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Enhancement of Optical Parameters for PVA/PEG/Cr_2O_3 Nanocomposites for Photonics Fields

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ABSTRACT

In this study, many samples have been synthesized by using solution casting technique with different additive content of Chromium oxide nanoparticle (Cr_2O_3NPs), poly vinylalcohol (PVA) and polyethylene glycol (PEG). The UV-Vis. spectrophotometer used to record the absorbance spectrum in the range of (200-800) nm. The absorption of UV waves is improved while the transmittance is reduced when Cr_2O_3 NPs were added to the polymeric system which are useful for a number of applications including low-cost UV protection and solar radiation shield. When Cr_2O_3 NPs concentrations increased, the optical energy gap for indirect transition (allowed and forbidden) was decreased. Furthermore, all the optical constant has been improved.

1. INTRODUCTION

Polymer nanocomposites have recently gained popularity due to the unique properties that these materials can achieve. Metal [1-3] and semiconductor [4-6] nanoparticles exhibit extraordinary optical and electrical properties, and polymers are regarded to be a good host material for these nanoparticles. Similarly, Because of their high surface-to-bulk ratio, nanoparticles have a considerable impact on the matrix, producing in some exceptional properties that aren't available formed at one of the pure materials. More research into theto better predict the composite's final properties therefore, the impact of nanoparticles on the properties of a polymer matrix is required [7-9]. Lately, composites of polymer/ceramic filler obtain raised consideration related their attractive electronic and electrical characters, angular acceleration accelerometers, integrated decoupling capacitors, electronic packaging and acoustic emission sensors are several potential fields [10]. PVA is a semi crystalline polymer, offers a wide range of uses owing to the role of the OH collection and hydrogen bonding [11]. Because of its compatibility with the living body, it can also be used as a medical substance [12]. In addition, PVA can selectively absorb metallic ions like as copper, palladium, and mercury. PVA is made up of the chemical formulation (C2H4O)x, which has a density of (1.19-1.31)g/cm^3 and a melting temperature of 230℃. Over 200℃, it degrades rapidly [13]. is a form of thermoplastic polymer with a flexibility of C–O–C bonding. It also possesses solubility in organic solvents, hydrophilicity, crystallinity y, and self-lubricating properties. As a result, PEG is one of the most widely used polymers for the creation and growth of a wide range of vital applications [14]. There are several studies on PEG and PVA nanocomposites for various applications like energy storage [15-17], antibacterial [18] and humidity sensors [19-21]. This paper aims to prepare the PVA-PEG-Cr_2O_3 nanocomposites and investigating its optical properties.

2. EXPERIMENTAL WORK

Nanocomposites films of polyvinyl alcohol (PVA)/ polyethylene glycol (PEG) with different contents of chromium oxide (Cr_2O_3) nanoparticles were prepared by casting process. The PVA/PEG blend was prepared with ratio(70%PVA/30%PEG) by dissolving of 1 gm in distilled water (30 ml). The Cr_2O_3 NPs were added to the (PVA/PEG) blend with ratios 1%, 2%, and 3%. The optical characteristics of PVA/PEG/Cr_2O_3 nanocomposites were tested using spectrophotometer (UV-1800^{0}A-Shimadzu).

3. RESULT AND DISCUSSION

Figure 1 displays the influence of Cr_2O_3 NPs on the absorbance of PVA-PEG blend with wavelength range (200-800) nm. Because free electrons absorb incident light, the absorbance of nanocomposite increases as the concentration increases [22]. This result is agreement with previous studied [23, 24]. The high absorbance of nanocomposites at UV region due to the photon energy enough to interact with atoms lead to the high absorbance [25].

The optical transmittance of PVA-PEG-Cr_2O_3 nanocomposites is shown in Figure 2. The transmittance decreases when the Cr_2O_3 concentration in the PVA-PEG nanocomposite increasing from 1% to 3%, as shown in this figure.

The absorption coefficient (α)calculated by the equation [26]:

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

where, (A) is the absorption and (t) is the specimen thickness.

The absorption coefficient versus photon energy are shown in Figure 3. When the increasing of the Cr_2O_3NPs concentration, the α increase. The increase of α is due to an increase in light absorption [27]. The nanocomposites are said to have an indirect energy gap if the value of α is less than 10^4 cm^{-1}. The polymer blend had low α this may be as a result of low crystallinity [28, 29].

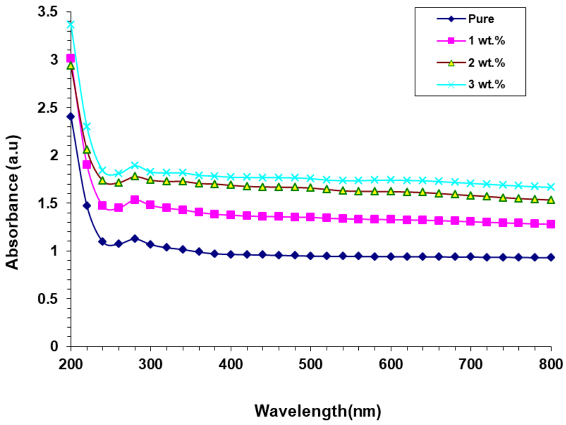

Figure 1. Influence of Cr_2O_3 NPs on the absorbance of PVA-PEG blend

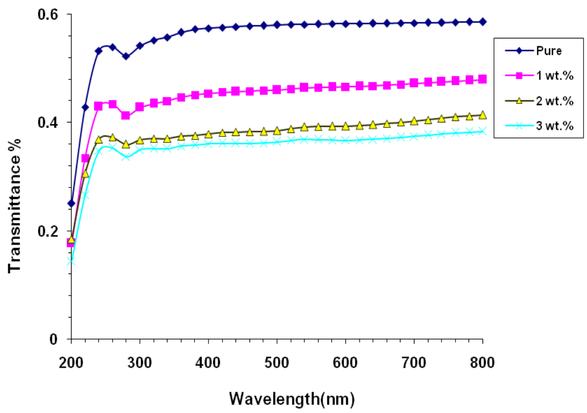

Figure 2. Optical transmittance of PVA-PEG-Cr_2O_3 nanocomposites

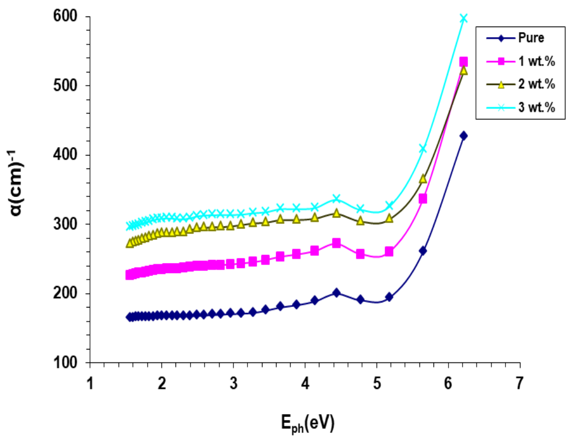

Figure 3. Absorption coefficient of PVA-PEG-Cr_2O_3 nanocomposites versus photon energy

The energy gap is calculated using the Tauc relation [24]:

$$\alpha h\nu = B(h\nu - E_g)^r \quad (2)$$

where, E_g denotes the optical energy gap, r=2 or 3 denotes the allowed or forbidden indirect transition, hν denotes electromagnetic energy, and B is a constant.

By graphing $(\alpha h\upsilon)^{1/2}$ and $(\alpha h\upsilon)^{1/3}$ versus hν in Figures 4, 5, the band gap was calculated. The allowed energy gap decreased from 4eVfor the pure PVA-PEG to 3.4 eV for the PVA-PEG- 3% Cr_2O_3nanocomposite and 3.2eV for the pure PVA-PEG to 2 eV for the PVA-PEG-3% Cr_2O_3 nanocomposite for the forbidden energy gap. The energy gap reduces with rise in the Cr_2O_3 NPs content which is due to the create of localized levels in the band gap [30, 31]. The value of energy gap are shown in Table 1.

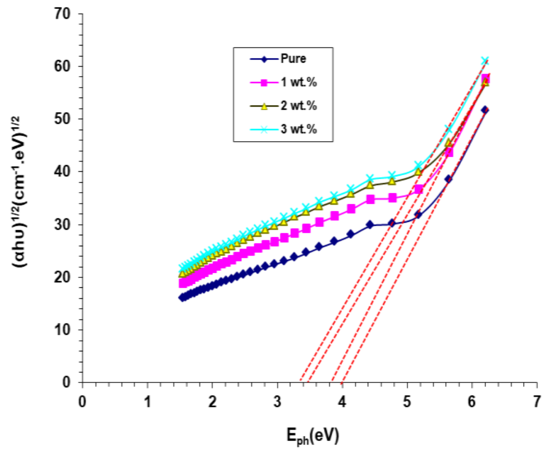

Figure 4. $(\alpha h\upsilon)^{1/2}$ versus hν of PVA-PEG-Cr_2O_3 nanocomposites

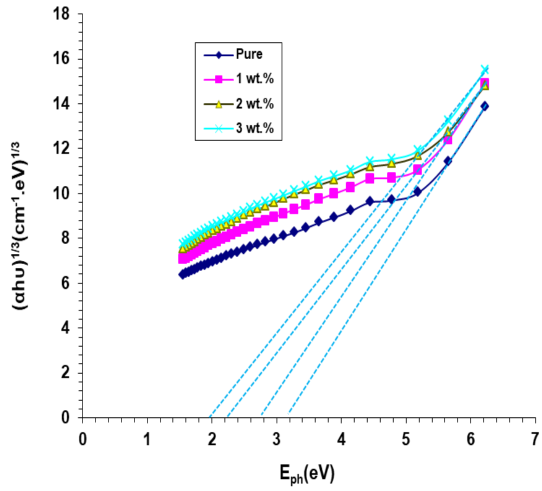

Figure 5. $(\alpha h\upsilon)^{1/3}$ versus hν of PVA-PEG-Cr_2O_3 nanocomposites

Table 1. Energy gap values of PVA-PEG-Cr_2O_3 nanocomposites

Cr_2O_3 NPs wt.%	E_g(eV)	
	allowed	**forbidden**
0	4	3.2
1	3.85	2.8
2	3.5	2.23
3	3.4	2

Using the following relation to determine the extinction coefficient (K) [32]:

$$K = \alpha\lambda / 4\pi \quad (3)$$

The extinction coefficient for ($PVA-PEG-Cr_2O_3$) nanocomposites is revealed in Figure 6 as a function of wavelength. It is worth noting that K increases as the concentration of Cr_2O_3NPs increases. This reason attribute to the enhancement of the absorption coefficient when the additive of Cr_2O_3NPs. This result agreement with the previous studied [33].

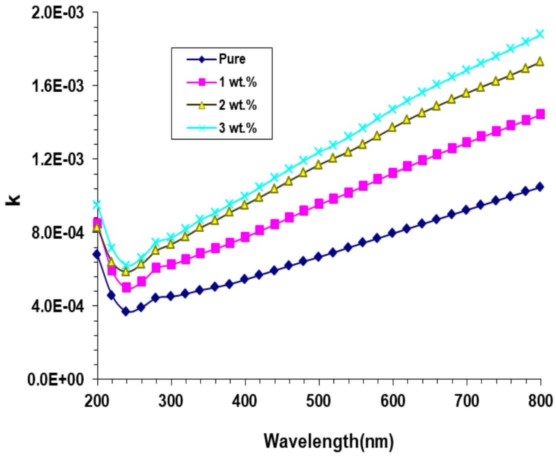

Figure 6. Extinction coefficient for ($PVA-PEG-Cr_2O_3$) nanocomposites

The refractive index (n) of ($PVA-PEG-Cr_2O_3$) nanocomposites was calculated by [34]:

$$n = (1 + R^{1/2}) / (1 - R^{1/2}) \quad (4)$$

The refraction index of ($PVA-PEG-Cr_2O_3$) nanocomposites versus of wavelength as shown in Figure 7. As revealed in the numeral, the refractive index tends to increase as the increase of Cr_2O_3NPsconcentration in the PVA-PEG film. The reason for this is that as the increase of Cr_2O_3 concentration, the density of the nanocomposites increases as well [35, 36].

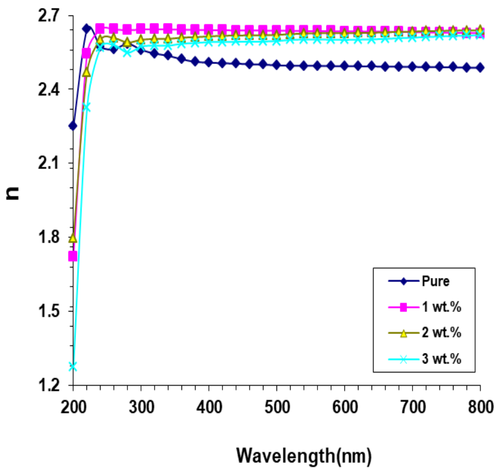

Figure 7. Refraction index of ($PVA-PEG-Cr_2O_3$) nanocomposites versus wavelength

The following equations were used to calculate the real and imaginary (ε_1 and ε_2) portions of dielectric constant [37]:

$$\varepsilon_1 = n^2 - k^2 \quad (5)$$

$$\varepsilon_2 = 2nk \quad (6)$$

The variation of (ε_1) versus of wavelength is indicated in Figure 8. Because of the low value of K^2, the real dielectric constant increases as the concentration of Cr_2O_3 nanoparticles increases. The change in ε_2 versus of wavelength is shown in Figure 9. Due to the relationship between α and K, it should be said that ε_2 is dependent on K values that vary with the absorption coefficient. This result is agreement with the previous studied [38].

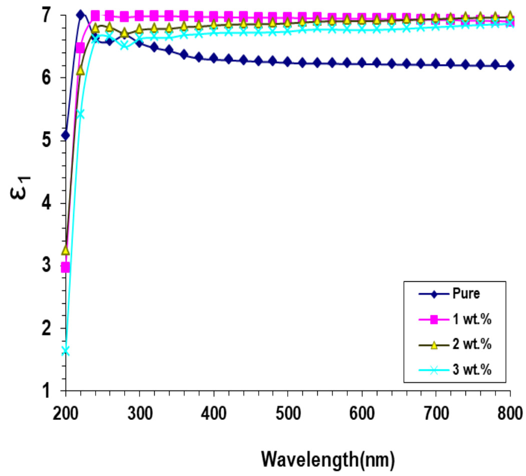

Figure 8. Variation of (ε_1) versus wavelength

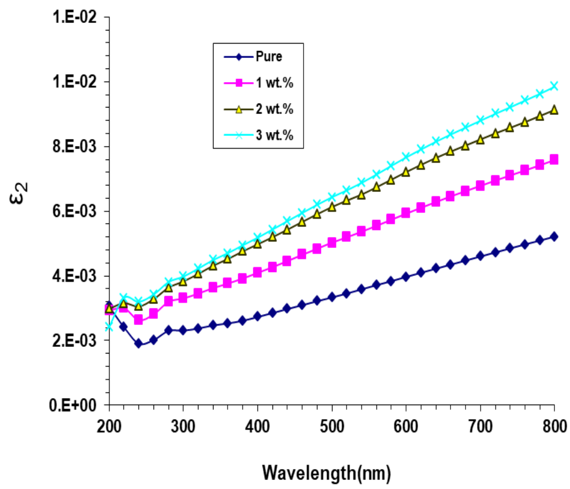

Figure 9. Variation of (ε_2) versus wavelength

Optical conductivity (σ) was determined using the equation [39]:

$$\sigma = \alpha nc / 4\pi \quad (7)$$

In which c denotes the light speed, n the refractive index, and is the absorption coefficient. Figure 10 shows the optical conductivity of $PVA-PEG-Cr_2O_3$ nanocomposites versus of wavelength. (σ) of the $PVA-PEG-Cr_2O_3$ nanocomposite increases as the Cr_2O_3content increases.

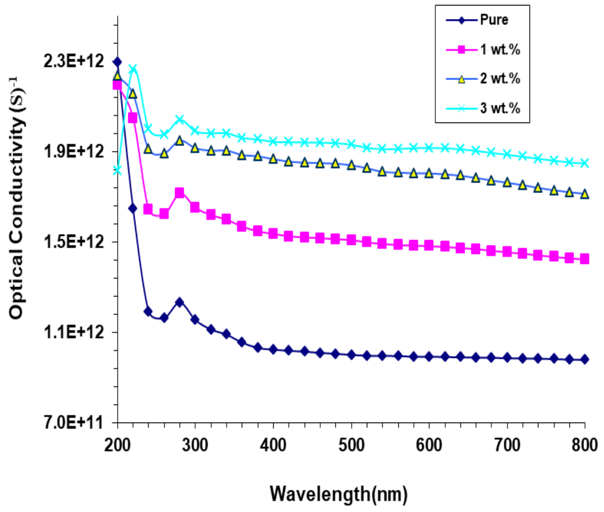

Figure 10. Optical conductivity of PVA-PEG-Cr_2O_3 nanocomposites versus wavelength

4. CONCLUSION

This paper includes the preparation of (PVA-PEG-Cr_2O_3) nanocomposites and studying its optical properties. The obtained results indicated that improvement in the optical properties of the (PVA-PEG-Cr_2O_3) nanocomposite when adding different percentages of Cr_2O_3NPs. Therefore, the nanocomposite (PVA-PEG-Cr_2O_3) can be used in different application such as photodetector and low-cost UV protection.

REFERENCES

[1] Akamatsu, K., Takei, S., Mizuhata, M., Kajinami, A., Deki, S., Takeoka, S., Fujii, M., Hayashi, S., Yamamoto, K. (2000). Preparation and characterization of polymer thin films containing silver and silver sulfide nanoparticles. Thin Solid Films, 359(1): 55-60. http://dx.doi.org/10.1016/S0040-6090(99)00684-7

[2] Zeng, R., Rong, M.Z., Zhang, M.Q., Liang, H.C., Zeng, H.M. (2002). Laser ablation of polymer-based silver nanocomposites. Appl. Surf. Sci., 187(3-4): 239247. https://doi.org/10.1016/S0169-4332(01)00991-6

[3] Zhu, Y.J., Qian, Y.T., Li, X.J., Zhang, M.W. (1998). A nonaqueous solution route to synthesis of polyacrylamide-silver nanocomposites at room temperature. Nanostruct. Mater., 10(4): 673-678. https://doi.org/10.1016/S0965-9773(98)00096-8

[4] Chen, W.M., Yuan, Y., Yan, L.F. (2000). Preparation of organic/inorganic nanocomposites with polyacrylamide (PAM) hydrogel by ^{60}Co γ irradiation. Mater. Res. Bull., 35(5): 807-812. https://doi.org/10.1016/S0025-5408(00)00266-X

[5] Zhang, Z.P., Han, M.Y. (2003). One-step preparation of size-selected and well-dispersed silver nanocrystals in polyacrylonitrile by simultaneous reduction and polymerization. J. Mater. Chem. Commun., 13(4): 641. https://doi.org/10.1039/B212428A

[6] Godovsky, D.Y. (2000). Device Applications of Polymer-Nanocomposites. In: Biopolymers PVA Hydrogels, Anionic Polymerisation Nanocomposites. Advances in Polymer Science, vol 153. Springer, Berlin, Heidelberg. https://doi.org/10.1007/3-540-46414-X_4

[7] Qian, X.F., Yin, J., Huang, J.C., Yang, Y.F., Guo, X.X., Zhu, Z.K. (2001). The preparation and characterization of PVA/Ag_2S nanocomposite. Mater. Chem. Phys., 68(1-3): 95-97. https://doi.org/10.1016/S0254-0584(00)00288-1

[8] Kumar, R.V., Elgamiel, R., Diamant, Y., Gedanken, A., Noewig, J. (2001). Sonochemical preparation and characterization of nanocrystalline copper oxide embedded in poly (vinyl alcohol) and its effect on crystal growth of copper oxide. Langmuir, 17(5): 1406-1410. https://doi.org/10.1021/la001331s

[9] Kumar, R.V., Palchik, O., Koltypin, Y., Diamant, Y., Gedanken, A. (2002). Sonochemical synthesis and characterization of Ag_2S/PVA and CuS/PVA nanocomposite. Ultrason. Sonochem., 9(2): 65-70. https://doi.org/10.1016/S1350-4177(01)00100-6

[10] Al-Ramadhan, Z., Hashim, A., Kadham Algidsawi, A.J. (2011). The D.C electrical properties of (PVC-Al_2O_3) composites. AIP Conference Proceedings, 1400(1): 180. https://doi.org/10.1063/1.3663109

[11] Pacansky, J., Schneider, S. (1990). Electron beam chemistry in solid films of poly (vinyl alcohol): Exposures under vacuum and under nitrogen at atmospheric pressure; irradiation monitored using infrared spectroscopy. J. Phys. Chem., 94(7): 3166-3179. https://doi.org/10.1021/j100370a077

[12] Salim, O.M., Abdullah, H.J., Hamzah, M.Q., Tuama, A.N., Hasan, N.N., Roslan, M.S., Agam, M.A. (2019). Synthesis, characterization, and properties of polystyrene/SiO_2 nanocomposite via sol-gel process. AIP Conference Proceedings, 2151(1): 020034. https://doi.org/10.1063/1.5124664

[13] Lei, R., Jie, X., Jun, X., Ruiyum, Z. (1994). Structure and properties of polyvinyl alcohol amidoxime chelate fiber. J. Appl. Polym. Sci., 53(3): 325-329. https://doi.org/10.1002/app.1994.070530309

[14] Falqi, F.H., Bin-Dahman, O.A., Hussain, M., Al-Harthi, M.A. (2018). Preparation of miscible PVA/PEG blends and effect of graphene concentration on thermal, crystallization, morphological, and mechanical properties of PVA/PEG (10wt %) blend. Int. J. Polym. Sci., 2018: 1-10. https://doi.org/10.1155/2018/8527693

[15] Rashid, F.L., Hadi, A., Al-Garah, N.H., Hashim, A. (2018). Novel phase change materials, MgO nanoparticles, and water based nanofluids for thermal energy storage and biomedical applications. International Journal of Pharmaceutical and Phytopharmacological Research, 8(1).

[16] Agool, I.R., Kadhim, K.J., Hashim, A. (2017). Synthesis of (PVA-PEG-PVP-ZrO_2) nanocomposites for energy release and gamma shielding applications. International Journal of Plastics Technology, 21(2): 444-453. https://doi.org/10.1007/s12588-017-9196-1

[17] Agool, I.R., Kadhim, K.J., Hashim, A. (2016). Preparation of (polyvinyl alcohol–polyethylene glycol–polyvinyl pyrrolidinone–titanium oxide nanoparticles) nanocomposites: electrical properties for energy storage and release. International Journal of Plastics Technology, 20(1): 121-127. https://doi.org/10.1007/s12588-016-9144-5

[18] Kadhim, K.J., Agool, I.R., Hashim, A. (2016). Synthesis of (PVA-PEG-PVP-TiO_2) nanocomposites for antibacterial application. Materials Focus, 5(5): 436-439.

https://doi.org/10.1166/mat.2016.1371
[19] Hashim, A., Habeeb, M.A. (2019). Synthesis and characterization of polymer blend-$CoFe_2O_4$ nanoparticles as a humidity sensors for different temperatures. Transactions on Electrical and Electronic Materials. https://doi.org/10.1007/s42341-018-0081-1
[20] Ahmed, H., Abduljalil, H.M., Hashim, A. (2019). Analysis of structural, optical and electronic properties of polymeric nanocomposites/silicon carbide for humidity sensors. Transactions on Electrical and Electronic Materials, 20: 206-217. https://doi.org/10.1007/s42341-019-00100-2
[21] Hashim, A., Hamad, Z.S. (2019). Fabrication and characterization of polymer blend doped with metal carbide nanoparticles for humidity sensors. J. Nanostruct., 9(2): 340-348. https://doi.org/10.22052/JNS.2019.02.016
[22] Habeeb, M.A., Hashim, A., Hadi, A. (2017). Fabrication of new nanocomposites: CMC-PAA-PbO_2 nanoparticles for piezoelectric sensors and gamma radiation shielding applications. Sensor Letters, 15(9): 1-6. https://doi.org/10.1166/sl.2017.3877
[23] Hashim, A., Habeeb, M.A., Khalaf, A., Hadi, A. (2017). Fabrication of (PVA-PAA) blend-extracts of plants bio-composites and studying their structural, electrical and optical properties for humidity sensors applications. Sensor Letters, 15(7): 589-596. https://doi.org/10.1166/sl.2017.3856
[24] Asogwa, P.U. (2011). Band gap shift and optical characterization of Capped PbO thin films: Effect of thermal annealing. Chalcogenide Letters, 8(3): 163-170.
[25] Hashim, A., Hadi, A. (2017). Synthesis and characterization of (MgO-Y_2O_3-CuO) nanocomposites for novel humidity sensor application. Sensor Letters, 15(10): 1-4. https://doi.org/10.1166/sl.2017.3900
[26] Donald, A.N. (1992). Semiconductors physics and devices. Mexico University.
[27] Hadi, S., Hashim, A., Jewad, A. (2011). Optical properties of (PVA-LiF) composites. Australian Journal of Basic and Applied Sciences, 5(9): 2192-2195.
[28] Jasim, F.A., Lafta, F., Hashim, A., Ali, M., Hadi, A.G. (2013). Characterization of palm fronds-polystyrene composites. Journal of Engineering and Applied Sciences, 8(5): 140-142.
[29] Jasim, F.A., Hashim, A., Hadi, A.G., Lafta, F., Salman, S.R., Ahmed, H. (2013). Preparation of (pomegranate peel-polystyrene) composites and study their optical properties. Research Journal of Applied Sciences, 8(9): 439-441. https://doi.org/10.3923/rjasci.2013.439.441
[30] Hashim, A. (2021). Fabrication and characteristics of flexible, lightweight, and low-cost pressure sensors based on PVA/SiO_2/SiC nanostructures. J Mater Sci: Mater Electron, 32: 2796-2804. https://doi.org/10.1007/s10854-020-05032-9
[31] Hashim, A., Hamad, Z.S. (2020). Lower cost and higher UV-absorption of polyvinyl alcohol/ silica nanocomposites for potential applications. Egypt. J. Chem., 63(2): 461-470. https://doi.org/10.21608/EJCHEM.2019.7264.1593
[32] Mohammed, M.K., Al-Dahash, G., Al-Nafiey, A. (2020). Synthesis and characterization of PVA-Graphene-Ag nanocomposite by using laser ablation technique. Journal of Physics: Conference Series, 1591(1).
[33] Crane, M., Hassan, Y. (1989). Solar cells. Collage of Education, University of Mousl.
[34] Mahalakshmi, K., Lakshmi, V., Dhivyachristoanitha, S. Mary Jenila, R. (2021). Optical, structural and morphological analysis of rGO decorated $CoSe_2$ nanocomposites. International Journal of Innovative Science, Engineering & Technology, 8(2): 180-192. www.ijiset.com.
[35] Rashid, F.L., Hashim, A., Habeeb, M.A., Salman, S.R., Ahmed, H. (2013). Preparation of PS-PMMA copolymer and study the effect of sodium fluoride on its optical properties. Journal of Engineering and Applied Sciences, 8(5): 137-139.
[36] Hashim, A. (2020). Enhanced structural, optical, and electronic properties of In_2O_3 and Cr_2O_3 nanoparticles doped polymer blend for flexible electronics and potential applications. Journal of Inorganic and Organometallic Polymers and Materials, 30: 3894-3906. https://doi.org/10.1007/s10904-020-01528-3
[37] Amin, P.O., Ketuly, K.A., Saeed, S.R., Muhammadsharif, F.F., Symes, M.D., Paul, A., Sulaiman, K. (2021). Synthesis, spectroscopic, electrochemical and photophysical properties of high band gap polymers for potential applications in semi-transparent solar cells. BMC Chemistry, 15: 25. https://doi.org/10.1186/s13065-021-00751-4
[38] Asogwa, P.U. (2011). Band gap shift and optical characterization of PVA Capped PbO thin films: Effect of thermal annealing .Chalcogenid Lett., 8(3): 163-170.
[39] Upadhyay, V.S., Dubey, S.K., Singh, A., Tripathi, S. (2014). Structural, optical and morphological properties of PVA/ Fe_2O_3 nanocomposite thin films, IJCPS, 3(4).