Investigation of the Non-linear Properties of Hybrid Chlorophyll a doped TiO_2 Nano Particles

Ali H. Al-Hamdani, Ehsan Mohsen Abass, Slafa I. Ibrahim , Abdul Kareem A.Al-Khafaj, Durree Adnan, Yasmeen Z. Dawood, Mostafa Jabir and Wesam A.A. Twej

Abstract- ***Our work is studying the optical nonlinearity properties of Chlorophyll-a doped epoxy resin polymer with TiO_2 nanoparticle effect. Using EZ-scan technique with continuous wave Nd: Chlorophyll YAG laser operating at (532) nm wavelength as an excitation source. The samples exhibit absorption nonlinearities which due to saturable absorption (SA) process. The nonlinear refractive index n2 is a positive sign, indicates self-focusing optical nonlinearity process. The nonlinear refractive index n2, and the nonlinear absorption coefficient B are found to be of the order of 10^{-11} cm^2/W and 10^{-1} cm/W respectively. The Tio_2 nanoparticle concentration enhancing the nonlinear optical properties of samples.***

Index Terms— **eclipsing scan, nonlinear optics, Chlorophyll, and nonlinear refractive index.**

I. INTRODUCTION

HE phase, change the frequency of incident light, and the polarization could be control for nonlinear optical properties of materials. The field which study of the phenomena that happen as a result of the amendment of the optical properties of a material system in the presence of light called non-linear optics. The laser light is preferred to modify the optical properties of system due to the high intensity of it. The optical properties of organic materials have been attracting considerable attention, and this due to their it can be used in several applications in optoelectronic and photonic applications such as, optical switching, optical telecommunications devices, and optical disks [1-5]. The liquid system of organic dye have some the problems, so, the solid matrices containing host doped with dyes have been developed to solve this problem [6-8]. In recent years nanoparticle composites have attracted the attention of many researchers due to their great enhancement in the mechanical, electrical, optical, magnetic, thermal and nonlinear optical properties. Which have, the development of fast, low optical loss materials and large values of third order nonlinear susceptibility χ [9-12]. The Z-scan technique proposed by Sheik-Bahae based on the spatial distortion of a laser beam is a simple method to study the nonlinear optical properties of materials [13-17]. Recently, the focus was of interest in the outer edges of the beam rather than the central part, to increase the sensitivity, and the name of the method is eclipsing Z-scan or EZ-scan [18-23].

In this work the effect TiO_2 nanoparticles on the nonlinear optical properties of Chlorophyll dye doped epoxy resin polymer was studied using EZ-scan technique. This work is a part of the continuous effort of The Energy and Renewable Energies Technology Center, University of Technology, Baghdad, Iraq [24-77]

Ali H. Al-Hamdani, is currently Assistant Prof in Laser and Optoelectronics Engineering Department, University of Technology, Baghdad IRAQ. Email; - 140002@uotechnology.edu.iq
Ehsan Mohsen Abass, is currently with Dijlah university College, Baghdad, Iraq.
Slafa I. Ibrahim, is currently lecturer in University of Technology, Energy and Renewable Energies Technology Center. Email;- 11009@uotechnology.edu.iq
AbdulKareem A.Al-Khafaj, is currently with Department of Physics, College of Education for pure Science/ Ibn Al-Haitham, University of Baghdad, Iraq.
Durree Adnan, Yasmeen Z. Dawood, and Mostafa Jabir, are currently in Department of physics, College of Education.University os Al-Mustansiriya,Iraq.
Wesam A.A.Twej, is currently with Department of Physics, College of Science, University of Baghdad, Baghdad, Iraq.

EXPERIMENTAL

A. Material:

The Chlorophyll dye was extracted from the parsley according to the method used by N. Yamauchi and T. Minamide (1985) method.
The dye has the chemical formula ($C_{55}H_{72}MgN_4O_5$) and molar mass (893.51 g/mol).
Acetone has the chemical formula (CH_3COCH_3) and molar mass (58.08 g/mol) with purity (99 %), from the Gainland Chemical Company (UK).
The dye doped in epoxy resin (Euxit 50 KI) supplied by Egyptian Swiss chemical industries company, which consists of two materials, the first called the base (resin), denoted by the letter (A), and the second material called sclerosing (hardener) and denoted by the letter (B) with ratio mixer (A:B) (3:1). The TiO_2 nanoparticle was used with particle size (25) nm, which supplied from Intelligent Materials Pvt. Ltd company.

B. EZ-Scan method:

To determine nonlinear optical properties dyes we employed the EZ-scan technique developed by T. Xia et al. EZ-scan experiments were performed with Nd:YAG laser at (532) nm wavelength. The laser beam has a beam waist of (85) μm, and the Rayleigh length ZR of (42) mm. A 30 cm focal length lens was used with input power (10) mW, and the sample thickness is (0.6) mm.

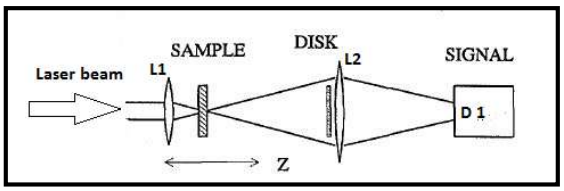

Fig. 1: Experimental setup of EZ-scan

The nonlinear absorption coefficient was calculated by using the normalized transmittance T(z) [9,10,11]:

$$\boldsymbol{T(z)} = \sum_{m=0}^{\infty} \left[\frac{[-q_0(z)]^m}{(m+1)^{3/2}}\right] \quad (1)$$

Where:

qo (z)= Io Leff β / [1+], and , the effective length of the sample, L is the thickness of the sample, α is a linear absorption coefficient, and I0 is the intensity of the laser beam at the focus (z = 0).

The nonlinear refraction n2 was calculated according equation [12]:

$$\boldsymbol{n_2 = \Delta\Phi_0 / I_0 L_{eff} k} \quad (2)$$

Where:

$$\Delta T_{pv} = 0.68(1-S)^{-0.44} |\Delta\Phi_0|$$

III. RESULT AND DISCUSSION

The absorption spectrum of α-Chlorophyll doped epoxy resin with different weight of TiO_2 nanoparticle is shown in figure (2). It was noted the α-Chlorophyll spectrum invisible reign of light, and the absorption peak at a wavelength (670) nm, which increase as the concentration of TiO_2 increased.

Open EZ-scan was used in order to calculate the nonlinear absorption coefficient β of the samples. The figure (3) showed the transmittance of laser beam after pass through the sample, which varies with position of the sample (z). It was observed, when the samples away from focal point (z=0), the nonlinear exhibit does not appear, and when the sample close to the focus (z=0), the transmittance increase to form a peak at the focus, which indicates the saturable absorption (SA), i.e. negative type of nonlinear absorption coefficient [13].

The closed aperture EZ-scan was used by placing the disc in front of the photodetector, this allowed to determine the magnitude and sign of the nonlinear refraction index (n2). The closed aperture curve from close EZ-scan of the samples at different concentration of nanoparticle is shown in figure (4). The EZ-scan curve exhibits peak–valley and change to valley–peak the nanoparticle concentration increased, this signature indicates the self-defocusing and self-focusing, where self-defocusing is negative nonlinear refractive index n2 and self-focusing is a positive nonlinear refractive index n2 [14].

The nonlinear optical properties of samples an increase as the concentration of the nanoparticle increased, as shown in the table (1). This may be attributed to increase the particles which absorb the laser light, and enhancing the thermal effect, where, the nonlinearity is due to thermal effects under CW laser irradiation [15].

Thus, increase the concentration of the nanoparticle enhancing the nonlinear optical properties of the samples. This good, to use the properties of these materials in various optical applications. The results of nonlinear optical properties of samples are agreed with the work of researcher [16, 17].

IV. CONCLUSION

We have studied the nonlinear optical properties of α-Chlorophyll doped epoxy resin at various concentrations of TiO_2 nanoparticle by using EZ-scan method with Nd:YAG laser at 523 nm wavelength. The dyes were characterized by a negative nonlinear absorption coefficient. It was observed an increase in nonlinear optical properties of samples as the concentration of nanoparticle increased, and the samples showed large nonlinearity properties.

REFERENCES

[1] S. Pramodini and P. Poornesh, "Optics and Laser Technology," 63, 114-119, 2014.
[2] R. S. Gawaad, S. K. Sharma and S. S. Sambi, Comparative Study of Nana and RO Memrance for Sodium Sulphate Recovery from Industrial Waste Water, ARPN Journal of Engineering and Applied Sciences, 6(11), 1-6, 2011.
[3] M.T. Chaichan & K. I. Abaas, "Practical Investigation for Improving Concentrating Solar Power Stations Efficiency in Iraqi Weathers," Anbar J for Engineering Science, 5(1), 76-87, 2012.
[4] M.T. Chaichan & H.A. Kazem, "Using Aluminum Powder with PCM (Paraffin Wax) to Enhance Single Slope Solar Water Distillator Productivity in Baghdad-Iraq Winter Weathers," International Journal of Renewable Energy Research, 1(5), 151-159, 2015.
[5] M.T. Chaichan & S.T. Ahmed, "Evaluation of Performance and Emissions Characteristics for Compression Ignition Engine Operated with Disposal Yellow Grease," International Journal of Engineering and Science, 2(2), 111-122, 2013.
[6] R.W. Boyd, 3rd edition, Rochester, New York, 2007.
[7] M.T. Chaichan & H.A. Kazem, "Water Solar Distiller Productivity Enhancement Using Concentrating Solar Water Heater and Phase Change Material (PCM)," Case Studies in Thermal Engineering, Elsevier, 5: 151-159, 2015.
[8] RS. Gawaad, S.S. Sambi, S.K. Sharma, Nano Filtration Membrane in Dairy Plant, International Journal of Heat and Mass Transfer- Theory and Applications(IREHEAT), 3(4), 481-485, 2011.
[9] M.T. Chaichan, H.A. Kazem, A. A. Kazem, K. I. Abaas, K.A.H. Al-Asadi, "The Effect of Environmental Conditions on Concentrated Solar System in Desertec Weathers," International Journal of Scientific and Engineering Research, 6(5), 850-856, 2015.
[10] M.T. Chaichan, K.I. Abaas, H.A. Kazem, "Design and Assessment of Solar Concentrator Distillating System Using Phase Change Materials (PCM) Suitable for Desertec Weathers," Desalination and Water Treatment, 57(32), 14897-14907, 2016. DOI: 10.1080/19443994.2015.1069221
[11] M.T. Chaichan, K.I. Abaas, "Performance Amelioration of a Trombe Wall by Using Phase Change Material (PCM)," International Advanced Research Journal in Science, Engineering and Technology, 2(4), 1-6, 2015.
[12] H.A. Kazem, M.T. Chaichan, S.A. Saif, A.A. Dawood, S.A. Salim, A.A. Rashid, A.A. Alwaeli, "Experimental Investigation of Dust Type Effect on Photovoltaic Systems in North Region, Oman," International Journal of Scientific & Engineering Research, 6(7), 293-298, 2015.
[13] A.H. Al-Hamdani, S.I. Ibrahim, R.S. Jawad, R. Nader, D. Adnan, M. Jabir, Non-linear Properties Measurement for Liquid Solution of α-Chlorophyll Dissolved in Acetone, International Journal of Computation and Applied Sciences IJOCAAS, 1(2), 28-36, 2016
[14] A. H. Al-Hamdani, A. S. Al-Ethawi and R. Al-Hamdani, Journal of Materials Science and Engineering, Vol. 4, pp. 58-61, (2010).
[15] M.T. Chaichan and K.A.H. Al-Asadi, "Environmental Impact Assessment of Traffic in Oman," International Journal of Scientific & Engineering Research, 6(7), 493-496, 2015.

[16] H.A. Kazem and M.T. Chaichan, "Effect of Humidity on Photovoltaic Performance Based on Experimental Study," International Journal of Applied Engineering Research (IJAER), 10(23), 43572-43577, 2015.
[17] R.S. Jawad, M. T. Chaichan, J.A. Kadhem, Nanoparticles (NPS) Leverage in Lithium-Ion Batteries Performance, International Journal of Pharmacy & Technology (IJPT), 8(3), 18995-19004 , 2016.
[18] H.A. Kazem, Al-Waeli A H A, A.S.A. Al-Mamari, A.H.K. Al-Kabi, M.T. Chaichan, "A Photovoltaic Application in Car Parking Lights with Recycled Batteries: A Techno-Economic Study," Australian Journal of Basic and Applied Science, 9(36), 43-49, 2015.
[19] H.M.S. Al-Maamary, H.A. Kazem and M.T. Chaichan, "Changing the Energy Profile of the GCC States: A Review," International Journal of Applied Engineering Research (IJAER), 11(3), 1980-1988, 2016.
[20] H.A. Kazem, M.T. Chaichan, "Experimental Analysis of the Performance Characteristics of PEM Fuel Cells," International Journal of Scientific & Engineering Research, 7(2), 49-56, 2016.
[21] M.T. Chaichan, H.A. Kazem, "Experimental Analysis of Solar Intensity on Photovoltaic in Hot and Humid Weather Conditions," International Journal of Scientific & Engineering Research, 7(3), 91-96, 2016.
[22] In-Yup Jeon, and Jong-BeomBaek, Materials, Vol. 3, pp. 3654-3674, (2010).
[23] G. Somasundaram and A. Ramalingam, Journal of Luminescence, Vol. 90, pp. 1-5, (2000).
[24] M.T. Chaichan, O.K. Marhoon, B.A. Mohammed, "The Effect of Spark Ignition Engine Cold Starting Period on the Emitted Emissions," Scientific and Eng. Reports, vol. 1, No.1, pp. 1-8, 2016. DOI: 10.18282/ser.v1.i1.40
[25] M.T. Chaichan, H.A. Kazem, T.A. Abid, "The Environmental Impact of Transportation in Baghdad, Iraq," Environment, Development and Sustainability, 2016. DOI: 10.1007/s10668-016-9900-x.
[26] M.T. Chaichan, J.A. Kadhum, K.S. Riza, "Spark Ignition Engine Performance When Fueled with NG, LPG and Gasoline," Saudi Journal of Engineering and Technology, 1(3), 105-116, 2016.
[27] Aya H. Makki, Ali H. AL-Hamadani and Mohammed Abdulridha Husien, "Dopant Effect on The Nonlinear Optical Properties of TiO2-PMMA Nano Composites for Optical Limiter Applications", Eng. and Tech.Journal, Vol. 34, pp. 1013-1016, (2016).
[28] A.H. Al-Waeli, K. Sopian, H.A. Kazem and M.T. Chaichan, "Photovoltaic Solar Thermal (PV/T) Collectors Past, Present and Future: A Review," International Journal of Applied Engineering Research, 11(22), 1075-10765, 2016.
[29] M.T. Chaichan, "GEM Ternary Blends Utilization as an Alternative to Conventional Iraqi Gasoline to Suppress Emitted Sulfur and Lead Components to Environment," Al-Khwarizmi Journal, 12(3), 38-51, 2016.
[30] M.T. Chaichan, "Spark Ignition Engine Performance Fueled with Hydrogen Enriched Liquefied Petroleum Gas (LPG)," Scholars Bulletin Journal, 2(9), 537-546, 2016.
[31] H.A. Kazem and M.T. Chaichan, "Experimental Effect of Dust Physical Properties on Photovoltaic Module in Northern Oman," Solar Energy, 139, pp: 68–80, 2016.
[32] M.T. Chaichan, H.A. Kazem, "Energy Conservation and Management for Houses and Building in Oman-Case study," Saudi Journal of Engineering and Technology, 1(3), 69-76, 2016.
[33] M. Sheik-bahae, A. A. Said, and E. W. Van Stryland, "High-sensitivity, single-beam n2 measurements", OPTICS LETTERS ,Vol.14, pp. 955-597, (1989).
[34] M. Sheik -Bahae, A. A. Said, T. H. Wei, D. J. Hagan, and E. w. Van stryland, IEEE Journal of Quantum Electronics. VOL. 26, pp. 405-414, (1990).
[35] A. H. AL-Hamdani, A. H. Ali, M. H. Mohamed, "Spectral and Third Non-Linear Properties for Mixture Solutions of (R6G, RB, AND RC) Dyes", Eng. & Tech. Journal, 33(1), 273-284, 2015.
[36] R. Nader, A.H. AL-Hamadani, S.I. Ibrahim, and R.A.U. Aed Ullah, "Non-Linear Properties for Memberances of Rhodamine Tincture by using Z-Scan Techniques", International Journal of Application or Innovation in Engineering &Management, 4(9), 52-57, 2015.
[37] H.A. Kazem and M.T. Chaichan, "Design and Analysis of Standalone Solar Cells in the Desert of Oman," Journal of Scientific and Engineering Research, 3(4), 62-72, 2016.
[38] A.H. Al-Waeli, H.A. Kazem, M.T. Chaichan, "Review and Design of a Standalone PV System Performance," International Journal of Computation and Applied Sciences IJOCAAS, 1(1), 1-6, 2016.
[39] H.A. Kazem and M.T. Chaichan, "The Impact of Using Solar Colored Filters to Cover the PV Panel on its Outcomes," Bulletin Journal, 2(7), 464-469, 2016. DOI: 10.21276/sb.2016.2.7.5.
[40] A. H. Al-Hamdani, S. I. Ibrahim, Raid S. Jawad, Rajaa Nader, Durree Adnan, AND Mostafa Jabir, "Non-linear Properties Measurement for Liquid Solution of α-Chlorophyll Dissolved in Acetone", International Journal of Computation and Applied Sciences IJOCAAS, Vol. 1, Issue 2, p (28-36), OCTOBER 2016.
[41] M.T. Chaichan, K.I. Abass, D.S.M. Al-Zubidi, H.A. Kazem, "Practical Investigation of Effectiveness of Direct Solar-Powered Air Heater," International Journal of Advanced Engineering, Management and Science (IJAEMS), 2(7), 1047-1053, 2016.
[42] M.T. Chaichan, K.I. Abaas K I, D.S.M. Al-Zubidi, "A Study of a Hybrid Solar Heat Storage Wall (Trombe Wall) Utilizing Paraffin Wax and Water," Journal of Research in Mechanical Engineering, 2(11), 1-7, 2016.
[43] H.A. Kazem, H.A.S. Al-Badi, A.S. Al-Busaidi & M.T. Chaichan, "Optimum Design and Evaluation of Hybrid Solar/Wind/Diesel Power System for Masirah Island," Environment, Development and Sustainability, 2016. DOI: 10.1007/s10668-016-9828-1
[44] M.T. Chaichan, "Effect of Injection Timing and Coolant Temperatures of DI Diesel Engine on Cold and Hot Engine Startability and Emissions," IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE), 13(3-6), 62-70, 2016.
[45] M.B. Alsous, M.D. Zidan, Z. Ajji, A. Allahham, Optik, 125, 5160–5163, 2014.
[46] M.T. Chaichan, H.A. Kazem, K.I. Abaas, A.A. Al- Waeli, "Homemade Solar Desalination System for Omani families," International Journal of Scientific & Engineering Research, 7(5), 1499-1504, 2016.
[47] M.T. Chaichan, H.A. Kazem, A.M.J. Mahdy & A.A. Al-Waeely, "Optimization of Hybrid Solar PV/Diesel System for Powering Telecommunication Tower," IJESET, 8(6), 1-10, 2016.
[48] M.T. Chaichan, H.A. Kazem, A.M.J. Mahdy & A.A. Al-Waeely, "Optimal Sizing of a Hybrid System of Renewable Energy for Lighting Street in Salalah-Oman using Homer Software," International Journal of Scientific Engineering and Applied Science (IJSEAS), 2(5), 157-164, 2016.
[50] M.T. Chaichan, O.K. Maroon, K.I. Abaas, "The Effect of Diesel Engine Cold Start Period on the Emitted Emissions," International Journal of Scientific & Engineering Research, 7(3), 749-753, 2016.
[51] T. Xia, D. J. Hagan, M. Sheik-Bahae, and E. W. Van Stryland, Optics letters, 19, 317-319, 1994.
[52] S. Pramodini, P. Poornesh, Y.N. Sudhakar, M. Selva Kumar, Optics Communications, 293, 125-132, 2013.
[53] S. Pramodini, P. Poornesh, Optics & Laser Technology, 62, 12–19, 2014.
[54] M.T. Chaichan, A.H Al-Hamdani, A.K. Kasem, "Enhancing a Trombe Wall Charging and Discharging Processes by Adding Nano-Al2O3 to Phase Change Materials," International Journal of Scientific & Engineering Research, 7(3), 736-741, 2016.
[55] M.T. Chaichan, "EGR Effects on Hydrogen Engines Performance and Emissions," International Journal of Scientific & Engineering Research, 7(3), 80-90, 2016.
[56] M.T. Chaichan, Q.A. Abass, "Effect of Cool and Hot EGR on Performance of Multi-cylinder CIE Fueled with Blends of Diesel and Methanol," Al-Nahrain Collage of Engineering Journal, 19(1), 76-85, 2016.
[57] S. Pramodini and P. Poornesh, Optics and Laser Technology, Vol. 63, pp. 114-119, (2014).
[58] D. Yan, S. You-Yi, W. Pie, Z. Deu-Guo, J. Xiao-Jin, M. Hai, Z. Qi-Jing, J. Yang, and S. Xiao-Quan, Chinese Physics Letters, Vol. 24, pp. 954-956, (2007).
[59] H. Mazin, H.A. Kazem, H.A. Fadhil, S. Alawi and M.T. Chaichan, "Global Linear, Nonlinear and ANN-Based Modeling of Monthly Diffuse Solar Energy," WREC XIV Proceedings, University POLITEHNICA of Bucharest, Romania, June 8 – 12, 2015.
[60] H.A. Kazem, M.T. Chaichan, A.H. Alwaeli and K. Mani, "Effect of Shadow on the Performance of Solar Photovoltaic," WREN/WREC World Renewable Energy Congress, Rome, Italy, 2015.
[61] S.T. Ahmed and M.T. Chaichan, "Effect of Fuel Cetane Number on Multi-Cylinders Direct Injection Diesel Engine Performance and Emissions," Al-Khwarizmi Eng. Journal, 8(1), 65-75, 2012.
[62] M.T. Chaichan, H.A. Kazem, "Energy Conservation and Management for Houses and Building in Oman-Case study," Saudi Journal of Engineering and Technology, 1(3), 69-76, 2016.

[64] H.A. Kazem, J.H. Yousif, M.T. Chaichan, "Modeling of Daily Solar Energy System Prediction using Support Vector Machine for Oman," International Journal of Applied Engineering Research, 11(20), 10166-10172, 2016.

[65] M.T. Chaichan, K.I. Abaas and H.M. Salih, "Practical Investigation for Water Solar Thermal Storage System Enhancement using Sensible and Latent Heats in Baghdad-Iraq weathers," Journal of Al-Rafidain University Collage for Science, 33, 158-182, 2014.

[66] R.S. Jawad, M.T. Chaichan, J.A. Kadhum, "Nanoparticles (NPs) Leverage in Lithium-Ion Batteries Performance," International Journal of Pharmacy & Technology, 8(3), 18995-19004, 2016.

[67] A.H. Al-Waeli, K. Sopian, H.A. Kazem and M.T. Chaichan, "Photovoltaic Solar Thermal (PV/T) Collectors Past, Present and Future: A Review," International Journal of Applied Engineering Research, 11(22), 1075-10765, 2016.

[68] H.A. Kazem, A.H.A. Al-Waeli, M.T. Chaichan, A.S. Al-Mamari, A.H. Al-Kabi, "Design, Measurement and Evaluation of Photovoltaic Pumping System for Rural Areas in Oman," Environment, Development and Sustainability, DOI: 10.1007/s10668-016-9773-z, 2016.

[69] M.T. Chaichan, J.A. Kadhum, K.S. Riza, "Spark Ignition Engine Performance When Fueled with NG, LPG and Gasoline," Saudi Journal of Engineering and Technology, 1(3), 105-116, 2016. DOI: 10.21276/sjeat.2016.1.3.7

[70] A.H. Al-Waeli, H.A. Kazem, M.T. Chaichan, "Review and Design of a Standalone PV System Performance," International Journal of Computation and Applied Sciences IJOCAAS, 1(1), 1-6, 2016.

[71] M.T. Chaichan, H.A. Kazem, K.I. Abaas, A.A. Al-Waeli, "Homemade Solar Desalination System for Omani Families," International Journal of Scientific & Engineering Research, 7(5), 1499-1504, 2016.

[72] H.A. Kazem, H.A.S. Al-Badi, A.S. Al Busaidi and M.T. Chaichan, "Optimum Design and Evaluation of Hybrid Solar/Wind/Diesel Power System for Masirah Island," Environment, Development and Sustainability, 2016. DOI: 10.1007/s10668-016-9828-1

[73] M.T. Chaichan, K.I. Abaas, D.S.M. Al-Zubidi, H.A. Kazem, "Practical Investigation of Effectiveness of Direct Solar-Powered Air Heater," International Journal of Advanced Engineering, Management and Science (IJAEMS), 2(7), 1047-1053, 2016.

[74] H.A. Kazem, M.T. Chaichan, I.M. Al-Shezawi, H.S. Al-Saidi, H.S. Al-Rubkhi, J.K. Al-Sinani and A.H.A. Al-Waeli, "Effect of Humidity on the PV Performance in Oman," Asian Transactions on Engineering, 2(4), 29-32, 2012.

[75] M.T. Chaichan, H.A. Kazem, T.A. Abid, "The Environmental Impact of Transportation in Baghdad, Iraq," Environment, Development and Sustainability, 2016. DOI: 10.1007/s10668-016-9900-x.

[76] S.S. Faris, M.T. Chaichan, M.F. Sachit and J.M. Jaleel, "Simulation and Numerical Investigation of Effect Air Gap Thickness on Trombe Wall System," International Journal of Application or Innovation in Engineering & Management (IJAIEM), 3(11), 159-168, 2014.

[77] M.T. Chaichan, O.K. Marhoon, B.A. Mohammed, "The Effect of Spark Ignition Engine Cold Starting Period on the Emitted Emissions," Scientific and Eng. Reports, 1(1), 1-8, 2016. DOI: 10.18282/ser.v1.i1.40

TABLE (1)
NONLINEAR PROPERTIES OF SAMPLES DOPED NANOPARTICLE

wt.% Nano	T%	α (cm)-1	Leff (cm)	absorption coefficient (β)	$\Phi * 10^{-5}$	nonlinear refractive index(n_2) $*10^{-11}$
0wt.%	85.905	3.08602	0.0463335	0.043022885	0.0411767	0.39447
0.1wt.%	30.276	23.85908	0.029199	0.307205905	0.159176	0.312972
0.2wt.%	3.18	70.14938	0.013828	0.693032202	0.817984	1.1551
0.3wt.%	8.308	50.8963	0.0181056	0.536727547	2.09638	3.11622

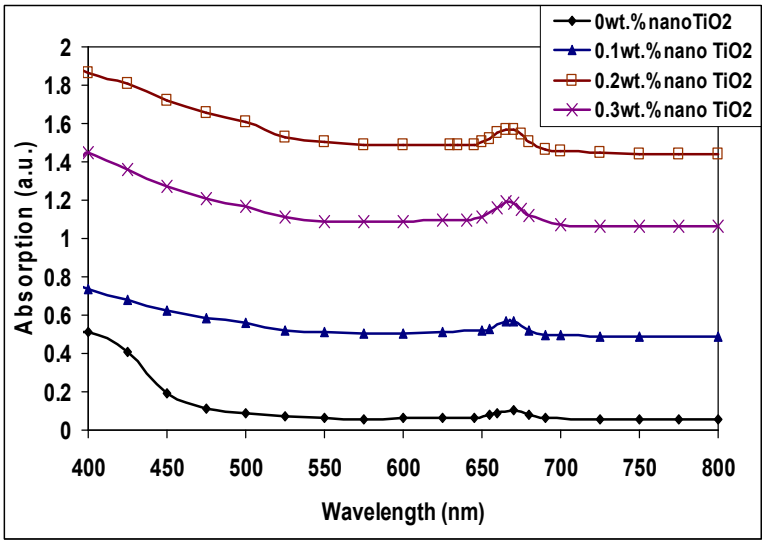

Fig: 2: Absorption of α-Chlorophyll in epoxy with different ratio of Nano TiO_2.

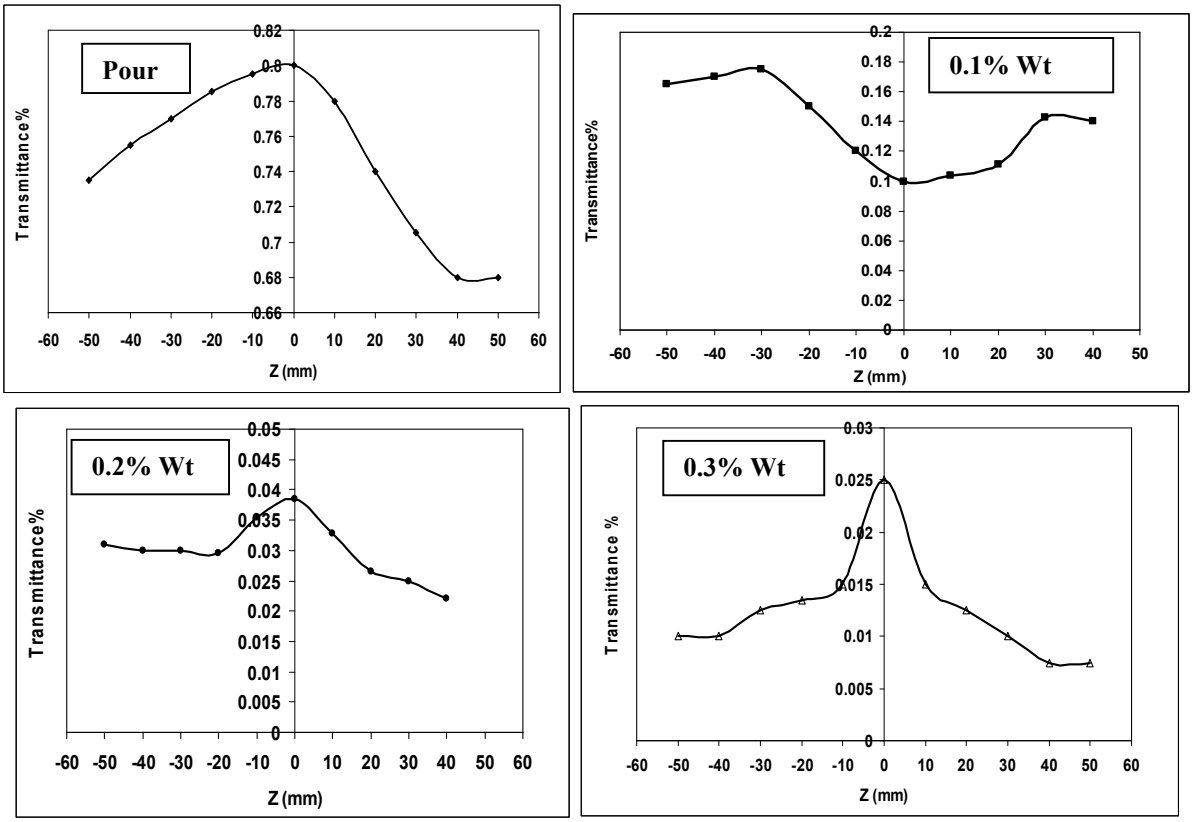

Fig: 3: Open aperture z-scan measurements of Chlorophyll a in Epoxy at different ratio of Nano TiO2.

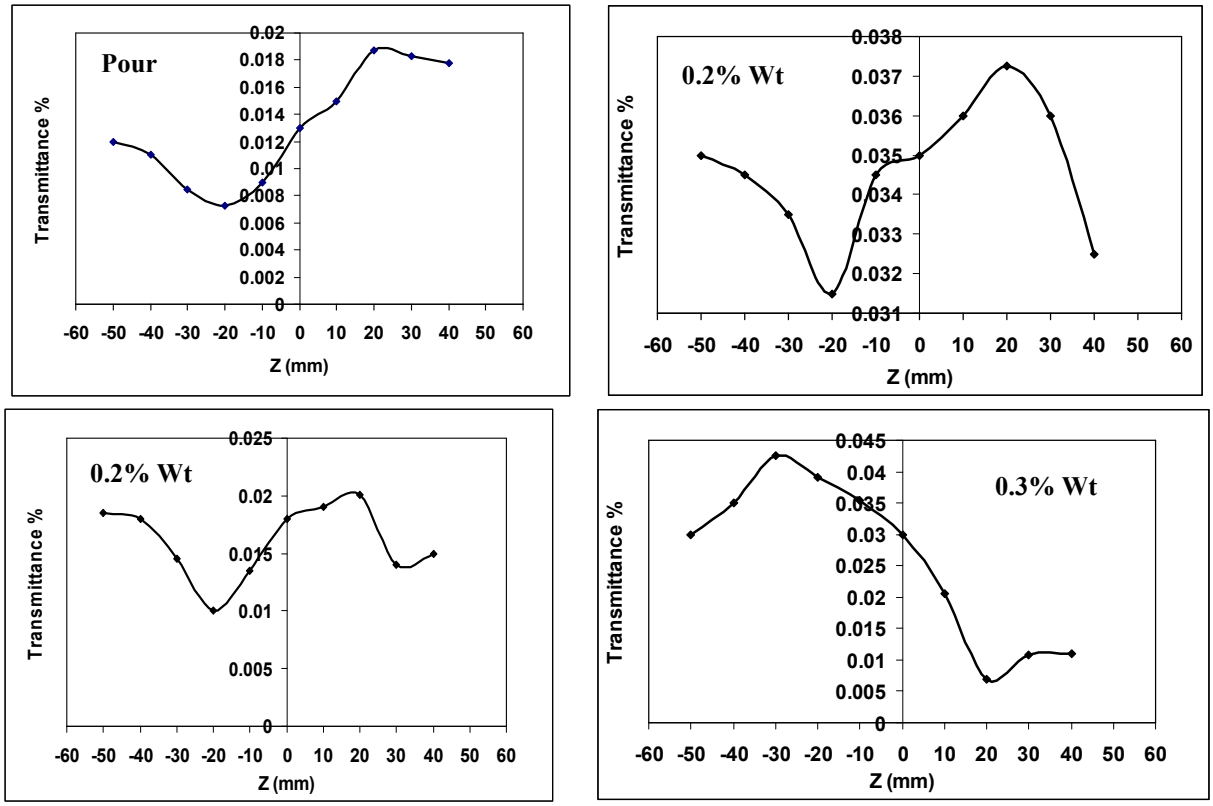

Fig: 4: Close aperture z-scan measurements of α-Chlorophyll in Epoxy at different ratio of Nano TiO_2.

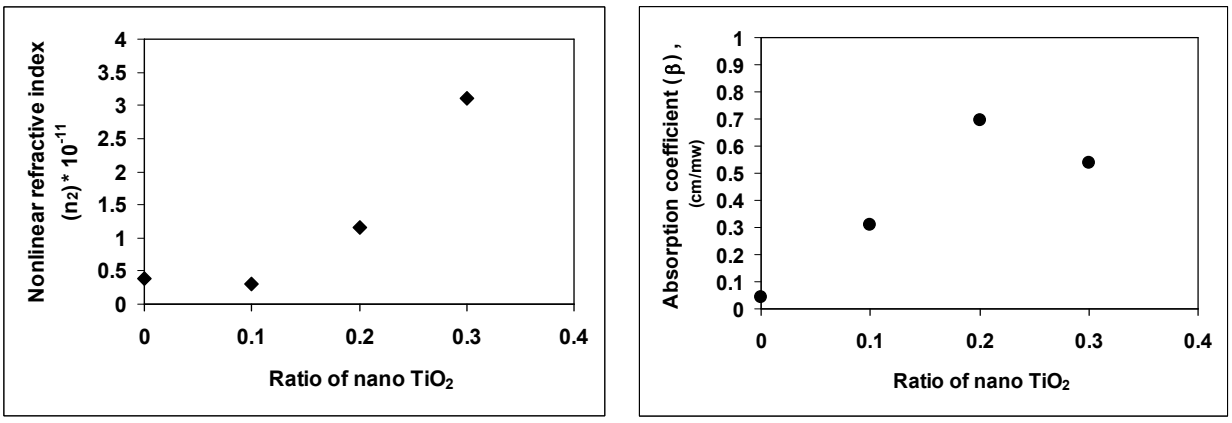

Fig. 5: Effect the concentration of TiO_2 nanoparticle on β and n2.