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EFFECT OF LASER SHOTS ON THE OPTICAL PROPERTIES OF FE2O3: CUO THIN FILMS PREPARED BY PULSE LASER DEPOSITION TECHNIQUE

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Abstract:

CuO-doped Fe2O3 thin films were deposited onto glass substrates using the Pulsed Laser Deposition (PLD) process at room temperature and a vacuum of 10-2 mbar, utilizing a Nd:YAG laser with a wavelength of 1064 nm, an average frequency of 6 Hz, and a pulse duration of 10 at various laser pulses (300,400 and 500 and).The effect of number of pulsed laser shots on the optical properties of the films was invesigated. UV-VIS spectrophotometer mentioned that the transmittance increases to 90 % when decresing the number of the laser shots. Furthermore, The optical measurements indicate that the Fe2O3:CuO films have a direct Egopt that diminishes as the number of laser pulses increases. The band gap energy of the Fe2O3:CuO found was 3.01 eV. This value was reduced significantly to 3.0 by increasing the number of laser blasts. However, optical constants such as the refractive index (n), the extinction coefficient (k), and the dielectric constant (r, I rise in a predictable manner as the number of laser flashes increases.

Key words: CuO –doped Fe2O3; PLD technique ; Thin Film; Optical Properties; Band Gap.

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Introduction:

Metal oxides nanoparticles have been intensively studied in the last decade,because of their sizes, morphology and structure.[1]Due to its high sensitivity to combustible gases, rapid reaction time, and long-term stability, iron oxide thin film (Fe2O3) may be utilized in a variety of applications such as gas sensor [2]. Due to its large optical band gap (Eg = 1.9 eV), strong optical absorption coefficient (a = 105cm-1) for wavelengths > 600 nm, and ability to exhibit both conductivity types by employing a suitable doping element, the photo electrochemical solar cell is well suited for solar energy conversion [3]. Ferromagnetic films are used in a wide variety of applications, including microwave devices and high-density recording medium [4].

As well as, the CuO is a p-type semiconductor with a bandgap value confined between 1.2-2.0 eV [5].It can be used in solar cells due to their high absorption in the visible region .Moreover, it can be used as an active substance in the gas sensor due to its high stability underexposure for many gasses, low-cost material and low base resistivity changes[6]. Also, Gas sensor [7] .To synthesize the Fe2O3:CuO compound, many different chemical and physical methods have been reported, such as Sol gel, chemical vapor deposition, electro-deposition, thermal oxidation, sputtering process and spray pyrolysis.The PLD approach has been extensively employed in recent years for the production of many types of thin films, particularly oxides of several metals and semiconductors. The current work focuses on the doping of iron Oxide thin films with CuO using the PLD technique. The effect of various pulsed lasers on diverse samples of Fe2O3 thin films has been examined and described in terms of morphology and optical characteristics. Section 2 details the experimental procedures. Section 3 contains the findings and conclusions.

2.Experimental Part

Pellets of (Fe2O3)0.85(CuO)0.15 nanoparticles were prepared by 2g maxing the powder togther and then the pressing process was carried out using an electro-hydraulic press with a pressure of (5 tons) and for a period of (10 minutes), with pellets diameter of (1.5 cm) and a thickness of (3 mm). then The thin films of (Fe2O3)0.85 :(CuO)0.15were prepared using PLD technique (DIAMOND-288) of 1064 nm wavelength, 10 ns pulse duration and 500 mJ pulse at different Laser pulses (300,400 and 500). The surface morphology properties of thin films was examined using Atomic Force Microscope (AFM), type (AA3000 Scanning Probe Angstrom Advance Inc.) . The thickness of thin films about 250 nm was measured using the reflectance probe (SR300 Angstrom Sun Technologies). The optical properties such as transmission absorpttion cofficient and optical constants have been investigated

3.Results and Discussion

Optical Properties

UV-V absorption measurements were used to determine the electrical structure and size effect of as-prepared nanoparticles.

Transmittance:

Figs.(1)shows the optical transmittance spectrum as a function of wavelength of Fe2O3)0.85(CuO)0.15thin films at different laser shots (300,400 and 500) in the wavelength range of (365-1100) nm.The results indicate that the films are transparent to visible light and infrared regions of the electromagnetic spectrum, with a sharp cut-off wavelength of about 500 nm. The transmittance value falls as the number of pulsed lasers rises.This implies that the film has a high level of UV and near-visible light absorption. This increase in optical transmittance caused by the thickness effect results in a reduction in structural homogeneity and crystallinity[8,9].

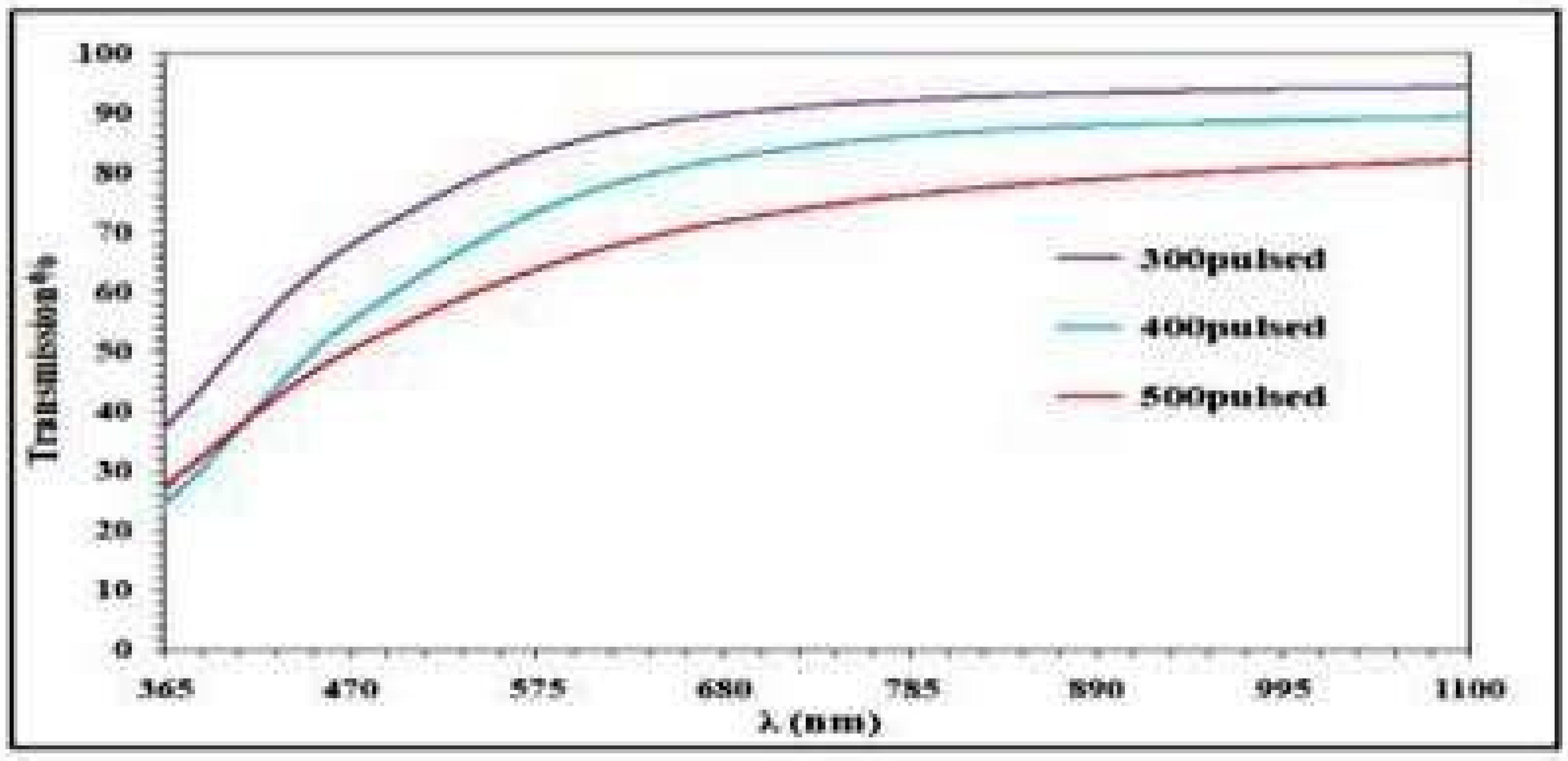

Fig.(1) The Transmittance spectrum as a function of wavelength of $(Fe_2O_3)_{0.85}:(CuO)_{0.15}$ thin films at different number of laser shots

Absorption Coefficient

The absorption coefficient(α) is calculated byusing equation[10]

$$\alpha = \frac{2.303A}{t} \qquad (1)$$

where A: is the Absorbance and t: is the thicknessof the thin films

The figure represents the fluctuation in the absorption coefficient (α) as a function of wavelength for $(Fe_2O_3)_{0.85}:(CuO)_{0.15}$thin films exposed to a variety of laser pulses (2). The absorption coefficient (α) is higher than (104cm-1) in this figure, indicating that the electronic transitions were direct. In general, the absorption coefficient reduces as the wavelength increases, as seen in the figure. Additionally, as a result of the thickness effect, the absorption coefficient (α) increases as the number of laser shots increases. This may be ascribed to an increase in layer particle size and density, as well as to the light scattering effect, which accounts for the high surface roughness [11].

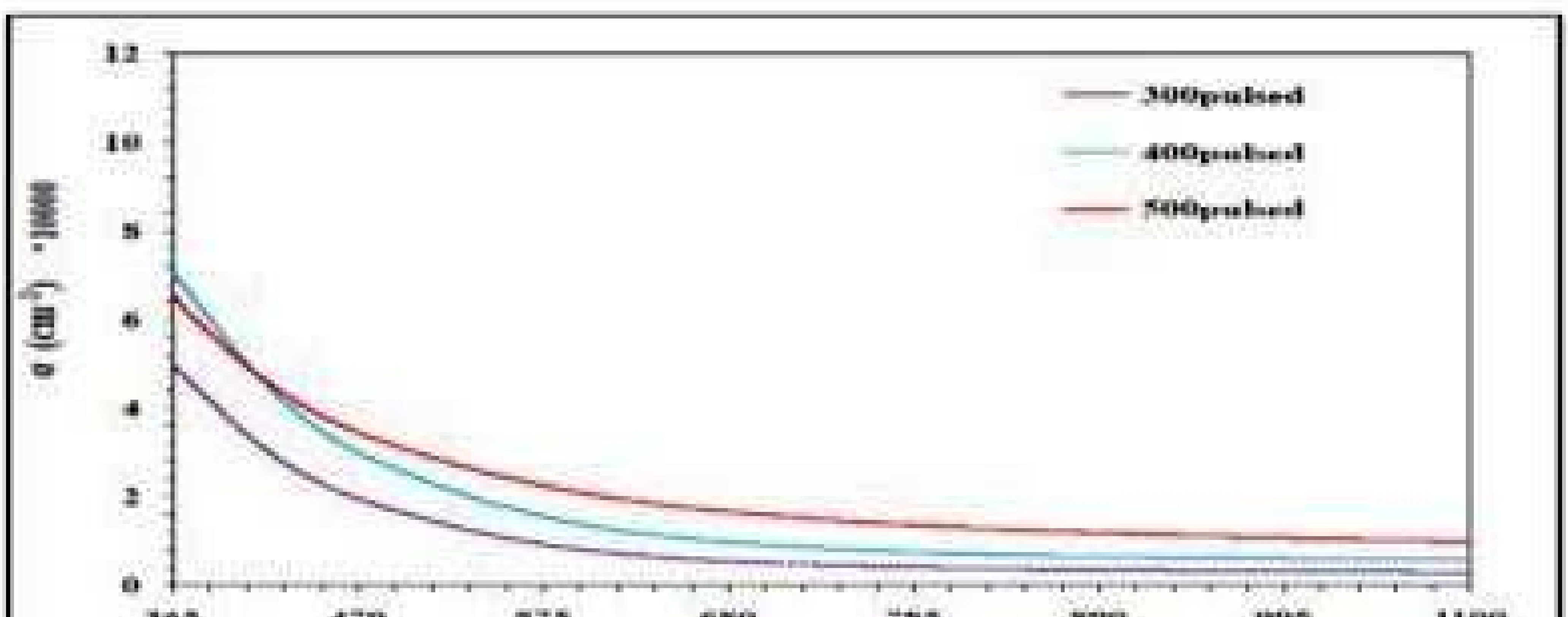

Fig.(2). The absorption coefficient spectrum as a function of wavelength for$(Fe_2O_3)_{0.85}:(CuO)_{0.15}$thin films at different number of laser shots

The Optical Band Gap

The energy gap values are known to be dependent on the crystal structure of the film in general. Crystal regularity also influences the arrangement and distribution of atoms inside the crystal lattice. The optical band gap of a films is calculated using the Tauc model in the area of high absorption using the relationship[12].

$$\alpha\, hv = B(hv - Eg)\, r \quad (2)$$

Where hv denotes the photon energy, Eg denotes the optical energy gap, B denotes a constant, and r denotes the kind of electronic transition, with r = 1/2 for direct permitted transitions and r= 2/3 for prohibited transitions.The change of (αhv)2as a function of photon energy for $(Fe_2O_3)_{0.85}$:$(CuO)_{0.15}$thin films is shown in Fig (3).

The optical energy gap is calculated by extrapolating the portionat (α=0)using the Tauc relation. It is discovered that the relation for r=1/2 produces linear dependency, which accurately represents the permitted direct transition. As seen in the figure, the optical energy gap diminishes as the number of laser pulses increases. This is because the concentrated density of states near the band boundaries increases with thickness, lowering the value of Eg. Additionally, the direct band gap decreases as the number of laser pulses increases.

The results of energy gap value shown in the table(1)

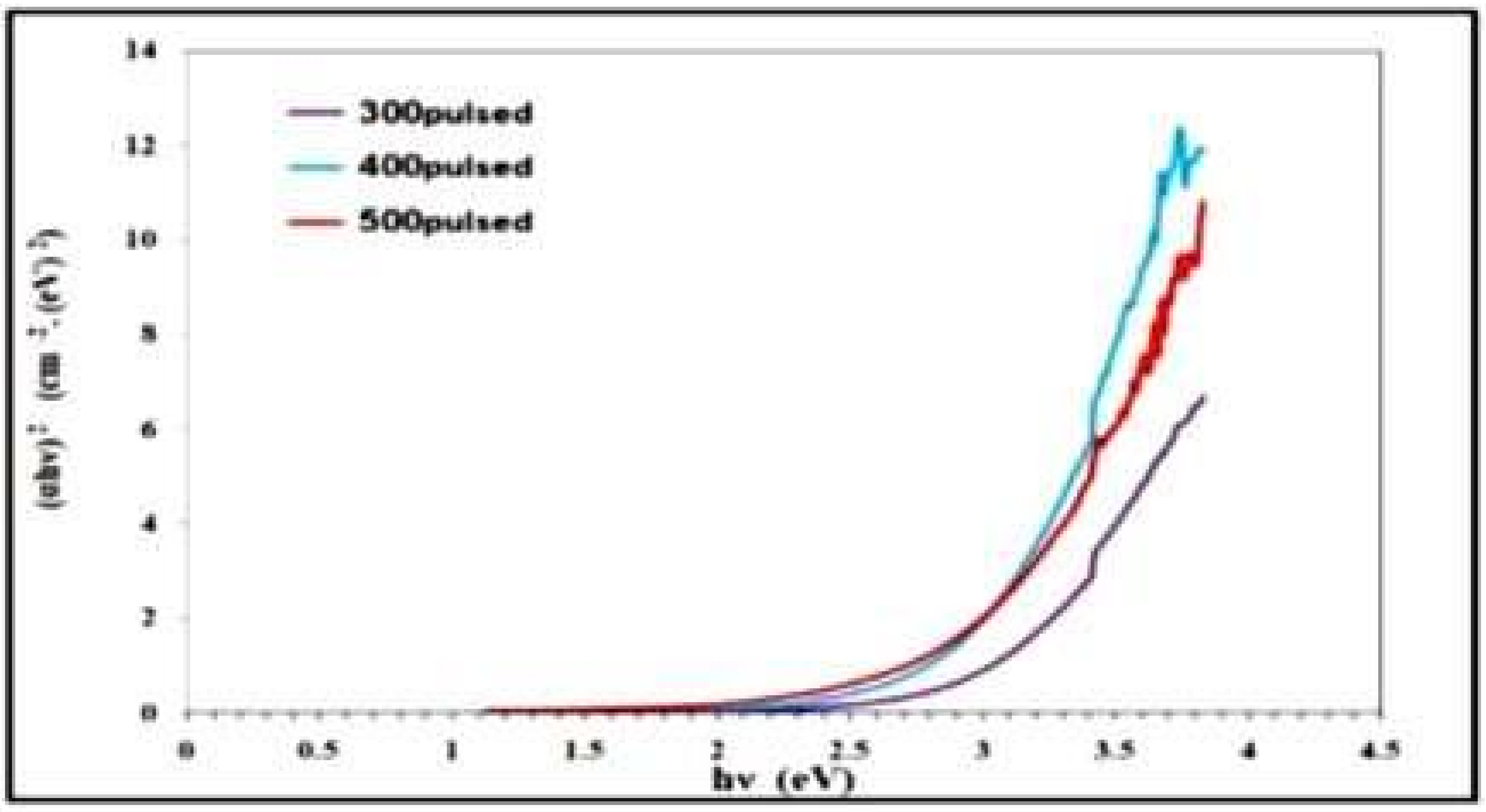

Fig.(3) $(\alpha\, hv)^2$ as a function of (hv) for $(Fe_2O_3)_{0.85}$:$(CuO)_{0.15}$ thin films at different number of laser shots

Extinction Coefficient

The extinction coefficient (K) indicates the amount of energy absorbed by a thin film material, which is equivalent to the attenuation of an electromagnetic wave passing through a material. It was determined using the relation [13].

$$K=\frac{\alpha\lambda}{4\pi} \quad (3)$$

Fig.(4) showsthe variation of extinction coefficient as function of wavelength for $Fe_2O_3)_{0.85}$:$(CuO)_{0.15}$thin films preparedat different number of laser shots (300,400 and 500) .It is seen that the extinction coefficient behaves just like the absorption coefficient (α) because they are joined by previous relation. It is obvious that the extinction coefficient rises with the number of laser blasts, which is related to the increase in thickness [14]. The table below contains the results of the K value calculation (1).

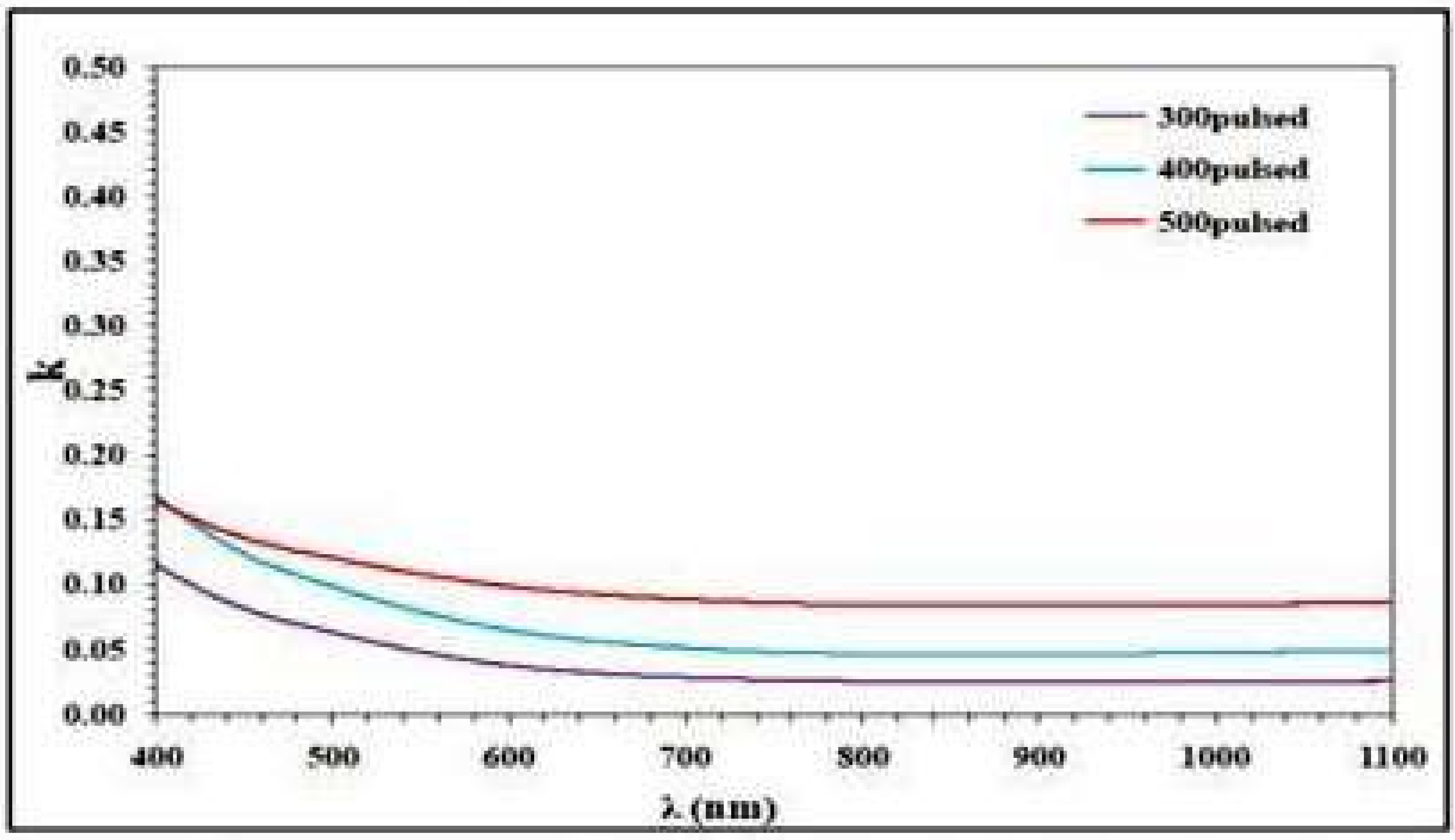

Fig. (4) Extiction coefficient variation as a function of wavelength for $(Fe2O3)0.85$:$(CuO)0.15$thin films at various laser shot counts

The Refractive Index

The thin films' refractive index (n) was calculated using equation [15].

$$n=\frac{\sqrt{1+R}}{\sqrt{1-R}} \qquad (4)$$

As seen in Fig. (5), the number of pulsed lasers has an effect on the refractive indices of the films. As the number of laser shots rises, the refractive index increases, and as the wavelength increases, the refractive index falls, as indicated in the Table (1).This behavior is expected and accompanies the increment of number of laser shots (with narrow energy gap) in $(Fe2O3)0.85$:$(CuO)0.15$thin films according to inverse relation between the refractive index and energy gap.

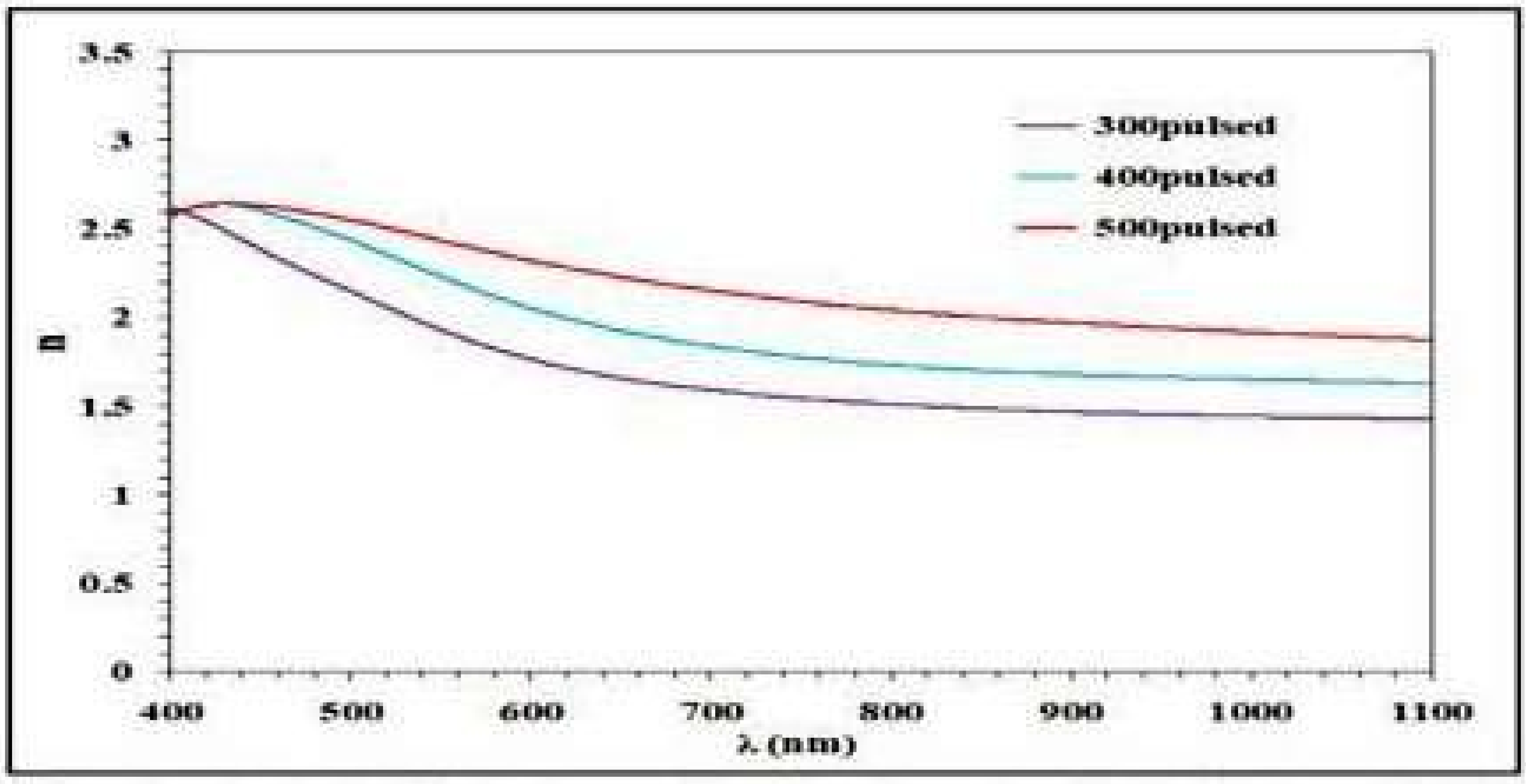

Fig. (5) The refractive index fluctuation as a function of wavelength for thin films of $(Fe2O3)0.85$:$(CuO)0.15$ at various laser shot counts

Dielectric Constants

Calculate the real portion of the dielectric constant using the following equations [16]:

$$\varepsilon_r = n^2 - k^2 \qquad (5)$$

Fig.(6) illustrates the variation of (εr) as a function of wavelength.Because k2 is lower than n2, the behaviour of εr is comparable to that of the refractive index, according to equation (5). The figure clearly shows that (εr) grows as the number of laser shots increases.

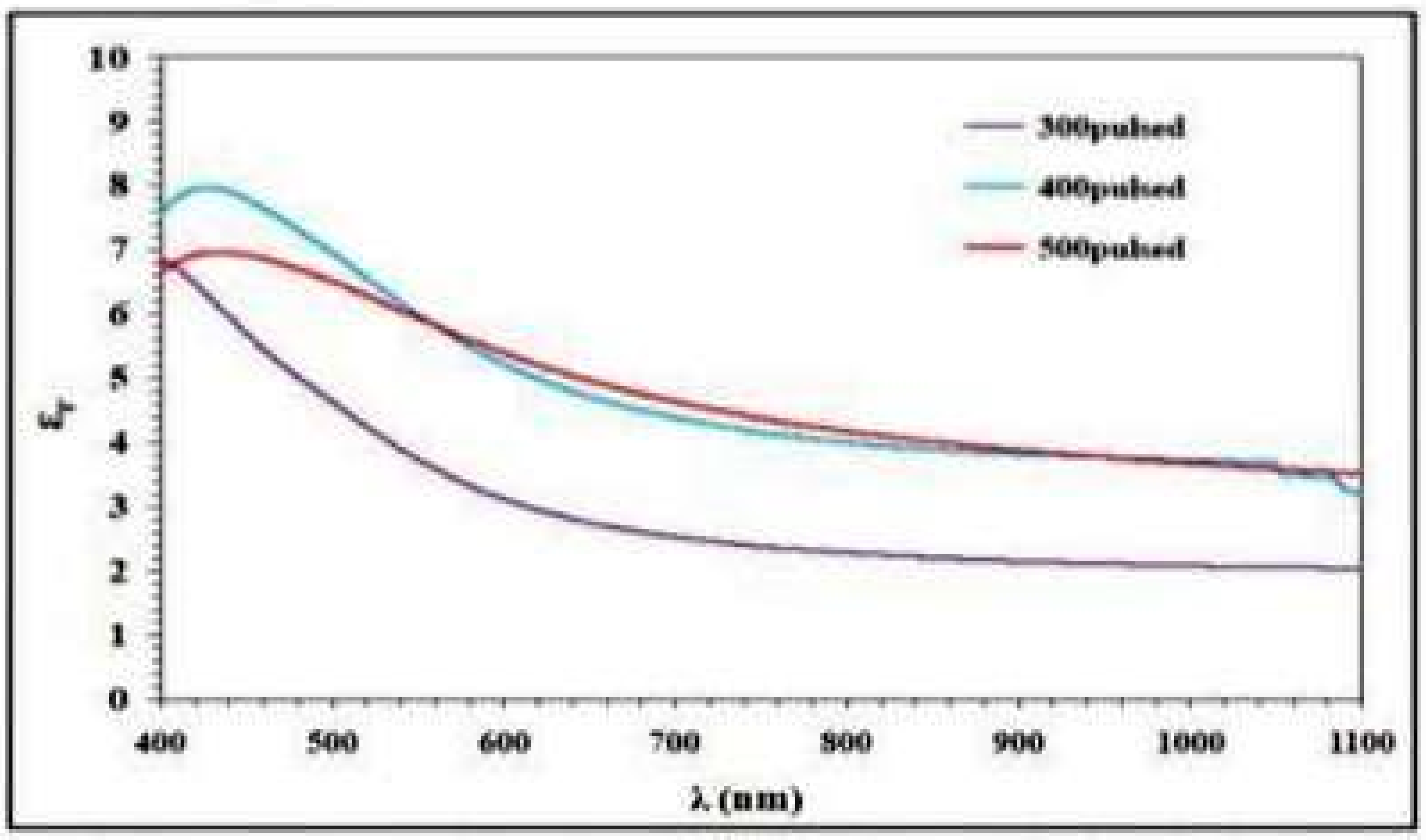

Fig (6).Variation of (εr) as a function of wavelength for thin films of (Fe2O3)0.85 :(CuO)0.15at various laser shots

The imaginary part of dielectric constant can be calculated by using [16]

$$\varepsilon_i = 2nk \qquad (6)$$

The change of (εi) as a function of wavelength is seen in Figure (7). In general, the figure depicts a reduction in (εi) as the wavelength increases.Also, the imaginary part of dielectric constant εi reveals the same behavior of Kwith the variation of number of laser shots as clear from Table (1).It is increses with incresing of number of the laser shots. (εi) can be explained in the same way as n and k.

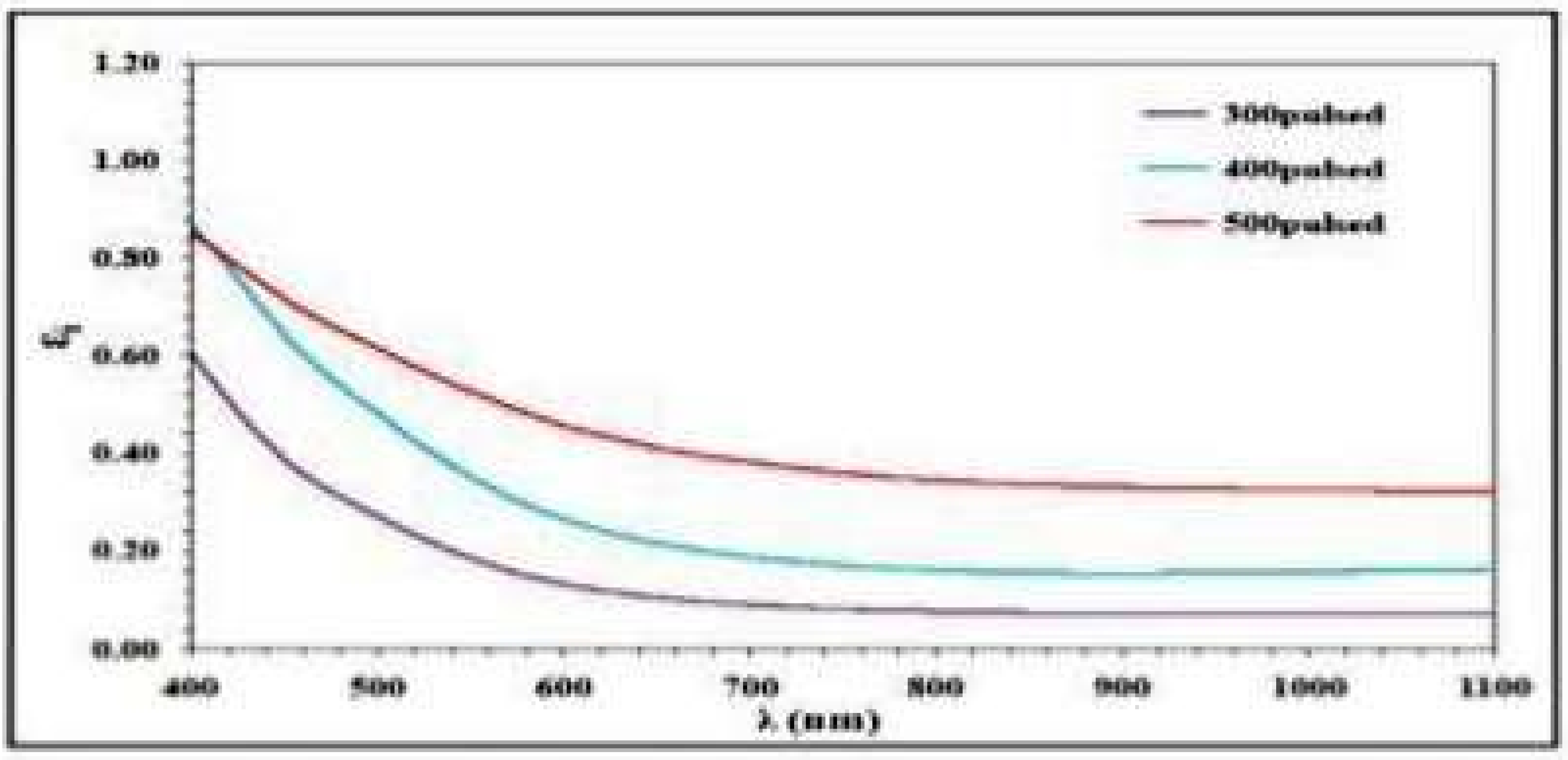

Fig. 10. Variation of (εi) as a function of the wavelength for (Fe2O3)0.85 :(CuO)0.15thin films at various laser shot counts

Finally we can conclude the results the optical parameter and theoptical constants at λ=500 nm for (Fe2O3)0.85 :(CuO)0.15thin films at different number of laser shots In the Table (1).

Table (1):- Optical properties and Direct allowed band gap (Fe2O3)0.85 :(CuO)0.15thin films at different laser shots and wavelength 500 nm

No. of pulsed	T%	α (cm-1)	K	n	εr	εi	Eg (eV)
300	72.91	15796	0.063	2.153	4.631	0.271	3.10
400	60.97	24737	0.098	2.442	6.951	0.481	3.05
500	54.63	30232	0.120	2.554	6.508	0.615	3.00

Conclusion

On a glass substrate, thin films of (Fe2O3)0.85:(CuO)0.15 were produced using the PLD approach to examine the impact of the number of laser pulses on the optical characteristics of the films.The absorption coefficient spectrum was determined using a UV-Visible spectrometer.The optical studies of (Fe2O3)0.85 :(CuO)0.15 thin films show that the transmission spectrum is in the visible region and its values are higher than 90% with a sharp cut-off wavelength values approximately 500 nm. The absorption coefficient (α) of the thin films is more than 104 cm-1, indicating a high chance of a direct electronic transition.
The forbidden energy gap for permitted direct transition reduced as the laser shot intensity increased. The optical band gap gained from Tauc plot reduces from 3.10 eV for Fe2O3 :CuO prepared at laser shot 300 to 3.0 for films prepared at 500 laser shot . Additionally, optical constants such as the real and imaginary dielectric constants were measured, which revealed that they dropped as the wavelength increased while increasing as the number of laser flashes increased. In the future, (Fe2O3)0.85:(CuO)0.15 may be utilised to significantly increase the efficiency of solar cells or the responsiveness of gas sensor devices.

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