variation of the dielectric constant which is related to refractive index of the copper oxide during the propagation.

Keywords: **Copper (II) Oxide, Wave, Dielectric constant, Profile, Propagation, Electromagnetic spectrum, Refractive Index, Thin Film, Wave profile,**

I. INTRODUCTION

As a result of the applicability of group (II) and (IV) elements based thin film such as Copper Sulphide/oxide, Indium disulphide etc in photovoltaic cell and opto-electronic devices [1], material scientists have geared their attention towards development and study of the optical/ the solid state properties such thin films both experimentally and theoretically For instance, solid state and optical characterization has been carried out for MnS,CuS,Fe_2S and Sb_2Se_3 etc [2,3,4,6]all in an attempt to know their optical characteristics and response to electromagnetic wave spectral behaviour when it propagates through such films especially for the following windows viz Ultraviolet ,Visible and Infrared. This is because it is a clear fact that the application of any thin film in harnessing solar energy for electrical use and also optoelectronics depends on the action of the film on any of the electromagnetic wave spectrum propagating [6] through it. Based on this fact, beam propagation method of different approach amenable to understanding optical response to the solid state properties of various types of thin film have been studied by material scientists. Such concept as diagonalization of Hermitian operator [7] 2by 2 matrix formalism [8] and geometrical optics approximation had been used approach. W.K.B approximation, phase integral and perturbation techniques have been utilized. [9, 10, 11, 12].Apart from these other number of derivations that facilitates the applications of the method of beam propagation to other specific problem have been explored.[13,14] relating the study of optical response of thin film [15]. Analytically, the influence of variation of dielectric constants and refractive index of

thin film materials are obvious [9,16,17,18] Based on the feature exhibited by Copper (II) oxide thin film as regard its low band gap and monoclinic structural characteristic, we become interested to use theoretical approach to ascertain its response to electromagnetic wave propagating through it.

II. THEORETICAL APPROACH

Introducing dielectric medium in wave equation, it becomes

$$\left(\nabla^2 - \frac{\varepsilon}{c^2}\frac{\partial^2}{\partial t^2}\right)\Psi_{(r)} = 0 \qquad (1)$$

The wave equation in which dielectric constant,ε is introduced to is written as

$$\nabla^2\,\Psi_{(r,t)} = \frac{\varepsilon}{c^2}\frac{\partial^2}{\partial t^2}\Psi_{(r,t)} \qquad (2)$$

Where ∇^2 is laplacian operator, ψ is wave function, c is speed of light, t = time, r = r(x,y,z).

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z}\right)\Psi_{(x,y,z,t)} = \frac{\varepsilon}{c^2}\frac{\partial^2}{\partial t}\Psi_{(x,y,z,t)} \qquad (3)$$

Applying method of separation of variables, the solution is of the form.

$$\Psi_{(r,t)} = e^{i\left(\frac{2\pi}{\lambda}\sqrt{\varepsilon}.\ r - wt\right)} \qquad (4)$$

Since electromagnetic waves propagate in z – axis, let r = z

$$\Psi_{(z,t)} = e^{i\left(\frac{2\pi}{\lambda}\sqrt{\varepsilon}.\ z - \omega t\right)} \qquad (5)$$

This is the solution to the electromagnetic wave equation where λ is wavelength propagating through z direction and ε is the dielectric constant is decomposed in real and imaginary parts

Real part

$$\varphi_{(r,t)} = \cos\left(\frac{2\pi}{\lambda}\sqrt{\varepsilon}.\quad z - \omega t\right) \qquad (6)$$

Imaginary part

$$\aleph_{(z,t)} = \sin\left(\frac{2\pi}{\lambda}\sqrt{\varepsilon}.\quad z - wt\right) \qquad (7)$$

The solution of the same equation in terms of refractive index which is related to dielectric constant as $\sqrt{\varepsilon} = n$ is shown below.

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$$n(x)=n_0+\sum_{k=0}^{\infty}\left[c_k\cos\left(\frac{2\pi kx}{a}\right)+s_k\sin\left(\frac{2\pi kx}{a}\right)\right] \tag{8}$$

The constants C_k and S_k are determined by replacing $n(x)$ by $n(E)=\frac{\pi}{2}\left(\frac{8m_0}{h^2}\right)^{\frac{3}{2}}E^{\frac{1}{2}}$, i.e.

$$n(E)=n_0+\sum_{k=0}^{\infty}\left[c_k\cos\left(\frac{2\pi kx}{a}\right)+s_k\sin\left(\frac{2\pi kx}{a}\right)\right] \tag{9}$$

Such that;

$$s_k=\frac{1}{a}\int_0^a\frac{\pi}{2}\left(\frac{8m_0}{h^2}\right)^{\frac{3}{2}}E^{\frac{1}{2}}\sin\left(\frac{2\pi kx}{a}\right)dx=\frac{1}{a}\int_0^a\frac{\pi}{2}\left(\frac{8m_0}{h^2}\right)^{\frac{3}{2}}\ \varepsilon := 3.19706\ \ \left(\frac{\lambda := 850}{a}\right)dx$$

$$=\frac{1}{a}\left\{\frac{4a\sqrt{2E}}{k}\left(\frac{m_0}{h^2}\right)^{\frac{3}{2}}-\frac{4a\sqrt{2E}}{k}\left(\frac{m_0}{h^2}\right)^{\frac{3}{2}}\cos(2\pi k)\right\} \tag{10}$$

$$s_k=\frac{4\sqrt{2E}}{k}\left(\frac{m_0}{h^2}\right)^{\frac{3}{2}}\left[1-\cos(2\pi k)\right] \tag{12}$$

MathCAD Plot of dielectric constant, ε and the refractive index, n(x) for various values of a and propagation distant x are given below

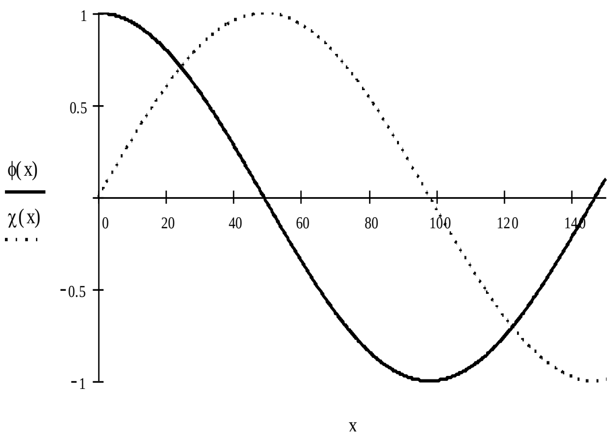

Fig.1: A graph of wave distribution of wave function, Ψ, as a function of wavelength, λ = 350nm, when dielectric constant, ε = 3.1970, for ultraviolet region

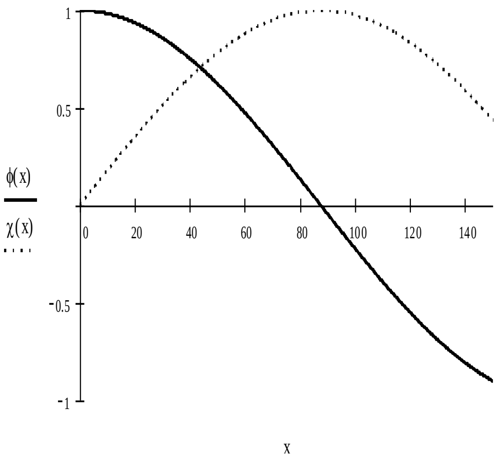

Fig.2: A graph of wave distribution of wave function, Ψ, as a function of wavelength, λ = 650nm, when dielectric constant, ε = 3.85477, for visible region.

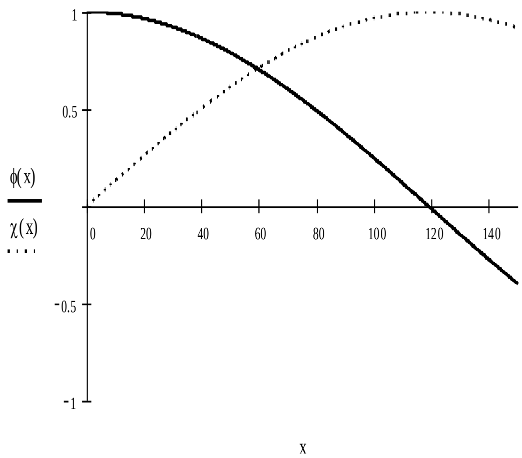

Fig.3: A graph of wave distribution of wave function, Ψ, as a function of wavelength, λ = 850nm, when dielectric constant, ε = 3.19706, for infrared region.

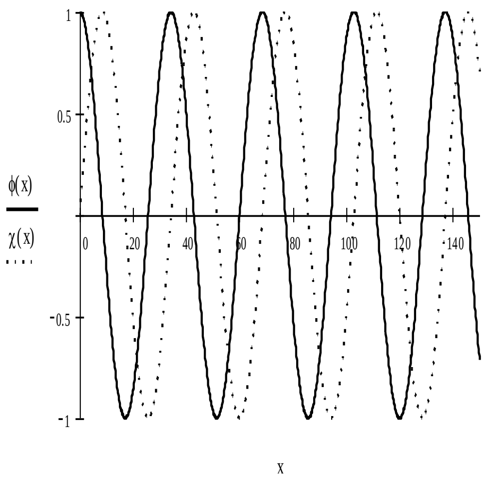

Fig.4:A graph of wave distribution of wave function, Ψ, as a function of wavelength, λ = 350nm, when dielectric constant, ε = 21.78758, for ultraviolet region.

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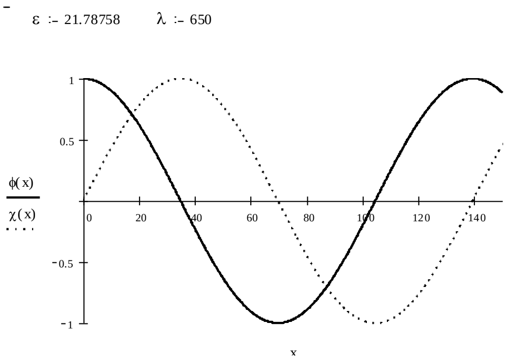

Fig.5: A graph of wave distribution of wave function, Ψ, as a function of wavelength, λ = 650nm, when dielectric constant, ε = 21.78758, for visible region

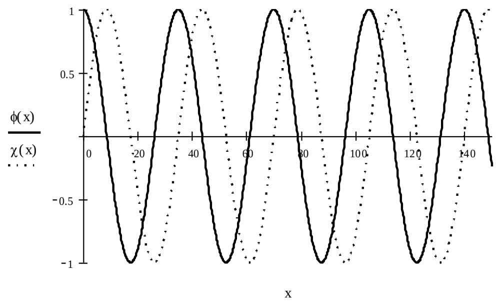

Fig.6: A graph of wave distribution of wave function, Ψ, as a function of wavelength, λ = 850nm, when dielectric constant, ε = 21.789442, for infrared region.

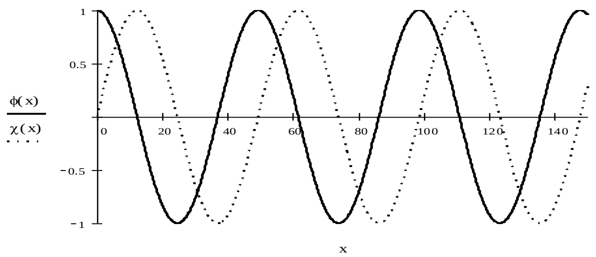

Fig.7: A graph of wave distribution of wave function, Ψ, as a function of wavelength, λ = 350nm, when dielectric constant, ε = 100.110908, for Ultraviolet region.

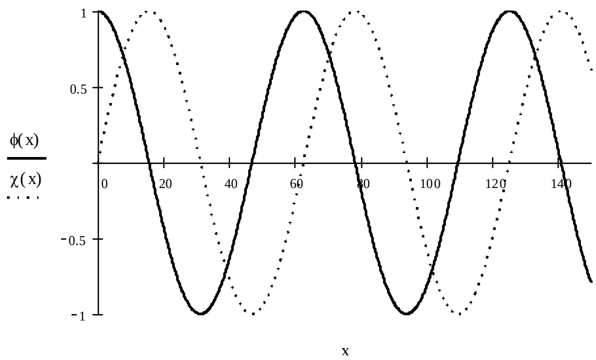

Fig.8: A graph of wave distribution of wave function, Ψ, as a function of wavelength, λ = 650nm, when dielectric constant, ε = 100.110908, for visible region.

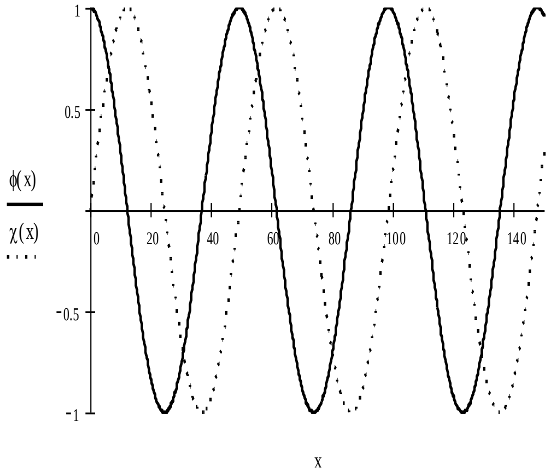

Fig.9: A graph of wave distribution of wave function, Ψ, as a function of wavelength, λ = 850nm, when dielectric constant, ε = 100.110908, for infrared region.

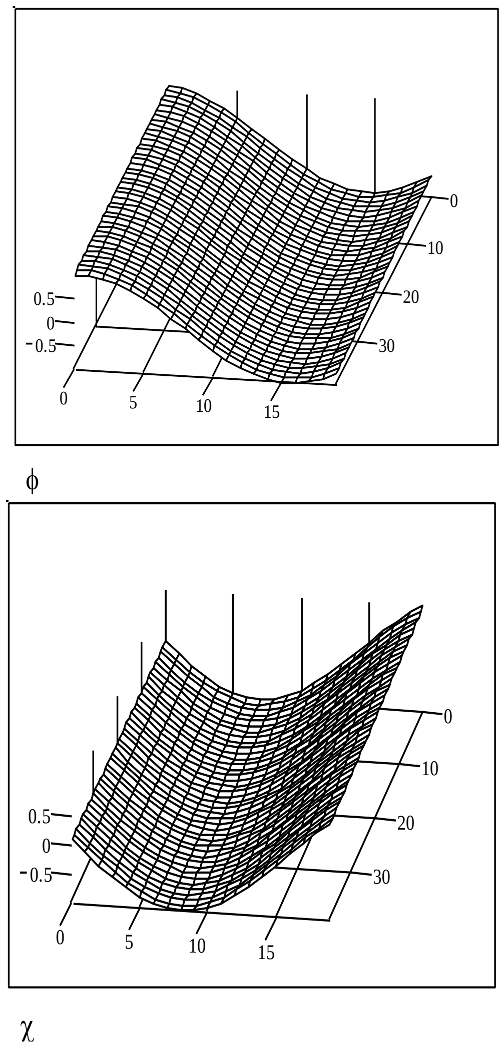

Fig.10: A graph of wave distribution of wave function as a function of wavelength, λ = 350nm, and time when dielectric constant ε = 3.85477, and ω = 0.2 for ultraviolet region.

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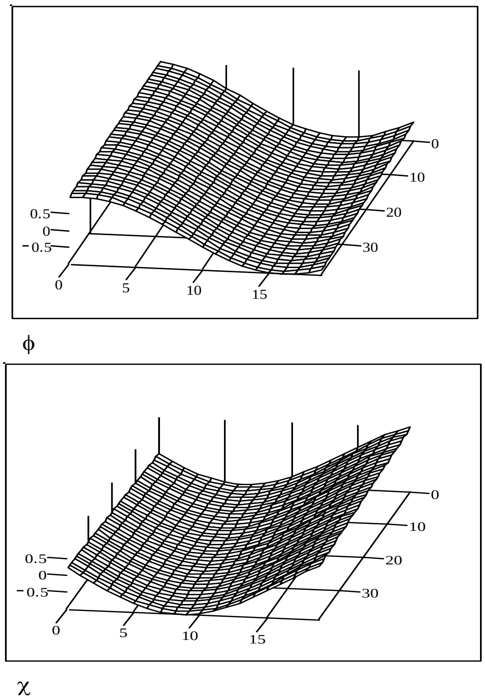

Fig.11: A graph of wave distribution of wave function as a function of wavelength, λ = 650nm, and time when dielectric constant ε = 3.19706, and ω = 0.2 for visible region.

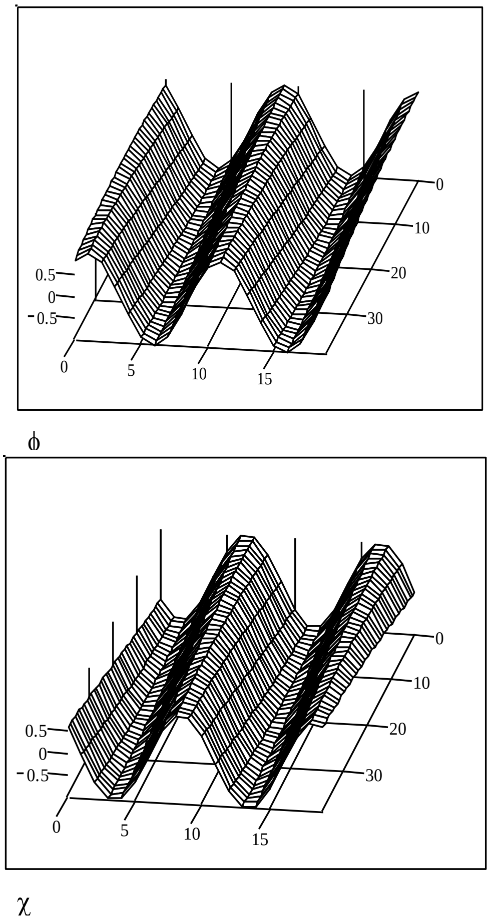

Fig.12: A graph of wave distribution of wave function as a function of wavelength, λ = 650nm, and time when dielectric constant ε = 18.758090, and ω = 0.2 for visible region.

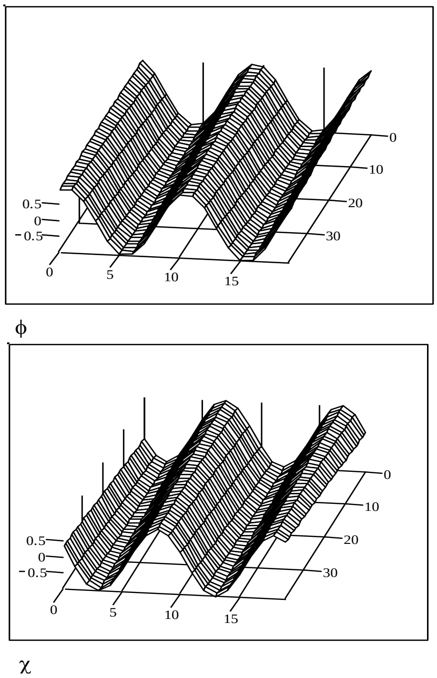

Fig.13: A graph of wave distribution of wave function as a function of wavelength, λ = 850nm, and time when dielectric constant ε = 31.289442, and ω = 0.2 for infrared region.

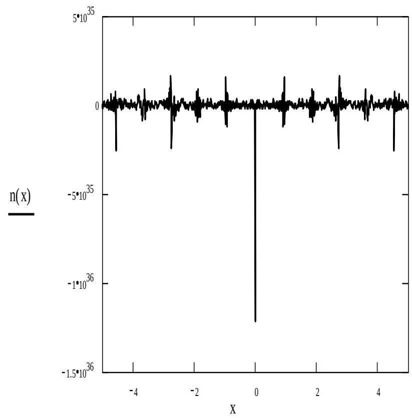

Fig.14 Refractive Index Profile as a function of propagation distant for a=10

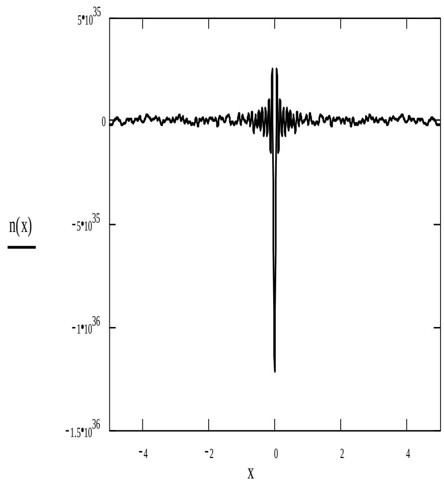

Fig.15 Refractive Index Profile as a function of propagation distant for a=100

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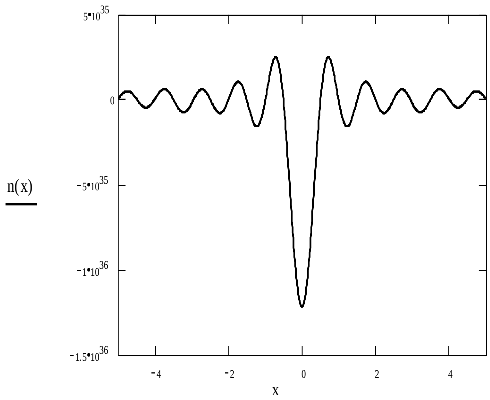

Fig.16; Refractive Index Profile as a function of propagation distant for a=1000

III. RESULT AND DISCUSSION

The, real and complex parts of wave function in terms of dielectric constant were shown in equation (6) and (7)while that in terms of refractive index is shown in equation (12). The plot of the wave function profiles for various values of dielectric constants considering three windows of electromagnetic wave spectra viz ultra-violet, visible and infrared regions as shown in fig 2to fig 5. From the graphs, it is observed that each profile exhibited a unique behaviour that is peculiar to its value of the dielectric constant considering the real or complex nature of the solution. Also the same parameters were used three dimensional profile distribution as shown in fig.6 to fig.8. The plots for refractive index profile for various values of (a)as seen in equation (12) were show cased in fig 9 to fig.12 where it was observed that the profile appeared like a spike at zero point of the propagation distant which broadened as a increased from 10 to 100. However, when the value a becomes 1000, as in fig 12, the spike broadened more with a broad central maxima like that of Fraunhofer diffraction pattern.

V. ACKNOWLEDGEMENT

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APPENDIX

$$n(x) := \sum_{n=1}^{1000} 4\cdot\sqrt{2\cdot E}\cdot\left(\frac{m\ e}{h^2}\right)^{1.5}\cdot\left[\frac{\sin(2\cdot\pi\cdot n)}{n}\cdot\cos\left(\frac{2\cdot\pi\cdot n\cdot x}{a}\right)+\left(\frac{1-\cos(2\cdot\pi\cdot n)}{n}\right)\cdot\sin\left(\frac{2\cdot\pi\cdot n\cdot x}{a}\right)\right]$$

(11)