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STUDY THE EFFECT OF LASER ENERGY CHANGE ON OPTICAL AND PROPERTIES OF FE_2O_3 THIN FILMS DEPOSITED BY PLD TECHNIQUE

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ABSTRACT

In this work, we prepared Fe_2O_3 thin films using a pulsed laser deposition method. The Nd:YAG laser is used to prepare Fe_2O_3 films on a glass substrate under a temperature of 200°C, and the effects of laser energy on the structure and optical properties of thin films have also been studied. The optical properties of the absorption and transmission spectra of the formed thin films were studied. The direct bandgaps of the samples were obtained by measuring the absorption and transmittance spectrometers ranging from 2.3 to 2.7 eV. Using atomic force microscopy (AFM) technique and taking pictures, the surface structure of the formed films was studied. The size of the nanoparticle grains is observed in the range of (73.87), (69.28) and (102.38) nm for energy (700, 800, 900)mJ, respectively.

Keywords: iron oxide, pulse laser deposition, optical properties structure properties.

INTRODUCTION

One of the most important oxides of transition metals Fe_2O_3 with a gap of 2.2eV. It has received great attention because of its good physical and chemical characteristics, such as its cheapness, stability in nature and considered environmentally friendly [1].

Because of these properties Fe_2O_3 nanoparticles can be used extensively in the field of magnetic recording, catalysis, photosynthesis, gas sensing [2]. There are many types of iron oxide groups, which include those containing the binary iron ions in the form of Fe (II) and those containing the triple iron ions Fe (III). Some of them contain a mixture of valences. Polymorphs with the most common formula Fe_2O_3 can be used in many conditions because they are thermodynamically more stable [3, 4]. Fe_2O_3 phases are found in the forms hematite (α- Fe_2O_3), maghemite (g- Fe_2O_3), e- Fe_2O_3, and δ- Fe_2O_3; Phases a and b display the rhombic structure of the faces, g the spinel-like structure, and e the orthorhombic structure. The recombination process of electrons and gaps relative to the mobility of the gaps and electron capture by oxygen-deficient iron sites could be responsible for the low electrical conductivity and the photocurrent of Fe_2O_3 have low efficiency [2, 5].

During previous years, iron oxides have been extensively studied. Recently, these iron oxides have been developed in various forms (such as nanopowders as well as thin films). This makes iron oxide a wide range of applications in various fields of science and technology. These applications were drug delivery vehicles, recording device, circulating electric valves, solar filters, electrical devices, lithium-ion batteries, and the system for hydrogen generation [6, 7].

Thin films of iron oxide (Fe_2O_3) were prepared using many deposition techniques such as Aerosol - assisted chemical vapor deposition (AAC-VD) which is simple to operate and very versatile [8] and of Fe_2O_3 were prepared using technique pulsed laser deposition(PLD)[9], spray pyrolysis [10], Sputtering [11] and Sol-gel [12]. The presented work shows the effect of laser energy (700, 800 and 900) mj on optical properties of Fe_2O_3 thin films that prepared by pulse laser deposition.

EXPERIMENTAL WORK

Nd: YAG laser with wavelength 1064nm at repetition rate of 4 Hz and 10ns duration was used in PLD. Fe_2O_3 film precipitation was used as glass bases. The glass base was heated to 200°C and in a 10^{-5} torr low pressure vacuum chamber.

The laser spot is focused on an area of 1 mm^2. The laser beam will fall at an angle of 35 from the target surface. The target was positioned 25 cm from the substrate. The glass substrate slide was washed with alkali-free detergent and a piece of cloth and rinsed several times in distilled water. In addition, an ultrasonic device is used to place the glass substrate in it and rinse in de-ionized water. Finally, the substrate was dried. This saves in the PLD system to obtain good uniformity and adherence to films. The variation of laser power in the structural properties of the Fe_2O_3 thin film was investigated, and several samples were produced using different laser power of 700mj, 800mj and 900mJ.

The optical properties of samples (Absorption and transmission spectra) was measured by UV-V at room temperature in the spectral range of 300–900 nm the spectrophotometer DUC 3700instrument at ambient temperature. After measuring the transmittance and absorption of Fe_2O_3 films, by using equation(1) we calculated the absorption coefficient (α) [13, 14]:

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

Where: A is absorption and t: film thickness.

The relation represent in equation 2 was used to determine the energy band gap, Eg [5, 15]:

$$\alpha h v = K(hv - E_g)^{\frac{a}{2}} \qquad ....(2)$$

Where: hυ is the incident photo energy, K is a constant. We used a = ½ when indicates direct allowed transition, and a = 2 when indicates indirect allowed transition. The refractive index (n) and extinction coefficient (k) calculated from the transmission spectrum by equation [8, 15]:

$$n = \frac{1+R^{1/2}}{1-R^{1/2}} \qquad \text{…………(3)}$$

$$k = \frac{\alpha\lambda}{4\pi} \qquad \text{……….. (4)}$$

Atomic force microscopy (AFM) measurement was carried out to study the morphology surface of deposited films, using (SPM scanning prob microscope).

RESULT AND DISCUSSIONS

Figure-1 shows the transmittance spectra of a range of visible and ultraviolet spectrum of films prepared with different laser energy. These measured films have high transparency in the range of 600 nm to 900 nm. These results agree with many researchers [4, 7]. The transmittance increases with increasing laser energy reach to71% at 800mj then decreases to 50% at 900mj due to increasing thickness.

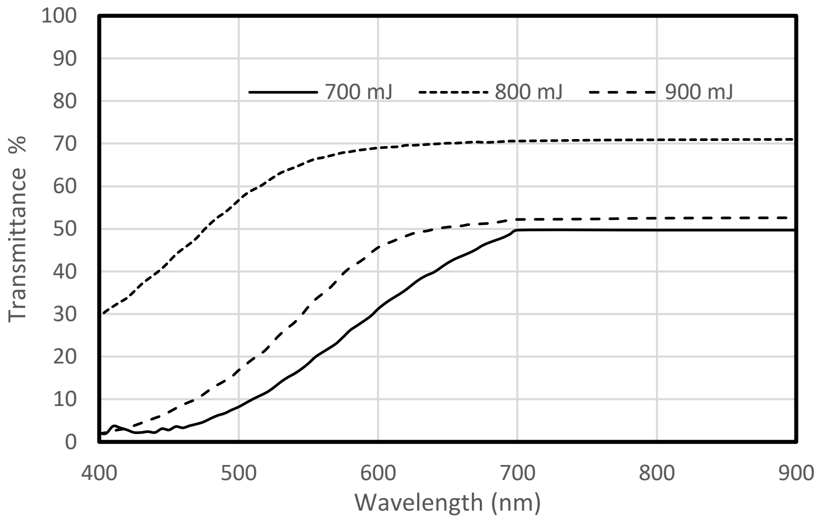

Figure-1. Transmission as function of wavelength for Fe_2O_3 films with different laser energy (700mJ, 800mJ and 900mJ).

Figure-2 shows the plot for the absorbance deposited thin film. The figure clear that the films have absorbance in the limited range of wavelength which opposite to that of the transmittance. The increase in wavelength of incident photon, the absorbance of all the samples tended to be have low value. This figure shows that the average absorbance decreases when the laser energy increases. The lower value of absorbance is obtained at laser energy (800mj).

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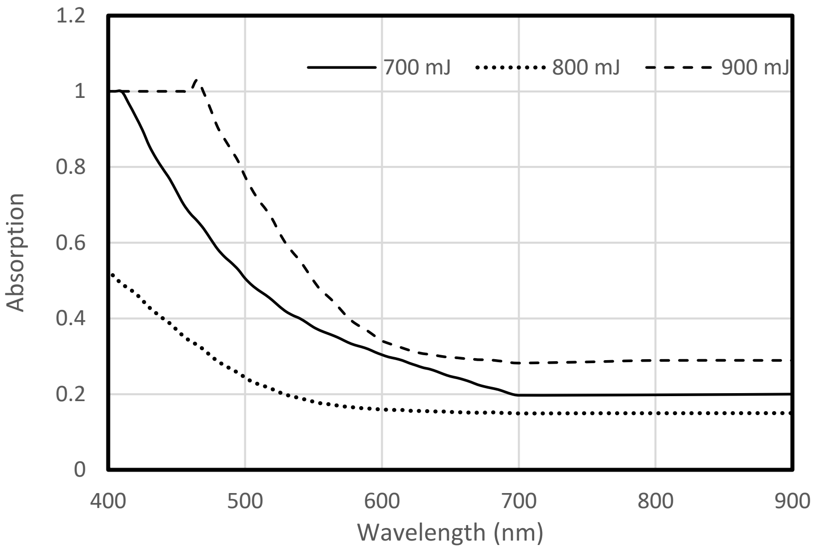

Figure-2. Absorption as function of wavelength for Fe_2O_3 films with different laser energy (700mJ, 800mJ and 900mJ).

In general, this in agreement with the scientific research that says that an increase in the absorption coefficient of some thin films corresponds to an increase in the photon energy. Figure-3 shows a draw curve of $(\alpha h\nu)^2$ with hν. The band gap of these films can be taken from the extrapolation of the straight line extension of the linear parts of the drawn curve to $(\alpha h\nu)^2 = 0$. The optical bandgap of Fe_2O_3 films at different laser energy was found (2.52, 2.74 and 2.32) eV for 700mJ, 800mJ and900mJ respectively.

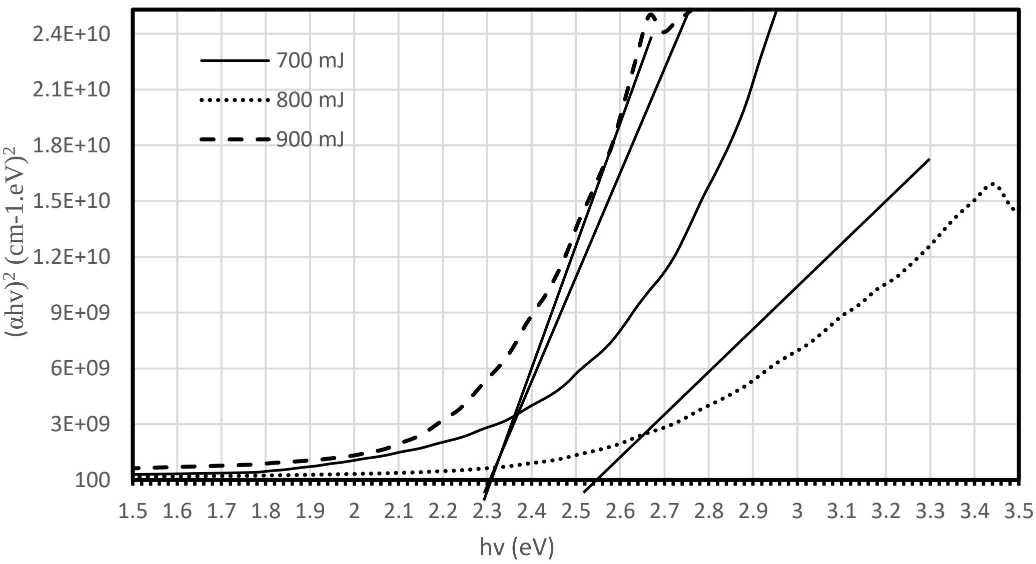

Figure-3. $(\alpha h\nu)^2$ verity as function of energy for Fe_2O_3 films with different energy of laser (700mJ, 800mJ and 900mJ).

The extinction coefficient was calculated (using equation (3)) for Fe_2O_3 thin films within the spectral range (300-900) nm for samples deposited at different laser power as shown in Figure-4. We can notice from Figure-4 that the extinction coefficient decreases sharply with λ increase for all thin films formed up to 600 nm wavelength, and it has a higher value at 800 mJ laser energy.

Refractive index change plays an important role in the study of materials and research on optical materials, because it is an important factor in applications for optical communication and in the design of some spectroscopic dispersion devices. Using equation (4), the refractive index of the deposited film was calculated. Figur-5 shows the change in refractive index with wavelength of Fe_2O_3 films deposited with different laser energy. From this figure, we notice that n decreases with increasing laser energy from 700mJ to 900 mJ, and this assures us that the films density will decrease.

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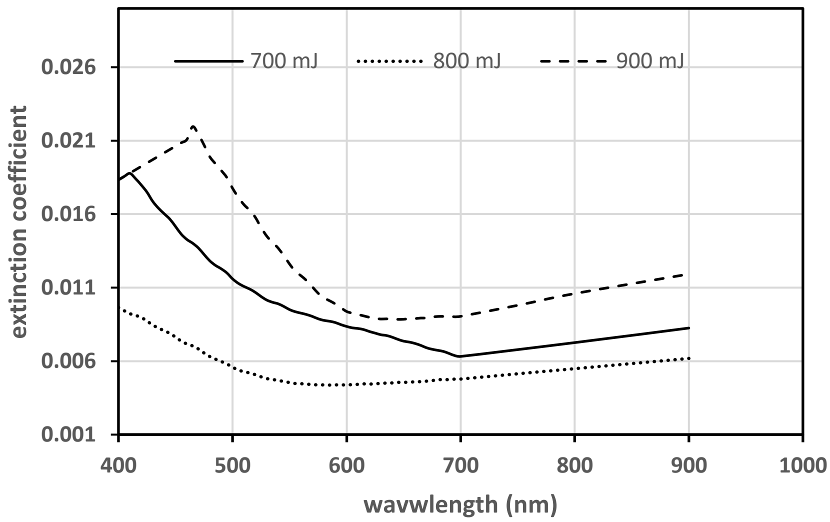

Figure-4. Extinction coefficient of Fe_2O_3 thin films at different energy of laser.

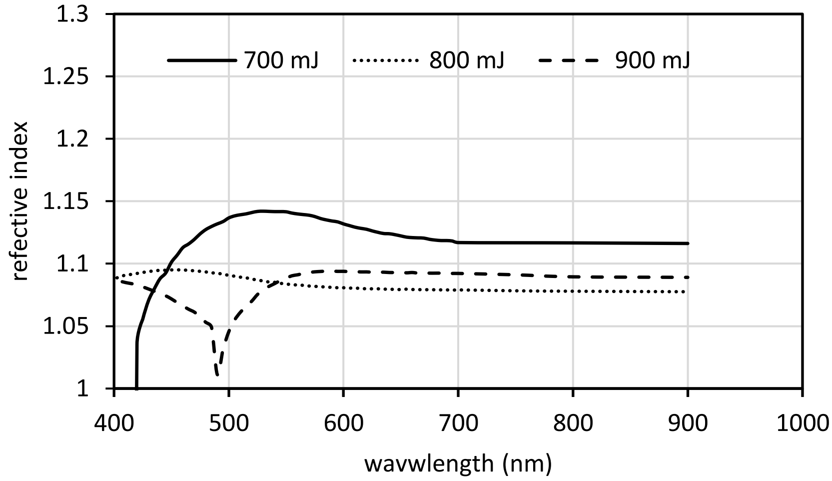

Figure-5. Refractive index as function of wavelength for Fe_2O_3 films with different laser energy (700mJ, 800mJ and 900mJ).

dielectric constant of tow parts (The real part (εr) and imaginary part (εi)) of can be explained by following equations [12, 14]:

$\varepsilon_i = n^2 - K_o^2$ ………5

$\varepsilon_r = 2nK_o$ ……….6

Figures (6) and (7) show the differences in the real (εr) and imaginary (εi) parts of the dielectric constant for a range of wavelengths. The film formed at a pulsed laser energy of 700 mJ has a well-defined maximum, and it decreases with increasing laser energy.

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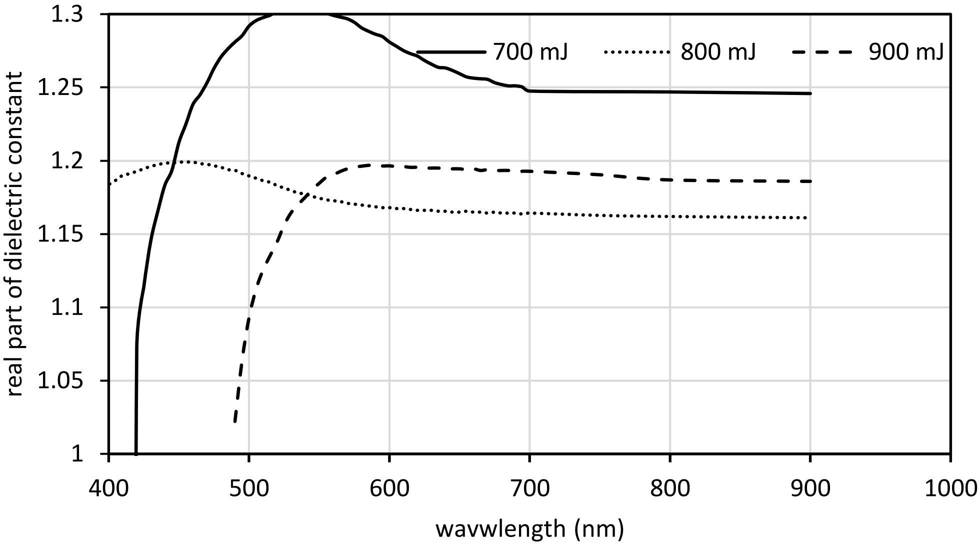

Figure-6. Real part of dielectric constant versus wavelength for Fe_2O_3 thin films.

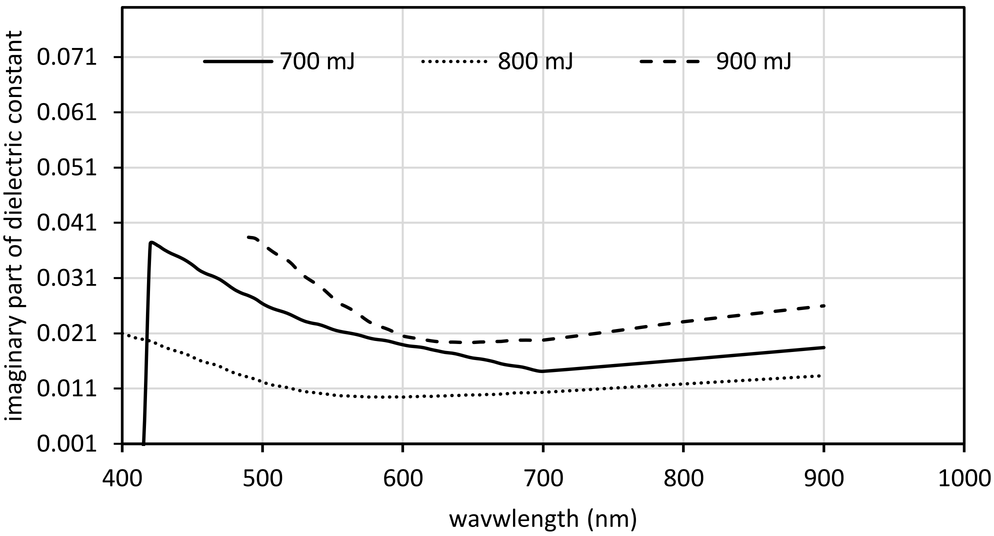

Figure-7. Imaginary part of dielectric constant as a function of wavelength for Fe_2O_3 films.`

Using atomic force microscopy the surface morphology of the Fe_2O_3 film was analyzed. . It shows uniform grain structures of Fe_2O_3 thin films on glass substrate (Figure-8) and varied in surface morphology with changing of laser energy as clear in Figure-8 (a, b and c). Various parameters such as variance of mean RMS roughness, surface roughness and average height of Fe_2O_3 thin particles are obtained from the data extracted from the AFM charts. Table-1 shown these parameters as a function of laser energy that used through depostied films.

The 2 Dimension micrograph shows rms roughness of Fe_2O_3 film is 0.512 nm and the average roughness is 0.445 nm at 800 mJ laser energy. The distance peak - peak is 2.71 nm. The highest value for film height is 610.02 nm average height reaches 259 nm which is the same value as film thickness was measured using gravimetric.

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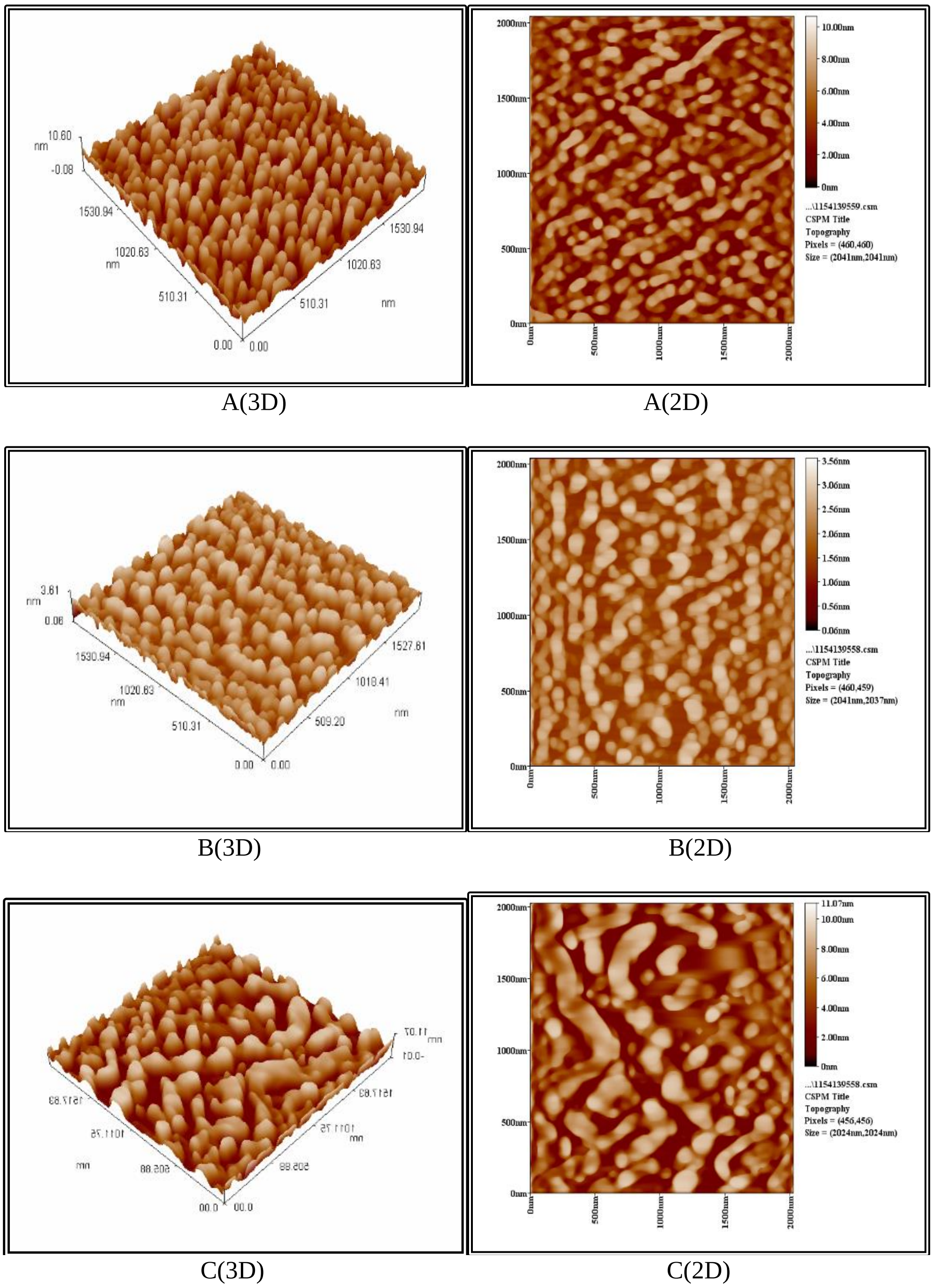

Figure-8. AFM image of Fe2O3 thin films deposited at laser energy: A)700mJ B)800mJ C)900mJ .

Table-1. Parameters of Fe_2O_3 thin films (Average roughness, RMS roughness and Average height) prepared at different condition.

Laser energy mJ	Grain size (nm)	RMS (nm)	Roughness (nm)	Peak-peak (nm)	Average height (nm)
700	73.87	1.87	1.64	6.72	6.22
800	69.28	0.512	0.445	2.71	1.91
900	123	2.28	1.94	8.07	7.36

CONCLUSIONS

Fe_2O_3 thin films have been successfully deposited on a substrate (glass) by pulse laser deposition technique. Optical properties is studied at different energy of laser (700, 800 and 900)mJ. From the calculations of the optical absorption coefficient it was found that the deposited film has an indirect bandgap of (2.3-2.7) eV, variation with laser energy. Also, study the effect of laser energy on Morphology surface, such as roughness root mean square average particle size and the distance between peak to peak, the beast values are (0.445, 0.512, 69.28 and 2.71) nm respectively.

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