Indian Journal of Science and Technology Vol. 4 No. 12 (Dec 2011) ISSN: 0974- 6846

Improve the performance efficiency of solar cell by using epoxy plates doped with Rhodamine 6G dye

B. Daram, K.R. AL- Rawi and S.H. ALShaikh Hussin

Department of Physics, *College of Science for Women, University of Baghdad, Baghdad, Iraq*
suma.hikmet@yahoo.com

Abstract

In this study the Luminescent Solar Concentrator (LSC) plates have been prepared with different thickness and concentration of dye Rhodamine 6G, by dissolving R6G dye in epoxy resin directly without dissolving the dye into a solvent first. This step of solving is the first of solving dye directly without any solvent used to solve the dye. The optical properties of dye doped and undoped epoxy and its applicability in solar cell were studied too. By using these plates on the solar cells, it was observed an increase in the solar cell efficiency up to 63.9% for (LSC) of (2mm) thickness and ($5x10^{-3}$ mol/L) concentration of the dye. The largest increase in the performance efficiency is 126.7% for (LSC) of (4.5mm) thickness and ($5x10^{-5}$mol/L) concentration of the dye. The reasons for the increase in solar cell performance efficiency were studied and discussed.

Keywords: Luminescent Solar Concentrator; Optical properties; Solar cells; Epoxy; Rhodamine 6G dye.

Introduction

Solar cells were used to convert renewable sun energy to electrical energy and because of high coast of the materials used in its manufacturing, new methods were followed to reduce that cost including luminescent solar concentrators (LSC). LSC consists of a transparent matrix material, usually a flat plate, with solar cells connected to one or more sides. The transparent matrix contains luminescent molecules or particles such as, organic dyes or quantum dots part of light emitted by the luminescent particles is guided towards the solar cell by total internal reflection, the plate functioning as a waveguide (Bargers *et al*., 2006; Slooff *et al*., 2007). LSC was original proposed in the 1970s and attracted much interest (Goetzberger & Grenbel, 1977; Ghosh, 2010). The LSC is particularly suited to this application as it is relatively inexpensive, does not require solar tracking and works in both diffuse and direct sun light (Dick, 2010). The LSC can be designed such that the luminescence energy matches the PV cell by this way the light reaching the cell is converted more efficiently, because the down-conversion of the radiation happens in LSC, unwanted thermalisation losses in the cell are avoided (Yuan *et al*, 2011).

Solar cells are clean source of energy; it doesn't cause contamination in environment like industries west or noise contamination, since it silent through the operation (Abdul Rahman, 2011). Also its age is long and doesn't need any maintenance (Cytryan, 2006). The aim of study is to improve conversion efficiency of solar cell by using LSC that made of epoxy polymer doped with Rhodamine 6G dye.

Solar cell parameter

(i)Open circuit voltage (V_{oc}) which is equal to (Shur, 1995):

$$V_{oc} = \frac{K_B T}{q} \ln\left(\frac{I_{sc}}{I_s} + 1\right) \quad ...(1)$$

Where:
I_s: Saturation current
I_{sc}: Short circuit current
K_B: Boltzmann constant
T: Room temperature

(ii) Short circuit current (I_{sc}).

It is represent a maximum photocurrent can be get from the solar cell in optimum condition and it is equal to (Gratzel & Moser, 2003):

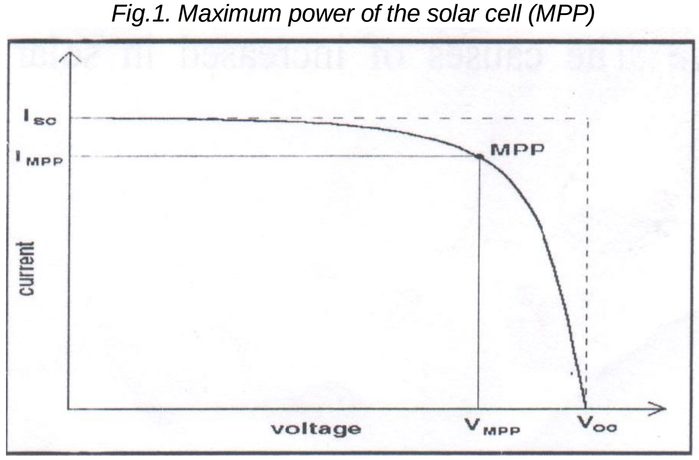
$$I_{sc} = I_s\left[\exp\left(\frac{qV_{oc}}{K_B T}\right) - 1\right] + \frac{V_{oc}}{R_{sh}} \quad ...(2)$$

Where:
R_{sh}=shunt resistance

(iii) Fill factor (FF).

It is represent the area under (I-V) characteristic of solar cell and it is equal to (Cytryan, 2006) (Fig.1):

Fig.1. Maximum power of the solar cell (MPP)



Indian Journal of Science and Technology Vol. 4 No. 12 (Dec 2011) ISSN: 0974- 6846

$$FF = \frac{I_m.V_m}{I_{sc}.V_{oc}} = \frac{P_m}{I_{sc}V_{oc}} \quad ...(3)$$

Where V_m,I_m represent maximum voltage and current at maximum output, or its the ratio of the maximum power point (MPP) divided by the open circuit voltage (V_{oc}) and the short circuit (I_{sc}) (Shur, 1995).

(iv) Conversion power efficiency η. A solar cell's energy conversion efficiency is the percentage of power converted (from absorbed light to electrical energy) and collected when a solar cell is connected to an electrical circuit. This term is calculated using the ratio of maximum power (p_m) divided by the input light irradiance (P_{in}) under standard test condition in (W/m^2) and the effective area of the solar cell a (in cm^2) (Alshaikh Hussin, 2010).

$$\eta = \frac{P_m}{P_{in}.a} \times 100\% = \frac{I_m V_m}{P_{in}.a} \times 100\% \quad ...(4)$$

An enhancement in the conversion power efficiency *(Δη%)* it's equal the different between conversion power efficiency by using (LSC)plate ($\eta\%_{LSC}$) and bare solar cell ($\eta\%_{bare}$) divided by the ($\eta\%_{bare}$) .

$$\Delta\eta = \frac{(\eta\%)_{LSC} - (\eta\%)_{bare}}{(\eta\%)_{bare}} \times 100\% \quad ...(5)$$

Optical properties of the epoxy

Optical properties of the epoxy, absorbance (A), transmittance (T) and reflectance (R) had been studied with and without Rhodamine 6G dye, to show its importance in determine the range of ability to use the epoxy in optical applied of solar cell.

The equation of A, T and R are (Alshaikh Hussin, 2010):

$$A = \log_{10}\frac{1}{T} \quad ...(6)$$

$$T = \exp(-\alpha t) \quad ...(7)$$

$$R = 1 - A - T \quad ...(8$$

Where:

α: is absorption coefficient.

t: is the thickness of the plates.

The absorption coefficient (α), extinction coefficient (k) and reflective index (n) has been calculated from the following equations respectively (Alshaikh Hussin, 2010).

$$\alpha = 2.303\frac{A}{T} \quad ...(9)$$

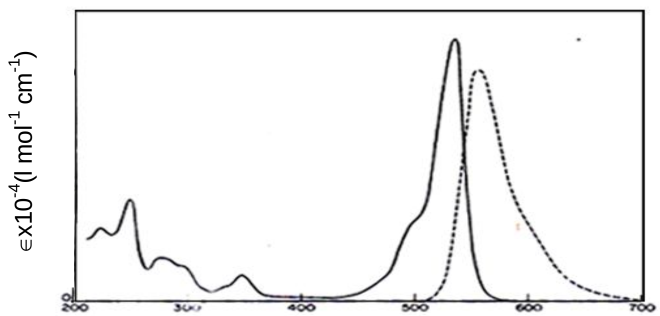
$$k = \frac{\alpha\lambda}{4\pi} \quad ...(10)$$

$$n = \left[\left(\frac{1+R}{1-R}\right)^2 - (k^2+1)\right]^{1/2} + \frac{1+R}{1-R} \quad ...(11)$$

The R6G has strong absorbance in visible region and also it has large cross section and that is what solar cells need (Kubine & Fletcher, 1982). (Fig.2)

Epoxy material has been used in manufacturing LSC for solar cells, it is polymers material, transparency, it has

Fig.2. Absorbance and fluorescence spectrum of R6G



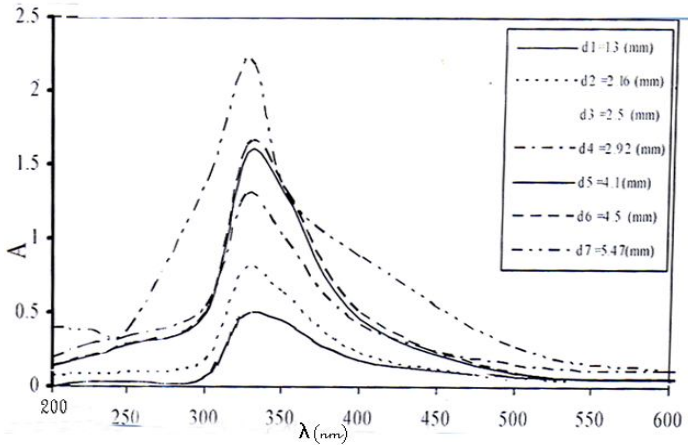
low viscosity, resistance to shocks and pressure, it doesn't effected by humidity and chemical materials, also it is electrical insulator material.

In this study, epoxy was used for the reasons such as: It is good solvent for R6G dye; High technique does not need to make LSC; It has high transparency and absorption coefficient at UV region, i.e. low absorbance in the range of the dye and solar cell absorbance and emitting; Availability and low cost materials; Rapid drying of LSC in laboratory without any assistance material; If has low refractive index (1.25) which gives a chance for fluorescent ray to transpire down from the critical angel toward the solar cell.

Experimental

All LSC plates have been prepared in Lab. with different thickness (0.5-6) mm and concentration of dye. Suitable amount of dye was weighted for a special concentration and dissolved in a volume by epoxy resin (a) directly and the mixtures had been mixed for 10 second then hardener (b) was added to the mixture and mixed and leave it 24 hours in room temperature until perfect polymerization and full curing. To be sure that all LSC plates are homogenous, optical measurements has been done for different regions for all plates. Lambda 9 Co. has been used to carryout the absorbance and transmittance spectrum in the wavelength range (0.4-1)µm region. Fluorescence spectrum for all the plates has been measured using spectrofluorometer (SL174) form ELICO limited Indian Co.

Fig.3. Absorption spectrums of pure epoxy plates in different thicknesses (d), $\lambda_{(max)}$ =325(nm)



Halogen lamp from PHYWE Co. model (SLV-1000-TUDIO) as sunsimulator has been used in lab. measurements. Solarmeter form DODGE. American Co. was used to measure the incident radiation on the solar cell.

Silicon solar cell of diameter (10cm) was used of a surface area (78.5±1.5) cm^2 thickness (0.5±0.15)mm. The applied base material of solar cell is a single-crystalline silicon which is n-type on the sensitized face. The short-circuit (I_{sc}) and open-voltage (V_{oc}) are measured using digital multimeter applied by Alpha. Co.

Results and discussion

The absorbance spectra for the pure epoxy plates at seven different thicknesses are shows in (Fig.3), the absorbance peak is appeared at (325nm) in ultraviolet region while in visible region it had lower absorbance and higher transmittance and that is what wanted in the substrate material because the visible region are the effect region for the solar cell (Rani *et al*., 2010).

Fig.4. Optical properties and optical constant of pure epoxy plate at thickness (d) = 4.5(mm)

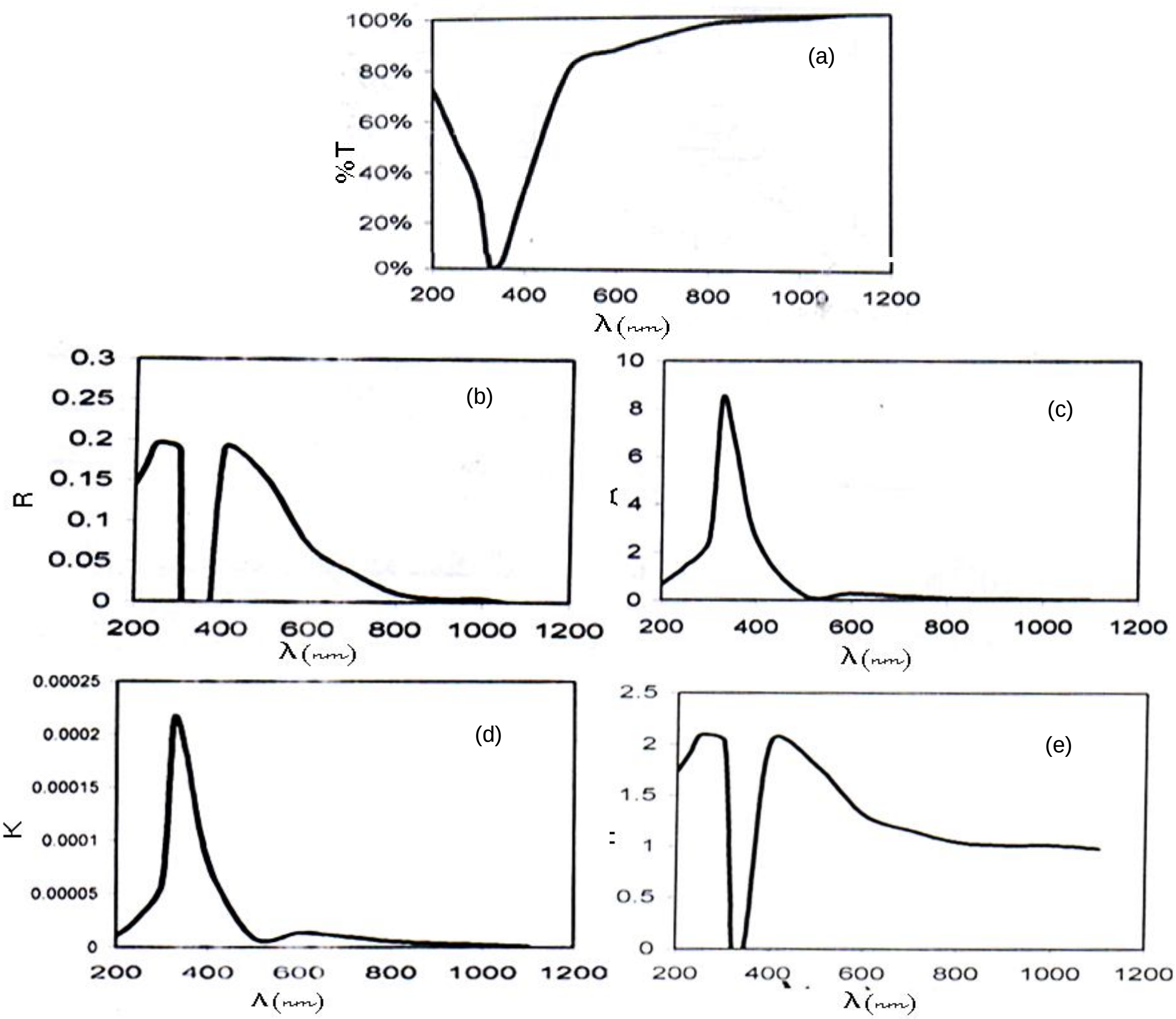


Fig.5.Stoke shift (Δλ) between top absorption spectrum and top fluorescence spectrum for pure epoxy plate in different thickness (d)

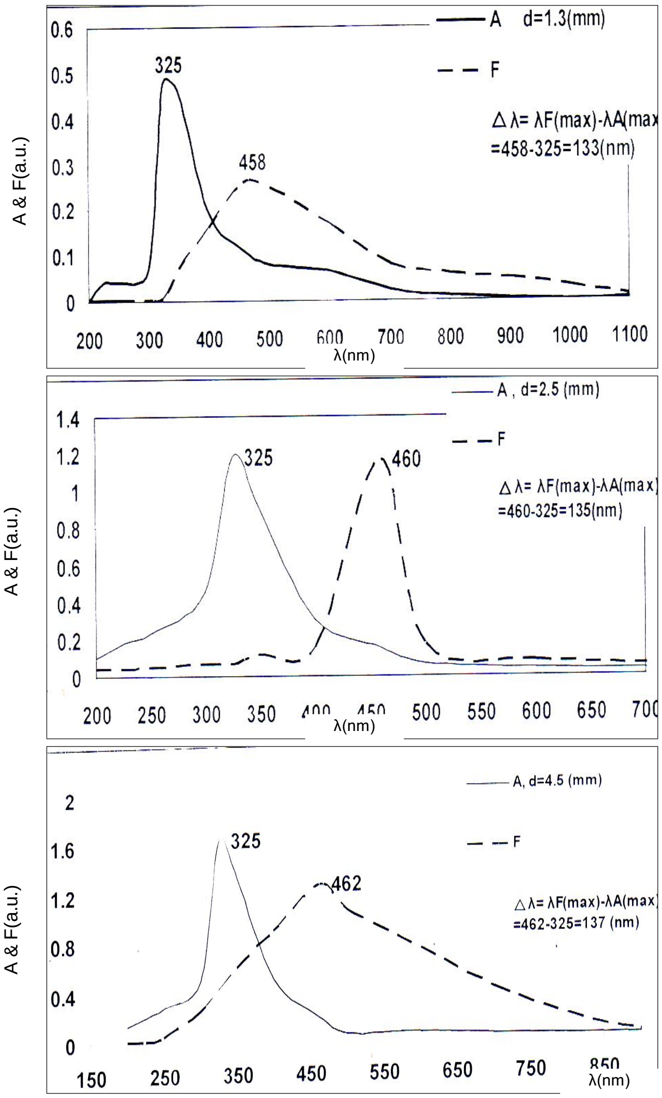
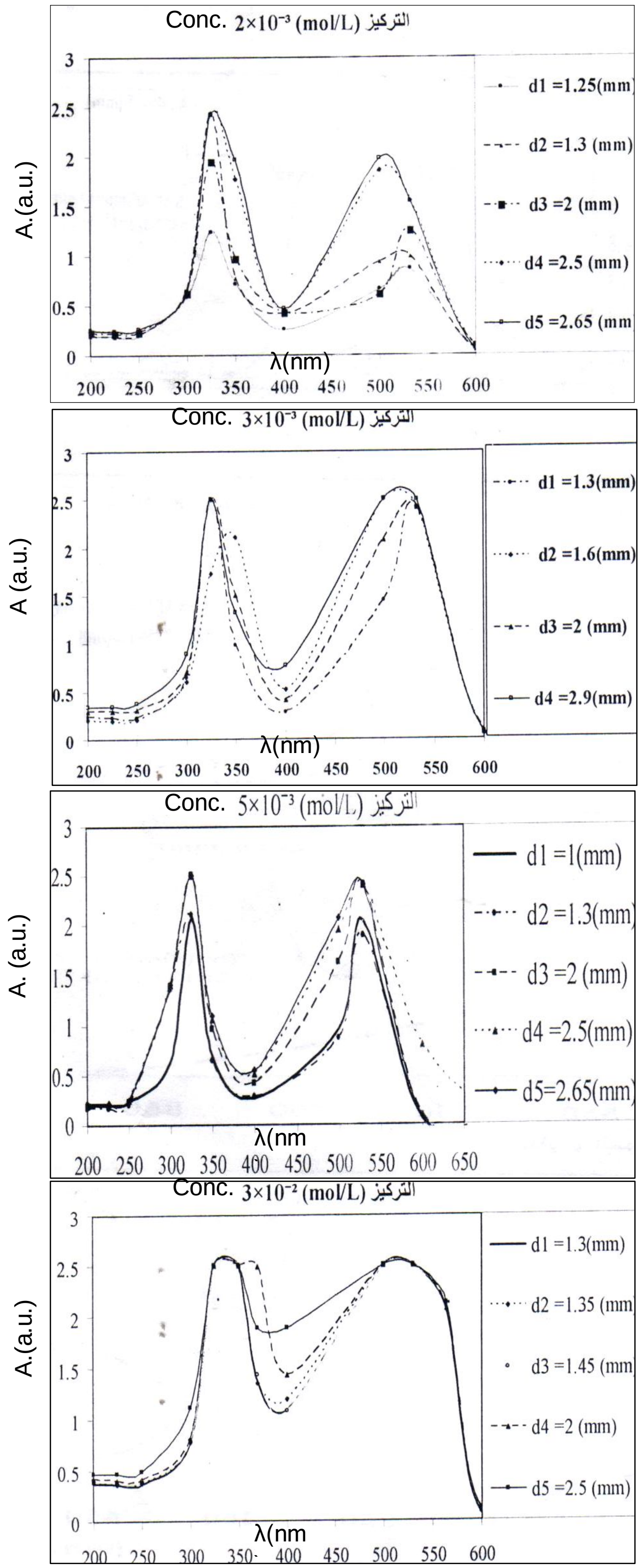


Fig.6.Relation between absorption and wavelength of (LSC) plates in different thickness (d) and concentration

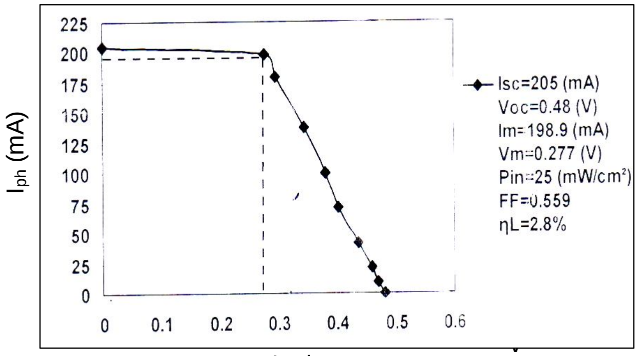


Transmittance of the pure epoxy plates are shown in (Fig.4a), the best transmittance was observed at wavelength (400-1000) nm which represent (90-98%), i.e. the plates have high transmittance in visible light, while the reflectance is shown in (Fig.4b) was small at those wavelengths. Absorption coefficient as a function of the wavelength was shown in (Fig.4c) it depends on the absorption and proportional directly with it and inversely with the thickness of the plats as in eq. (9).

From the calculation of extinction coefficient (k) using eq. (10), it was found that k is proportional directly with α and λ as shown in (Fig.4d) the value of refractive index (n) is (1.25) at (λ=700nm) as shown in (Fig.4e). Also fluorescence spectrums of pure epoxy plates with different thickness have be measured, this is red shift compare with absorbance spectrum i.e. Stock shift which is represent the difference between the peaks of absorbance and fluorescence is shown in (Fig.5).

Fig.7.Comparison between output parameters for bear solar cell at indoor and outdoor measurements

Out door



In door

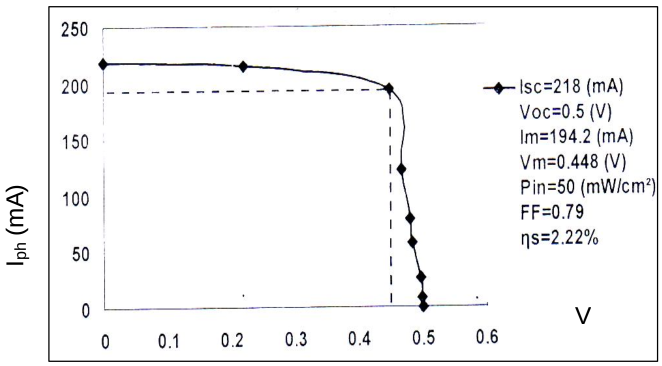
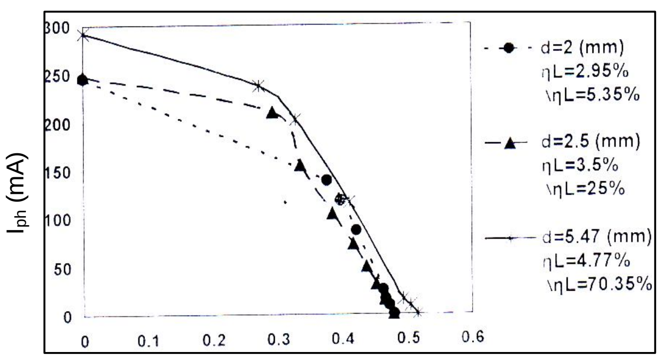


Fig.8.Comparison between conversion power efficiency by use pure epoxy plates and bare solar cell at indoor and outdoor measurements

outdoor



Indoor

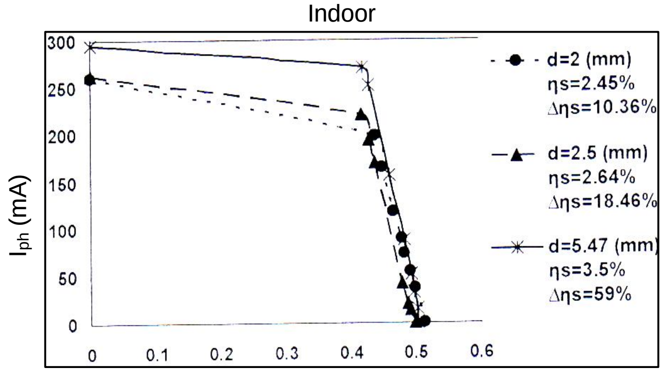


Fig.9.Relation of transmittance and wavelength for (LSC) plates in concentration (5x10^{-5}mol/L) and in different thickness (d)

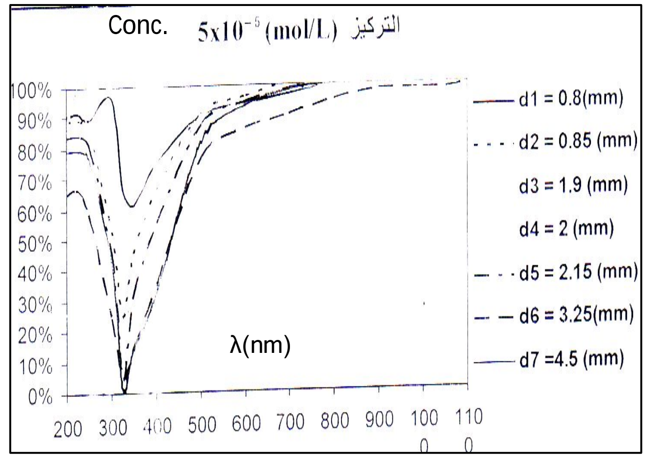
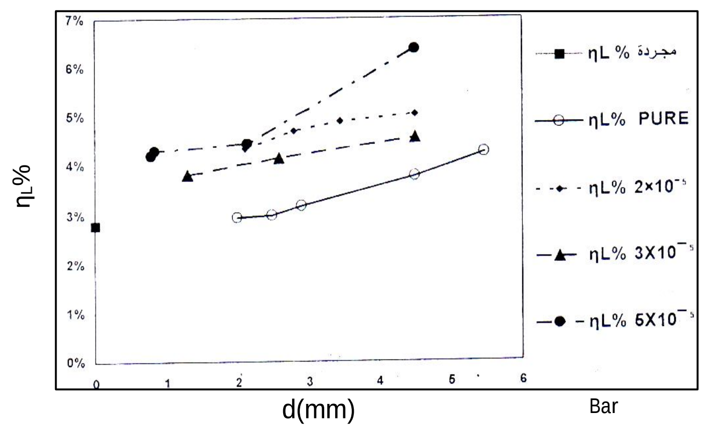
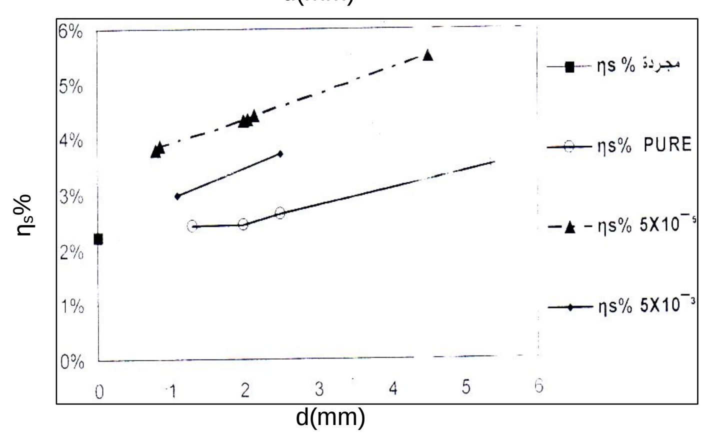


Fig.10. Increasing in conversion power efficiency with increasing (LSC) plates thickness of different concentration at indoor and outdoor measurements

Bar



Bar



Indian Journal of Science and Technology Vol. 4 No. 12 (Dec 2011) ISSN: 0974- 6846

Absorbance spectrum of all LSC plates at different thickness and concentration has been measured and depicted in (Fig.6), the first peak represents the absorbance of the pure epoxy at wavelength (325nm) and the second peak is belong to the R6G between the wavelength (525-530) nm.

The epoxy polymer has been used as solvent of the dye instead of any other solvent to avoid the negative effect on the polymer, and the peak of the absorption spectrum of the dye in LSC is like the stander peak of R6G which solvent in Ethanol (Schafer, 1977; Kubin & Fletcher, 1982). Conversion power efficiency of bare solar cell has been measured indoor and outdoor and compared with conversion power efficiency of solar cell with epoxy plate of different thickness as shown in (Fig.7) and (Fig.8). The cause of the increasing of the conversion power efficiency is the shift of the spectrum from UV region to visible region which is the more response to the solar cell. Transmittance of all LSC plates at different thickness has been studied and noticed that at concentration ($5x10^{-5}$mol/L) transmittance in visible region reach 98% as shown in (Fig.9) and it decreased with increasing thickness and concentration of LSC plate (Singh, 2009). The LSC plates have been designed to enhance the solar cell conversion power efficiency as in (Fig.10) shown an increasing in the conversion power efficiency of solar cell with increasing of the concentration dye and thickness of all plates.

Conclusions

R6G dye dissolve directly in Epoxy resin. Epoxy material has been used at first time in form of plate doped and undoped with R6G dye to improved the efficiency of solar cell. The LSC plate at concentration ($5x10^{-5}$mol/L) and thickness (4.5mm) gives the highest conversion power efficiency of solar cell.

References

1. Abdul Rahman F (2011) NTU unveils new center to develop solar cells and clean energy systems of tomorrow. *Nanyong Technol. Univ*. 6, 656-790.
2. Alshaikh Hussin SH (2010) Luminescent plates doped with stilbene 420 dye for enhanced silicon solar cell performance: Down- Conversion. *J. Irq. Appl. Phys.* 6, 3-8.
3. Alshaikh Hussin SH (2010) Study the optical properties of transparent epoxy resin (Epoprimer) plates. *J. Baghdad Sci.* Iraq. 1, 20-30.
4. Bargers A, Slooff L, Büchtemann A, and van Roosmalen JAM (2006) Performance of single layer luminescent concentrators with multiple dyes. *IEEE 4th WCPEC.*
5. Cytryan N, (2006) Solar power from photovoltaic. U.S. Department of Energy's office of Efficiency and Renewable Solar Energy.
6. Dick KG de Boer (2010) Luminescent solar concentrators: the road to low-cost energy from the sun. *Solar & Alternative Energy. SPIE*. 10,1-3.
7. Ghosh S Shcherbatyuk G, Inman R and Clayton J (2010) Nanostructured luminescent solar concentrators. *SPIE*. 10, 1-2.
8. Goetzberger A and Grenbel W (1977) *Appl. Phys*. **14,** pp:123-149.
9. Gratzel M and Moser JE (2003) Solar energy conversion. *Electron Transf. Chem.* Switzerland. 5, pp.3 .
10. Kubine RF and Fletcher AN (1982) Fluorescence quantum yields of some Rhodmine dyes. *J. Luminescence*. 27, pp.455.
11. Rani S, Shishodia PK and Mchra RM (2010) Development of dye with broadband absorbance in visible spectrum for an efficient dye- sensitized solar cell. *J. Renewable & Sustainable Energy*. 2, 1-8.
12. Schafer FP (1977) Dye laser topic in applied physics. *Springer-Verlage.* Berlin. 1.
13. Shur M (1995) Physics of semiconductor devices. Hall of India, New Delhi, 1st ed.
14. Singh V (2009) Optoelectronic study of interface and Ifs related effects in organic electronic dives Kyuta car. Kys shu. Inst. Technol. PhD. Thesis, Japan. 8, (1-184).
15. Slooff LH, Kinderman R, Burgers ARJ, van Roosmalen JAM, Büchtemann A, Danz R, Meyer TB, Chatten AJ, Farrell D and Barnham KWJ (2007) The luminescent concentrator. *Proc. Of 22nd European Photovoltaic Solar Energy Conf.* Milan.
16. Yuan Z, Pucker G, Marconi A, Sgrignuoli F, Anopchenko A, Jestin Y, Ferrario L, Bellutti P and Pavesi L (2011) energy materials and solar cells. *Solar Energy Materials & Solar cells*. 95, 1224-1227.