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Research Article

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Effects of Laser Irradiation on Copper Phthalocyanine Nanostructure and its Optoelectronic Device

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Abstract: Copper phthalocyanine (CuPc) films exhibit strong absorption as well as chemical stability against visible light and hence are attractive organic semiconductors for an optoelectronic device. In the present work, we have studied the influence of 650 nm laser irradiation on the 478.4 nm Cupc thin film and recorded its photodetector behavior. X-ray diffraction analysis showed increased crystallinity of laser-treated samples, in which the crystallite size enhanced from 30.48 to 39.03 nm with diminished microstrains. The average grain size increased from 35.77 nm to 95.19 nm, while the surface roughness decreased as observed by an atomic force microscope (AFM), evidencing a remarkable grain growth and surface smoothing process. The optical properties revealed small changes in the π–π* transitions and a slight increase in the optical band gap from 1.82 to 1.84 eV, indicating a decrease in the disorder of the structure. Hall effect measurements revealed that an increase in the carrier mobility from 0.16 to 28.9 cm²/V•s resulted in good electrical properties despite a decrease of the free electron concentration (n) due to the hole compensation mechanism. Meanwhile, the responsivity of laser-treated CuPc photodetector dramatically improved from 54.92 to 190.98 µA/mW as well as external quantum efficiency increased from 10.89% to 37.89% at a wavelength of 625 nm. These enhancements are ascribed to the laser-induced molecular realignment, reduced trap density, and enhanced charge transport path.

Keywords: CuPc thin film, Charge transport, Laser Irradiation, Organic Photodetector.

1. Introduction

As an emerging class of optoelectronic materials, organic semiconductors have been attracting increasing attention due to their various advantages, such as being low-cost and easy to fabricate, outdoor mechanical flexibility, lightweight, and tailorable optoelectronic characteristics [1-3]. Among these, metal phthalocyanines have been considered as an attractive family of materials for various optoelectronic applications, including organic photodetectors (OPDs), solar cells, and gas sensors, owing to their chemical stability, strong absorption coefficients in the visible region, and effective charge transport properties [4-5]. Especially CuPc is one of the most studied organic semiconductors due to its thermal stability, environmental strength, and preferable molecular structure [6-8]. The opto-electronic properties

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of CuPc thin films are greatly determined by the degree of ordering, surface morphology and defect density, all significantly affected by the fabrication and post-depositing treatment conditions [9-11].

Laser irradiation has lately become an appealing post-deposition modification treatment, because it is local and controllable, no-contact technique [12]. Unlike classical thermal treatments, the laser can locally deposit the needed energy in the material, thus minimizing global heating of the substrate and facilitating structural/morphological optimization. Previous studies have mainly concentrated on the ultraviolet or high-energy laser, which might generate too many thermal effects and chemical damage to organic semiconductors [13]. In this situation, there is a rising interest in the use of visible-light laser irradiation as an alternative, low-energy, and non-destructive method. In the case of CuPc thin film, laser irradiation at 650 nm is particularly attractive since the resulting optical excitation coincides exactly with its intrinsic Q band absorption itself [14].

This spectral complementation ensures that photons can efficiently interact with the molecules to facilitate molecular rearrangement, reinforced π–π stacking, and crystallinity without changing the chemical composition of the material [15]. However, to date, a comprehensive study of the relationship between laser-induced structural and morphological (in terms of charge transport) changes and photodetector performance originating from visible laser-exposed CuPc thin films is still unexplored [16]. Hence, the purpose of the present study is to systematically explore the effect of 650 nm laser light on structural, morphological, optical, and electrical properties in thermally evaporated CuPc thin films. Through systematic characterizations using X-ray diffraction (XRD), atomic force microscopy (AFM), UV–Vis spectroscopy, Hall effect measurements, current–voltage and photoresponse measurements, we discover details of the mechanisms responsible for laser-induced enhancement. By directly correlating laser-induced molecular ordering with device performance, this work offers a useful guideline for developing a simple yet effective approach to improve CuPc-based organic photodetectors.

2. Materials and methods

The blue CuPc pigment powder, with the molecular formula $C_{32}H_{16}CuN_8$, obtained in this work from Sigma-Aldrich Chemical (99% purity), is used as the raw material. After purification, thin CuPc films of varying thicknesses are deposited using thermal evaporation under vacuum. The copper phthalocyanine is heated, evaporated, and then cooled upon contact with a low-temperature surface, forming a single thin film. In this thin-film deposition process, a vacuum of (2×10^{-5}) Torr was used. The dimensions of the deposition tank are designed to ensure the homogeneous distribution of the deposited copper phthalocyanine particles on the substrate, which is the objective of the deposition process. The homogeneity of the deposition layer is crucial for achieving the desired properties and performance. Thin film of copper phthalocyanine 478.4 nm represents S1 thick were produced in a tungsten metal vessel when the evaporation chamber pressure reached 2×10^{-5} Torr, using a coating unit. At room temperature, the material was deposited onto glass, 30 cm from the evaporation tank. The samples are then cooled in the evaporation chamber, and the thickness is measured. The laboratory subsequently ponders over those films' structure, optics, morphology and electrical features (refer to Figure 1), the Diagram of a thermal evaporation system. The evaporation temperature of CuPc depends on the conditions. Still, in general, it requires a higher temperature, ranging from 300 to 400°C, since CuPc is not easily evaporated due to its good thermal resistance.

2.1. Laser irradiation 650 nm

A laser source at 650 nm is based on the visible red-light portion of the electromagnetic spectrum, and serves to be a common wavelength for photo-process applications due to its moderate photon energy and a strong interaction with organic semiconductor absorption bands agree with [17]. This wavelength is significant in the case of copper phthalocyanine (CuPc) thin films since it coincides with the Q-band absorption, allowing efficient excitation of molecular electronic states. Under 650 nm light irradiation with the laser power 15 mW, and time of irradiation at 10 min, the CuPc experiences photothermal and photochemical processes, which may rearrange molecular packing, improve crystallinity and distribute defects in the film. Red laser photons possess a low enough energy to cause a thermal degradation risk and high enough energy to lead to localized heating for improving the charge mobility via defect healing, and also through molecular reorientation. In addition, the exposure of CuPc thin film represent S2 to 650 nm laser radiation can lead to changes in optical properties; thus, it is a powerful technique for tuning the performance of CuPc-based optoelectronic devices such as photodetectors, sensors and thin film transistors. The controlled and non-invasive nature of this wavelength allows precise tuning of material properties without altering chemical composition, thereby offering a versatile approach for tailoring the functional characteristics of organic thin films.

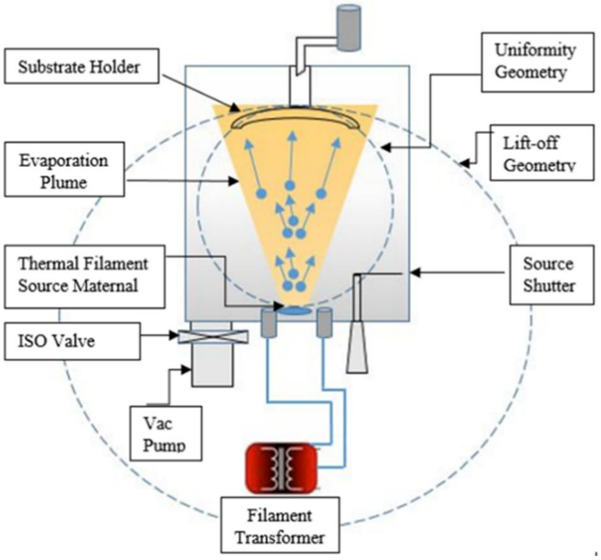


Fig. 1: Thermal evaporation system diagram.

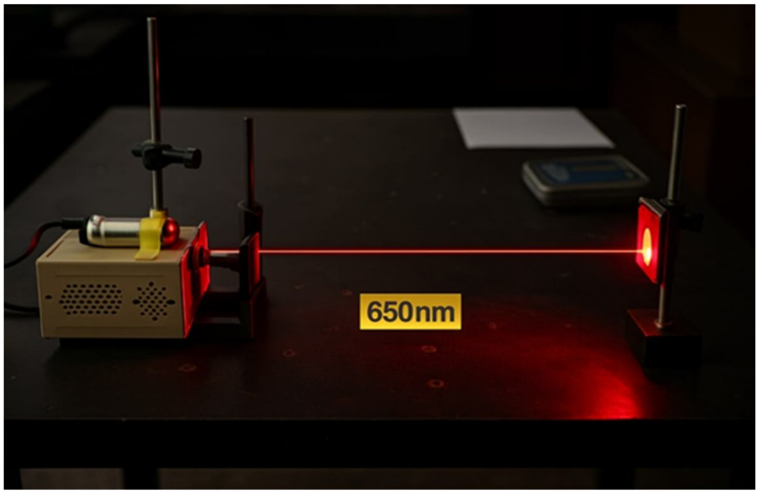


Fig. 2: Schematic of the Laser irradiation 650 nm system.

3. Result and discussion

3.1. Hall effect measurement (HEM)

Finally, the Hall coefficient (RH) of the CuPc films with a thickness of 478.4 nm was derived using Eq. (1). The Hall carrier concentration (nH) and the Hall mobility (μH) could then be obtained by Eqs. (2) and (3), respectively [18,19]. The Hall effect is a crucial tool for characterizing charge carrier dynamics and transport in organic semiconductors. The results in Table 1 show that the resistivity of the two samples are in one order of magnitude of 10^5 Ω•cm, which demonstrates the intrinsic low electrical conductivity of CuPc. However, laser irradiation results in a modest decrease of resistivity from the as prepared value to 1.101 × 10^5 Ω•cm and accordingly an increase in electrical conductivity from 8.807 × 10^{-6} to9.080 × 10^{-6} $(\Omega•cm)^{-1}$. This improvement shows the increased charge transport capability after laser treatment probably related to a reorganization of structures and molecules induced by the laser. "Large" changes are also evident in the Hall coefficient: RH rose from 1.792 × 10^4 cm^3/C (untreated film) to 3.183 × 10^6 cm^3/C (laser treatment), confirming that carrier transport has been greatly altered. In accordance with this, the Hall carrier concentration is greatly decreased from 3.483 × 10^9 to 1.961 × 10^7 cm^{-3}.

Upon laser irradiation, indicating that the concentration of the free charge carriers for electrical conduction lowered down. In spite of the lower carrier concentration, there is a great improvement in Hall mobility, compared to that of as-prepared films (0.1579cm²/V•s), which reaches 28.90 cm²/V•s after laser irradiation. This large increase in mobility dominates the overall electrical transport response and more than compensates for the reduced carrier density, resulting in a net enhancement of conductivity. The mobility improvement is related to the suppression of trap-assisted scattering, and an enhancement in molecular order and intermolecular orbital overlapping that result in better charge transport efficacies. The conduction type is unchanged during the laser irradiation, indicating that the intrinsic electronic nature of CuPc does not change upon such a substrate treatment whereas the charge transport properties have been greatly enhanced. In general, the above results indicate that 650 nm laser improves the electrical performance of CuPc thin films mainly due to a remarkable enhancement in charge carrier mobility whereas carrier concentration is decreased simultaneously, leading to an enhancement of charge transport efficiency.

$$R_H = V_{H.t}/I.B \qquad (1)$$

$$n_H = \pm 1/R_{H.e} \qquad (2)$$

$$\mu_H = \sigma/n_H.e = \sigma.|R_H| \qquad (3)$$

Table 1. presents the extracted Hall parameters of the CuPc thin films

Sample	**(ρ) (Ω cm) Resistivity**	**(σ) $(\Omega\ cm)^{-1}$ Conductivity**	**(R_H) (cm^3/C) Average Hall Coefficient**	**n_H (/ cm^3) Sheet Concentration**	**μ (cm^2 / V_s) Mobility**	**Type**
S1	1.135 E+5	8.807 E-6	1.792 E+4	3.483 E+9	1.579 E-1	P
S2	1.101 E+5	9.080 E-6	3.183 E+6	1.961 E+7	2.890 E+1	P

3.2. X-ray diffraction

It is clearly shown from the XRD patterns of 478.4 nm thin films that the influence of 650 nm laser light irradiation on structural properties for CuPc is obvious. As depicted in Fig.3, the as-grown film is characterized by a relatively low intensity broad diffraction feature at the (312) plane, which suggests that the sample processed only moderate crystallinity and limited long-range structure order. Such broadening of peaks is indicative of an island like growth behaviour (Volmer–Weber mode), where non-oriented crystallites randomly nucleate on the substrate, leading to a heterogeneous microstructure. For the laser-irradiated CuPc film, by comparison, the diffraction intensity is significantly increased and a clearer, narrower peak appears to be the (312) plane. This behaviour is an indication of appreciable enhancement in crystallinity and molecular ordering brought about by laser irradiation. The observed structural improvement is ascribed to local photothermal effects created by the laser that serve the reorganization of molecules and a reduction in the structural disorder within the film. The enhanced peak sharpness of the laser treated film reveals the growth of crystallite size and a decrease of crystal lattice imperfection towards improving charge transfer characteristics by mitigating grain boundary defects and trap sites. This structural improvement is available in line with the improved carrier mobility determined by the Hall effect measurement. To quantify these changes, the size of crystallite was calculated using the Scherrer equation Eq. (4) [20], and the fitted values are listed in Table 2.

$$D = \frac{0.9\lambda}{\beta \, COS \, \theta} \tag{4}$$

Where:

D: represents the mean crystallite size

β: represents the full width at half maximum (FWHM) of the diffraction peak, expressed in radians.

λ: represents the X-ray wavelength.

θ: the diffraction angle or is the Bragg angle (half the diffraction angle)

K = 0.94: the Scherrer constant, which is approximately equal to one in the case of spherical crystallites.

A diffraction peak stemming from the (312) crystallographic plane is observed for both samples, which verifies that the basic crystal structure of the films is unchanged after irradiation with a laser. The diffraction angle (2θ) exhibited a little shift from 29.15° in the as-prepared film to 29.474° after laser-treatment. This shift indicates small changes in the lattice parameter, presumably due to molecular rearrangement induced by irradiation or relaxation of stress in the film. After the laser treatment, there is an apparent decrease in the full widths at half maximum (FWHMs) from 0.27° down to 0.211°. As FWHM is inversely proportional to crystallite size, this narrowing exactly reflects increasing crystallinity. The calculated crystallite size D increases significantly from 30.48 nm for the prepared film to 39.03 nm for the laser irradiated one.

This improvement could be explained by the establishment of higher-order, and larger crystalline domains probably induced by local photothermal effects on the molecular aligning process and disorder decrease. In addition, the microstrain (ε) decreases from 1.1×10^{-3} to 8.8×10^{-4} associated with laser processing, indicating a decrease in lattice distortion and internal defects, which indeed can be appreciated as a higher value because of the laser exposure. The enhancement can be ascribable to the promotion of columnar growth dependent primarily on film thickness and deposition conditions. (312) diffraction peak of 478.4 nm thickness film can be seen relatively weak and the width is somewhat broadening. This mode is attributed to columnar grain growth and increase of lattice imperfection density. Within an individual phase, the planar grain growth and microstrain accumulation are attributed to the peak broadening/lowing. This behavior is in agreement with the AFM characterization where bigger surface roughness and higher RMS value are reported for laser treated samples. The laser induced crystallite growth points towards a thermally assisted molecular rearrangement, rather than a phase transition maintaining the intrinsic CuPc crystal structure but with better long-range order. The micro-strain (ε) can be obtained from the XRD data in the table using the positive intercept of a linear fit to RMS value according to simplified Williamson-Hall equation Eq. (5) [21] was utilized. This method allows a full characterization of distortions in the film lattices and provides insight into the structural modifications promoted by the processing conditions.

$$\varepsilon = \frac{\beta \cos\theta}{4} \qquad (5)$$

The micro-strain (ε) can be obtained from the XRD data in the table using the positive intercept of a linear relationship according to simplified Williamson-Hall equation Eq. (5) [22] was utilized. This method allows a full characterization of distortions in the film lattices and provides insight into the structural modifications promoted by the processing conditions.

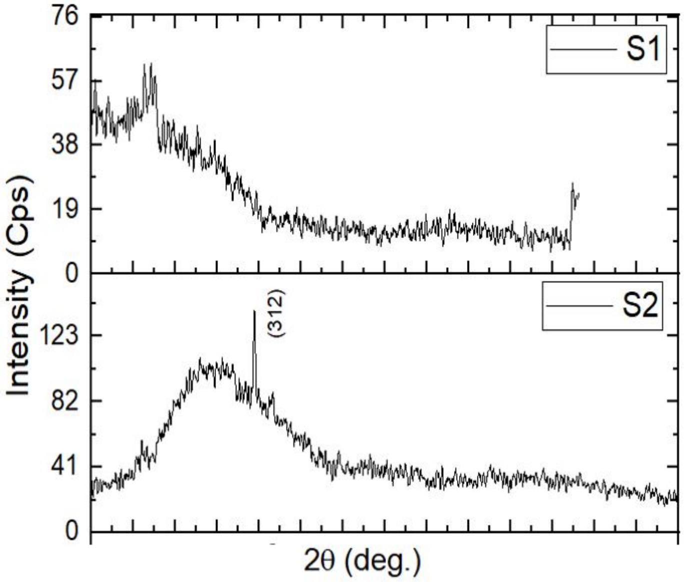


Fig. 3: X-ray diffraction patterns of CuPc thin film grown on a glass substrate at room temperature by thermal evaporation method for S1 and S2

Table 2. Results acquired from X-ray diffraction for copper phthalocyanine films of S1 and S2

Sample	2θ (Deg.)	FWHM (Deg.)	D (nm)	ε	hkl
S1	29.15	0.27	30.47674	$1.1*10^{-3}$	312
S2	29.474	0.211	39.02734	$8.8*10^{-4}$	312

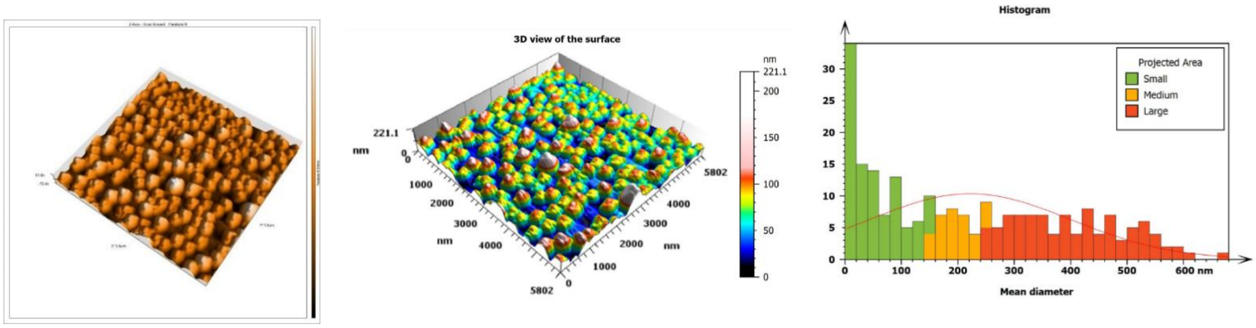
3.3. Atomic force microscopy analysis

AFM is the most reliable surface imaging technique, which provides a three-dimensional representation of nanoscale topography [23]. This allows an analysis of roughness, morphological, and crystal growth information on the CuPc layers before- as well as post-processing. In-situ characterization of surface evolution processes and the processed induced impact on film optical and electrical properties can be accomplished through AFM. Table (3) shows the surface morphological parameters of the CuPc thin films from and respectively.

The average grain diameter (Avg. D) of the as-deposited film is 35.77 nm, which implies that the small gain with a less ordered surface. Once the film is irradiated by laser, average grain size becomes notably larger stirring to be 95.19 nm, so that the energy of laser is able to induce grain growth and molecular rearrangement in the film. The root-mean-square (RMS) roughness, indicating the height difference over the surface, reduces from 169.2 nm in the as-deposited film to 109.4 nm upon laser irradiation. This decrease may be attributed to the smoothly uniform surface topography presumably realized by local melting or re-arrangement due to irradiation of the laser. The value of the Sa is significantly reduced after laser exposure from an average of 145.2 to 68.64 nm. The strong decrease in RMS and Sa values reveals that laser therapy smoothens the surfaces and reduces topography variations, shown in Figures 4 and 5.

Table 3. Values of Avg.D, (Sq), (Sa) of (CuPc) nanostructure of the temperature (R.T), and values of S1and S2

Sample	Avg.D	RMS (Sq)nm	Roughness (Sa)nm
S1	35.77	169.2	145.2
S2	95.19	109.4	68.64



(a (b (c

Fig. 4: AFM analysis for CuPc thin film (a) 2D image, (b) 3D image, and (c) granularity distribution diagrams at S1.

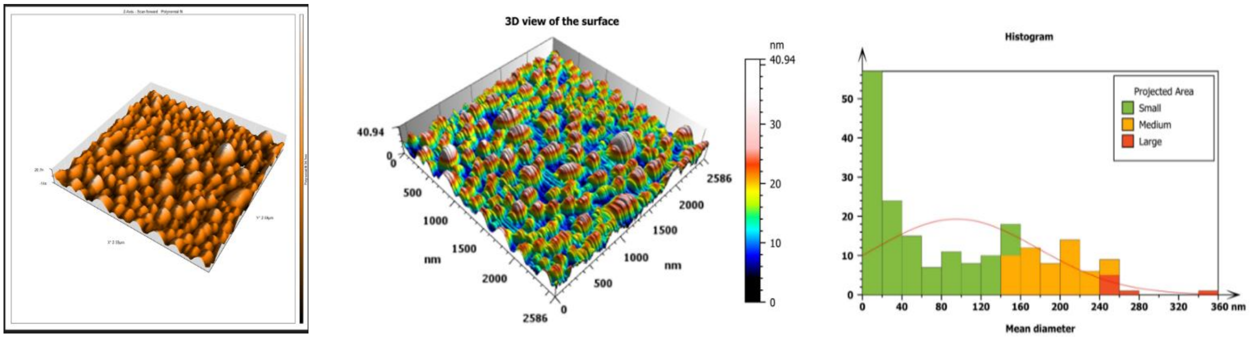


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Fig. 5: AFM analysis for CuPc thin film (a) 2D image, (b) 3D image, and (c) granularity distribution diagrams at S2

3.4. UV- visible analysis

Thermally evaporated CuPc thin films exhibit a noticeable modification in their optical absorption behavior following laser 650 nm treatment. Figure (6) illustrates the UV–Vis absorbance spectra of CuPc thin films before and after exposure to 650 nm laser irradiation. The spectra display the characteristic absorption features of metal–phthalocyanine compounds, namely the B-band (Soret band) in the near-UV region and the Q-band in the visible region, both of which arise from π–π* electronic transitions within the conjugated macrocyclic structure of CuPc. For the as-prepared film (t = 478.4 nm), the Q-band exhibits two well-defined components corresponding to the first and second π–π* transitions, located around ~670 nm and ~610 nm, respectively[24]. These peaks reflect strong molecular ordering and a high level of electronic coupling between CuPc molecules. A significant decrease in the absorbance intensity of Q-band, as well as a small broadening of peaks under laser excitation, was observed under 650 nm laser irradiation.

This decrease in intensity implies that changes in molecular structure may occur upon femtosecond laser irradiation, or a partial shift of electronic states causes recoiling. The movement and broadening of the π–π* transitions imply a change in intermolecular interactions, which may be caused by grain growth, smooth surface, or local heating effects that modify the stacking mode of CuPc molecules. And the B-band in the UV range is another peak that exhibits a drop of absorbance after laser irradiation, which can indicate that there is a shift of optical properties of the thin film. Lowering relative intensities in both the Q- and B-bands indicates that a lower transition probability is involved, which may arise due to reduced disorder and improved surface uniformity (values are consistent with AFM and XRD).

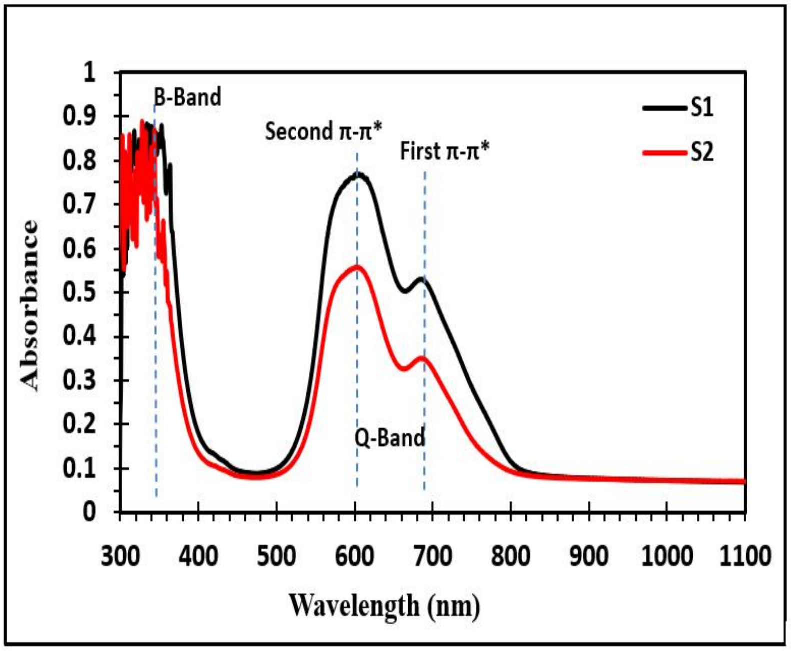

Fig. 6: Absorbance as a function of wavelength for CuPc thin films of S1 and S2 at ambient temperature

Table 4 shows the bandgap optical (Eg) for CuPc thin films before and after laser irradiation at 650 nm. The as-prepared film possesses a bandgap of 1.82 eV, typical for metal–phthalocyanine semiconductors and indicative of their molecular π–π* transition architecture. The bandgap is 1.84 eV on laser treatment. While the effect isn't large, this slight broadening of the optical band gap could result from to laserdriven changes in the molecular packing and surface structure. The enhanced crystallinity and decreased microstrain in the XRD pattern, together with a smoother surface topology of AFM measurement, could give rise to modified intermolecular interactions due to character variation at grain boundaries, causing anelectronic energy levels shift slightly.

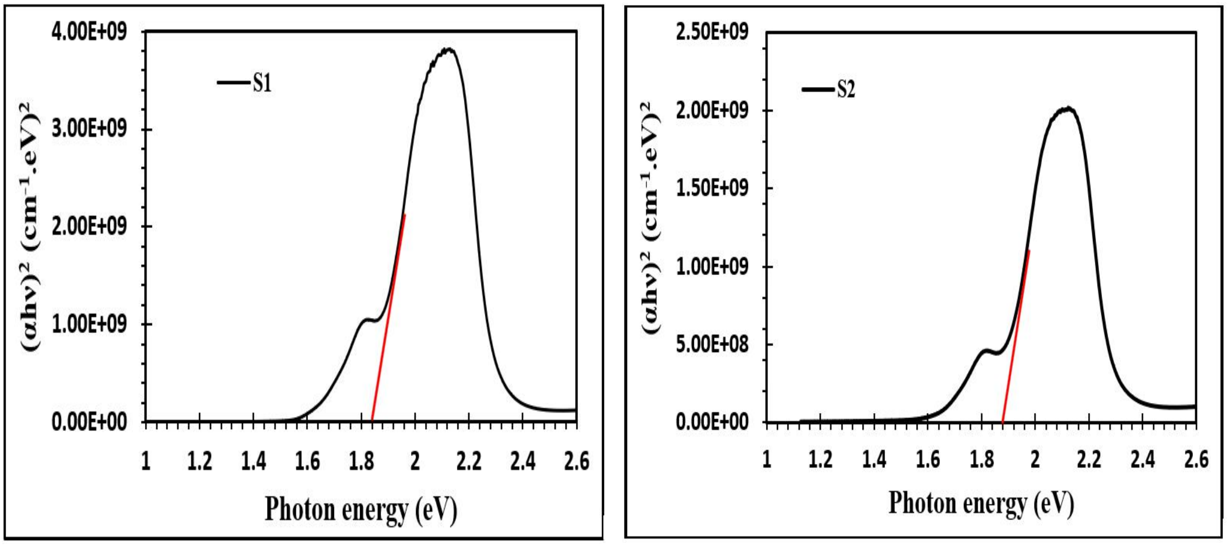

Fig. 7: The band gap of CuPc thin films deposited at S1 and S2 at ambient temperature

Table 4. The band gaps of thickness 478.4 nm and treatment with a laser at 650 nm at ambient temperature.

Sample	Eg (eV)
S1	1.82
S2	1.84

3.5. *I-V characteristics*

With the bias swept from -5 to +5 V in steps of 0.1 V over an active device area of 1 cm². The dark current subtracted from the gross measured current gives the net photocurrent, given by Eq. (6) [21].

$$I_{ph} = I_{light} - I_{dark} \qquad (6)$$

Here, I_{ph} is the photocurrent in the presence of light illumination, P signifies the incident optical power, and A represents the active area of the detector. Remarkably, the dark current is much smaller than the photocurrent, which implies weak leakage without illumination. Furthermore, the good contact electrode quality also contributes to an effective extraction of photo-generated carriers from CuPc thin films into the external circuit, which has a direct impact on device performance. Figure (8) shows the I–V curves of CuPc-based photodetectors obtained in the dark and under illumination with two different samples. In all cases, the presence of a separation between dark current (I_{dark}) and photocurrent (I_{light}) indicates photoconductive response in the CuPc thin films.

In Figure (8a) for the as-prepared CuPc film, the I–V characteristics show almost linear-symmetric behavior of I–V curves, which reveals Ohmic-type contacts between electrodes and organic layer. The photocurrent is significantly higher than the dark current in the entire protocol of applied voltages, indicating efficient photogeneration and conduction of charge carriers [25]. Dark current is very small (low intrinsic leakage), which is important for photodetectors. Upon laser treatment with the 650 nm (Figure (8b)) I–V curves reveal an increase in both photocurrent and dark current. The higher photocurrent intensity under illumination signifies enhanced photoconductive performance, possibly due to laser-induced structural changes (increased crystallinity, decreased microstrain, and better carrier mobility), which are consistent with XRD, AFM, and Hall measurements.

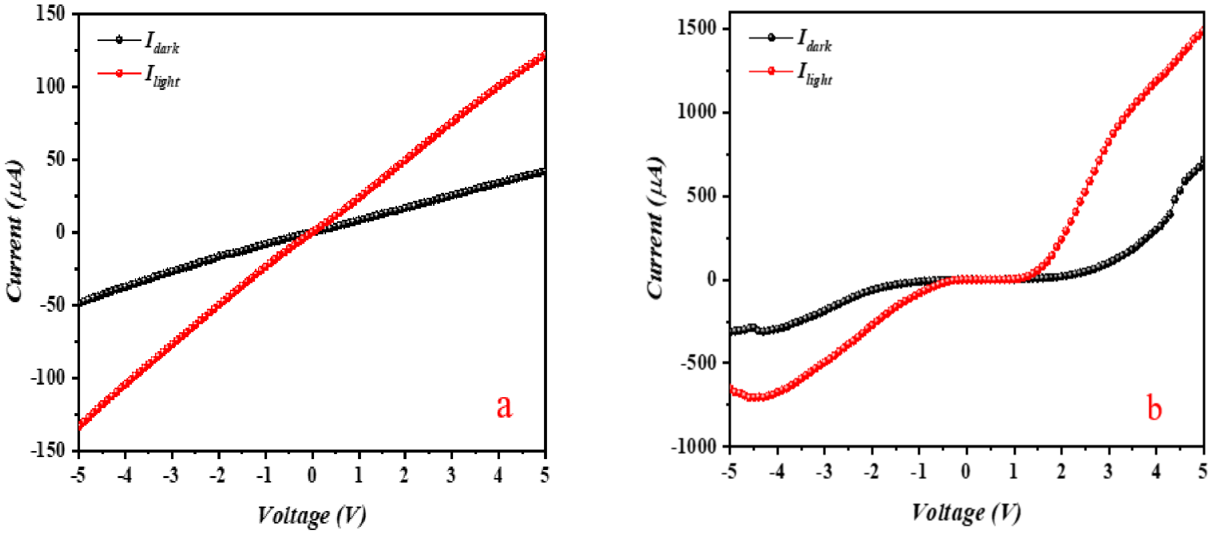

Fig. 8: (a) IV curves of S1 and (b) S2 in dark state and illuminated condition.

This dependence becomes clear when the difference between *I* light and *I* dark increases, indicating that the material has superior performance for photosensing applications. In particular, the thickness-dependent photoresponse properties of CuPc (responsivity R, specific detectivity D* in Eq. (7), (8), and (9) [21], and external quantum efficiency EQE) were systematically measured and their relation to surface morphology determined by AFM. This strategy delivers a systematic insight into the correlations between structural and morphological characteristics and the optoelectronic performance of the device.

$$R = \frac{I_{ph}}{PA} \qquad (7)$$

$$D^* = \frac{R.\sqrt{A}}{\sqrt{2qI_D}} \qquad (8)$$

$$EQE = \frac{I/q}{P/h\nu} \qquad (9)$$

The most relevant photoresponse parameters of the CuPc photodetectors (responsivity, R; detectivity, D*; external quantum efficiency, EQE; and temporal response times, Trise and Tfall) as displayed in Table 8, were obtained for both the pristine and laser-irradiated films at a wavelength of 625 nm. The as-prepared CuPc film (t = 478.4 nm) possesses a responsivity of 54.92 μA/mW, detectivity of 19.3 × 10^9 Jones, and

EQE of 10.89%. These values evidence a moderate photosensing behaviour, which agrees with the standard performance of organic photodetectors using phthalocyanine materials as the active layer. The significantly improved photoresponse of the device is faster with 650 nm light illumination. We observe that responsivity rises more than three times to be 190.98 μA/mW, indicating a far higher photocurrent generation under illumination. Similarly, detectivity can be enhanced to 33.8 × 10^9 Jones which demonstrates better performance of distinguishing weak optical signals from noise. This enhancement is due to the laser-induced improvement in film crystallinity, carrier mobility and reduction of surface roughness as evidenced by XRD and AFM measurements. Meanwhile, the EQE also reveals an obvious enhancement from 10.89% to 37.89% after laser treatment, further indicating the enhanced efficiency of transforming incident photons into charge carriers. This enhancement indicates the promoted optoelectronics property of the CuPc film with structural modification through laser treatment. In terms of the temporal response both the rise time (Trise) rises from 0.30 s to 0.63 s and the fall time (Tfall) falls slightly from 0.31 s to 0.29 s, which can imply that there is a slower trap-assisted process or carrier accumulation in the laser-treated film while at same time making recombination or trapped carrier release more efficient upon end of illumination.

Table 5. Parameters of the photo detector CuPc thin film with 625 nm for S1 and S2

Sample	**Responsivity (μA/mW) λ (625 nm)**	**Detectivity × 10^9 (Jones) λ (625 nm)**	**EQE (%) λ (625 nm)**	**T_{rise} (sec.)**	**T_{fall} (sec.)**
S1	54.92	19.3	10.89	0.30	0.31
S2	190.98	33.8	37.89	0.63	0.29

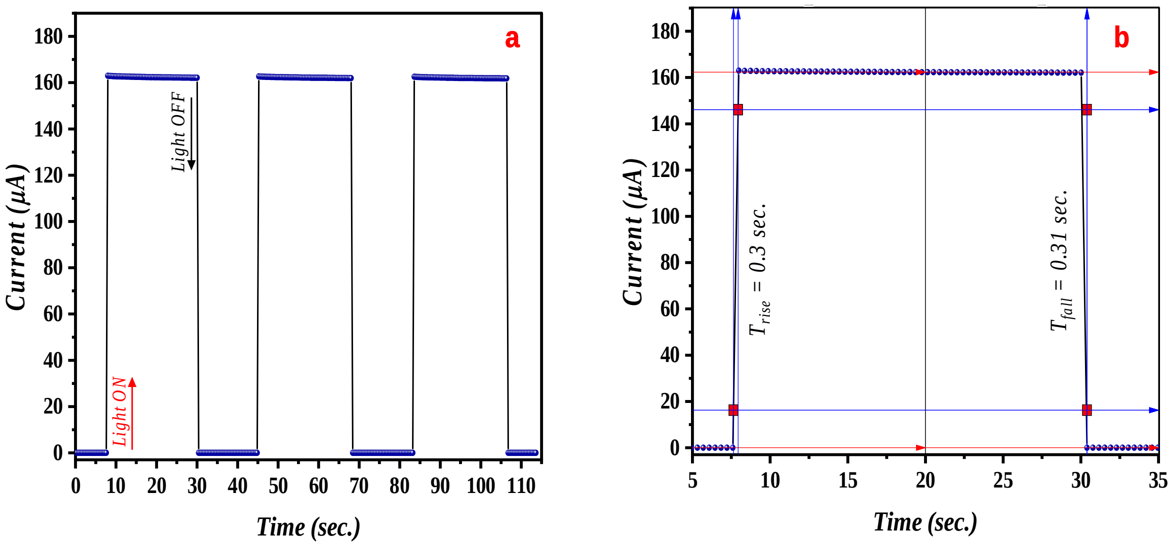

Fig. 9: (a) Time-dependent photocurrent response of CuPc photodetector; (b) Peak photocurrent of different light on-off cycles with S1

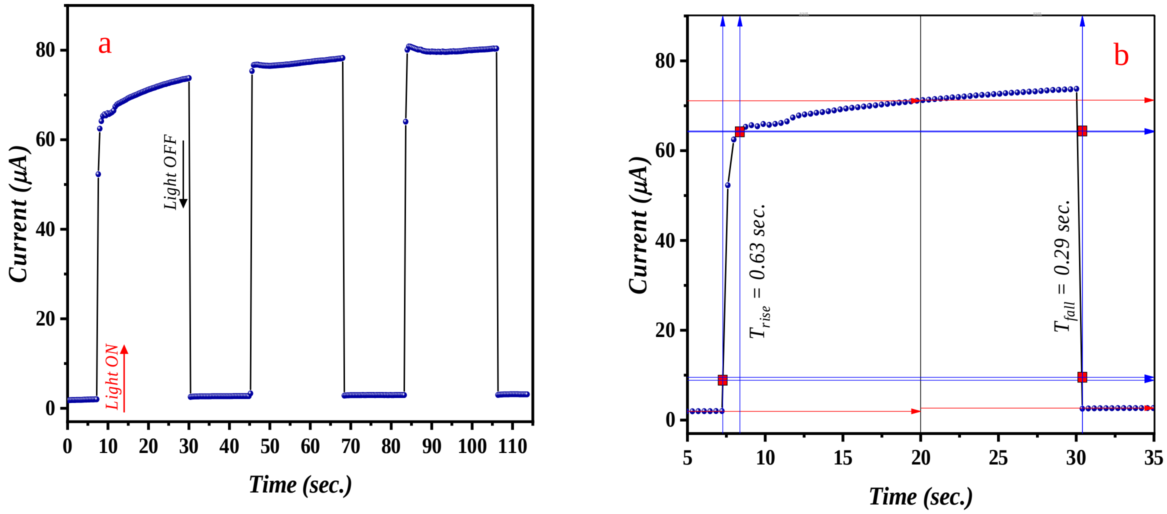

Fig. 10: (a) Time-dependent photocurrent response of CuPc photodetector; (b) Peak photocurrent of different light on-off cycles with S2.

4. Conclusion

This study shows that 650 nm laser irradiation is an effective and non-destructive post-treatment technique to modulate the optoelectronic properties of copper phthalocyanine (CuPc) thin films. The crystalline, grain size, and surface roughness are improved as a result of the laser treatment due to better molecular order and reduced structural defects. Such changes lead to a slight red shift of the optical band gap and a strong improvement in carrier mobility. As a result, the responsivity, detectivity, and external quantum efficiency of the CuPc-based photodetectors based on laser-treated films are greatly improved with stable photoresponse. In general, controlled laser irradiation provides a simple and powerful method for tuning CuPc thin films toward high-quality organic optoelectronic devices.

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تأثير معالجة الإشعاع الليزري على البنية النانوية لمركب فيثالوسيانين النحاس وتطبيقاته الكهروضوئية

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الخلاصة: تظهر أغشية فثالوسيانين النحاس (CuPc) امتصاصا قويا للضوء المرئي، فضلا عن استقرارها الكيميائي، مما يجعلها أشباه موصلات عضوية جذابة للأجهزة الكهروضوئية. في هذه الدراسة، بحثنا تأثير تشعيع الليزر بطول موجي 650 نانومتر على غشاء رقيق من CuPc بسمك 478.4 نانومتر، وسجلنا سلوكه ككاشف ضوئي. أظهر تحليل حيود الأشعة السينية زيادة في بلورية العينات المعالجة بالليزر، حيث ازداد حجم البلورات من 30.48 إلى 39.03 نانومتر مع انخفاض في الإجهادات الميكروية. كما ازداد متوسط حجم الحبيبات من 35.77 إلى 95.19 نانومتر، بينما انخفضت خشونة السطح كما لوحظ بواسطة مجهر القوة الذرية (AFM)، مما يدل على نمو ملحوظ للحبيبات وعملية تنعيم السطح. أظهرت الخصائص البصرية تغيرات طفيفة في انتقالات π–π^* وزيادة طفيفة في فجوة النطاق البصري من 1.82 إلى 1.84 إلكترون فولت، مما يشير إلى انخفاض في الاضطراب البنيوي. وكشفت قياسات تأثير هول أن زيادة حركة حاملات الشحنة من 0.16 إلى 28.9 سم^2/فولت.ثانية أدت إلى خصائص كهربائية جيدة على الرغم من انخفاض قيمة n نتيجة لآلية تعويض الثقوب. في الوقت نفسه، تحسنت استجابة كاشف الضوء CuPc المعالج بالليزر بشكل ملحوظ من 54.92 إلى 190.98 ميكروأمبير/مللي واط، كما زادت الكفاءة الكمية الخارجية من 10.89% إلى 37.89% عند طول موجي 625 نانومتر. تعزى هذه التحسينات إلى إعادة تنظيم الجزيئات بفعل الليزر، وانخفاض كثافة المصائد، وتحسين مسار نقل الشحنة.