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Effect of Titanium Nitrate Nanoparticles on Optical Properties of PVA/PEG Blend for Optoelectronics Detectors

Musaab Khudhur Mohammed, Eman Hammod Abdullah, Dalal Hassan, Ahmed Hashim*

Department of Physics, College of Education for Pure Sciences, University of Babylon, 51002, Iraq

Corresponding Author Email: pure.ahmed.hashim@uobabylon.edu.iq

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ABSTRACT

In this work, casting method was used to fabricate the polyvinyl alcohol (PVA)/ poly ethylene glycol (PEG) nanocomposite with different content of titanium nitrate nanoparticle (TiN NPs). This nanocomposite was analyzed to use a Spectrophotometry with a spectral region of 200-800 nm. The absorption enhances when the added TiN NPs to the polymeric matrix which may be used for various applications such as optoelectronic detector. The optical energy gap for indirect transition (allowed and forbidden) decreased as TiN NPs content increases. Moreover, all optical constants have been determined.

1. INTRODUCTION

Polymer nanocomposites have prompted a lot of interest, and they could be used in a variety of technological and industrial uses like flexible computer monitors, radio interference shielding for cables, and pharmaceutical industries [1]. Polymer composites have distinct properties that allow them to be used in an infinite number of applications. Among other advantages, novel compound polymers' easy treatingmethods and optical characteristic make them viable candidates for a wide range of optoelectronic uses, including integrated optics, sensor arrays, microlayers, nanophotonics, optical communication, and processing of data. [2–5].Polyvinyl alcohol (PVA) was a very well powerful and flexible aqueous solution polymer, with cheap cost, ease of therapy as a formed film, good elasticity and stable photoconductive substance, excellent dielectric characteristics, and great chargeability. As a result, it can be used in a large variation of viable uses in numerous industry and scientific fields [6-8]. Polyethylene glycol (PEG) has important properties such as excellent water solubility, protein rich adsorbent reaction, and low toxicity, and is thus used in a range of applications including a protective coating for biotechnical applications [9-10].TiN has been investigated for the last thirty years owing to the unique combined application of their properties of materials [11]. TiN's metallic behaviour, combined including its toughness and chemical stability, has sparked the interest of researchers in microelectronics [12]. The optical characterization of TiN thin films was expanded in response to the growing interest in the field of plasmonics [13-16]. PVA doped wiith various materials were investagated to apply in different electronics, photonics and biomedical fields [17-20]. This paper deals with synthesis of (PVA/PEG/TiN) nanocomposites and investigating optical properties to use in optoelectronics devices.

2. MATERIALS AND METHODS

Polyvinyl alcohol(PVA)/polyethylene glycol(PEG) with different content of titanium nitrate nanoparticle (TiN NPs)(1.5%, 3% and 4.5%) was prepared by casting technique. The nanocomposite prepared by dissolving (1gm) of (81%PVA/19%PEG) in (30ml) of distil water. The optical characteristics of PVA/PEG/TiN nanocomposite were examined via spectrophotometer (UV-18000A-Shimadzu).

The absorption coefficient (α) has been calculated by [21]:

$$\alpha = 2.303\ (A/d) \quad (1)$$

where A is the absorbance and d is the thickness.

The band gap energy (Eg) is given by [21]:

$$(\alpha h\upsilon)^{1/m} = C(h\upsilon - E_g) \quad (2)$$

where C is constant, hυ is the photon energy, Eg is the energy gap, m = 2 and 3 to allowed and forbidden indirect transitions.

The refractive index(n) defined as [22]:

$$n = \frac{1+\sqrt{R}}{1-\sqrt{R}} \quad (3)$$

where R denotes reflection.

The extinction coefficient (k) is calculated as follows [22]:

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

where λ denotes wavelength.

The dielectric constant parts: real (ε_1), and imaginary (ε_2) are defined by [23]:

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

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

The optical conductivity (σ_{op}) is given by [23].

$$\sigma_{op} = \frac{\alpha n c}{4\pi} \qquad (7)$$

3. RESULTS AND DISCUSSIONS

The absorbance spectra of (PVA/PEG/TiN) nanocomposite are shown in Figure 1. It is obtained that the absorbance rises when increasing the content of TiN NPs. This behaviour attributed to increase in the charges carriers numbers [24-26], therefore the transmittance reduces as shown in Figure 2.

The absorption coefficient (α) tells us about on the transition nature. The value of α for the PVA/PEG/TiN nanocomposite is shown in Figure 3. From this figure, it is observed that the $\alpha<10^4$ cm^{-1} which means the indirect transition happens. The rise of α is related to a rise in light absorption [23]. The nanocomposites are said to have an indirect energy gap if the value of α is less than 10^4 cm^{-1}. The blend has low α. This may be as a result of low crystallinity [24, 25]. Figures 4 and 5 show that the energy gap for allowed and forbidden for the PVA/PEG/TiN nanocomposite respectively. It is obtained that the E_g reduces when the rise of content of TiN NPs attributed to formation of defects and levels inside band gap therefore the value of E_g will be reduced [27-37].

The refractive index and extinction coefficient of PVA/PEG/TiN nanocomposite are represented in Figures 6 and 7. From these figures, it is obtained that the value of n and K increase when the increasing content in TiN NPs which is attributed to increase of α and density of films [38].

The dielectric constant includes real and imaginary of the PVA/PEG/TiN nanocomposite are performance in Figures 8 and 9. It is shown that the ε_1 and ε_2 rise when increasing the content of TiN NPs due to increase of the value of n and k [39, 40].

The optical conductivity of PVA/PEG/TiN nanocomposite is demonstrated in Figure 10. It is seen that the σ_{op}rise with rising of TiN NPs content due to relation to the decrease in energy gap and increase in absorbance [41-43].

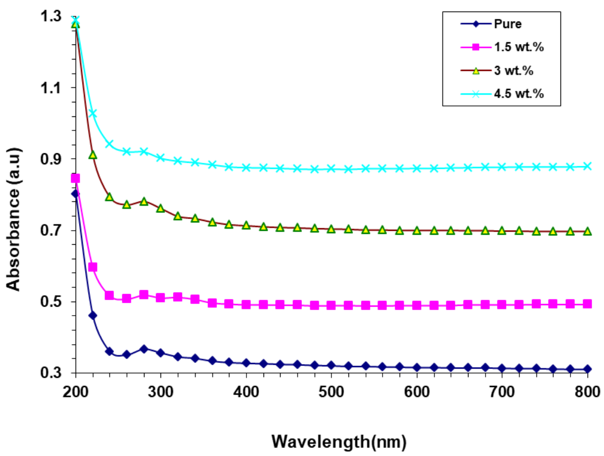

Figure 1. Absorbance pattern of PVA/PEG/TiN nanocomposite

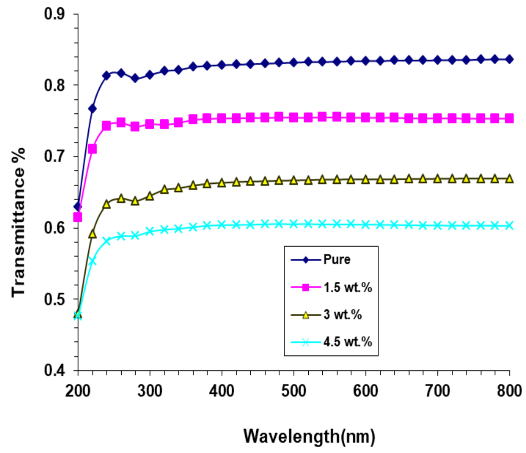

Figure 2. Transmittance pattern of PVA/PEG/TiN nanocomposite

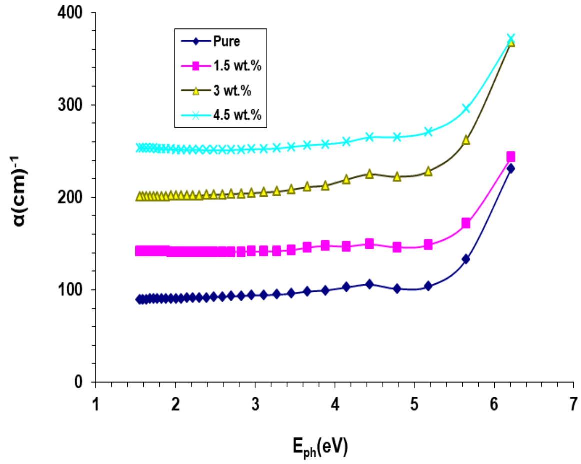

Figure 3. Absorbance coefficient pattern of PVA/PEG/TiN nanocomposite

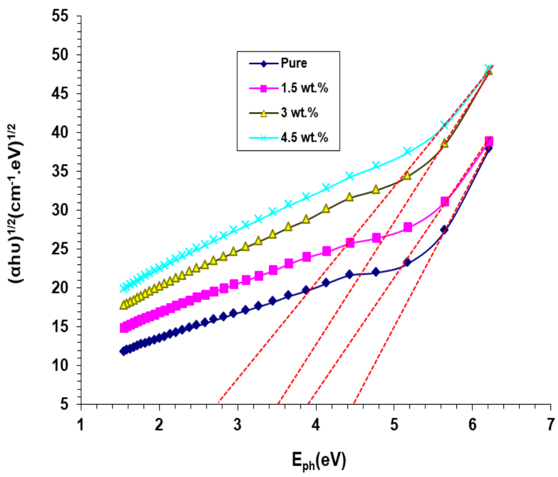

Figure 4. Energy band gap values of PVA/PEG/TiN nanocomposite

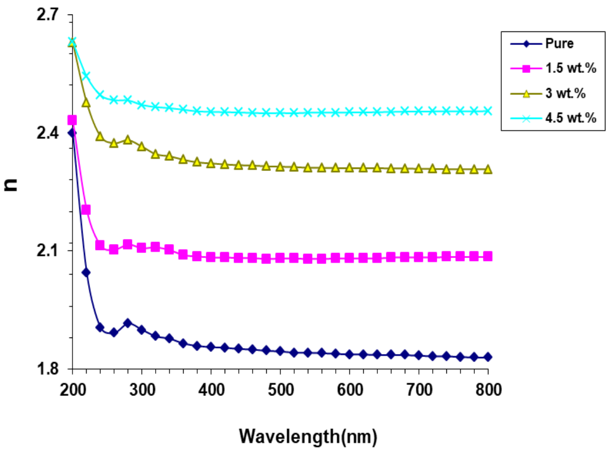

Figure 5. Energy band gap values of PVA/PEG/TiN nanocomposite

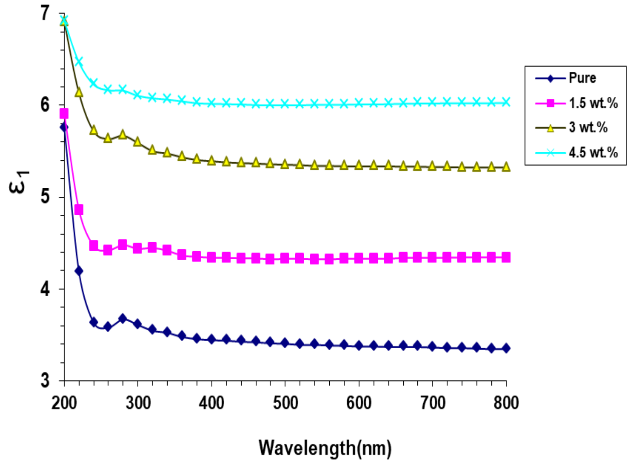

Figure 8. Real dielectric constant values of PVA/PEG/TiN nanocomposite

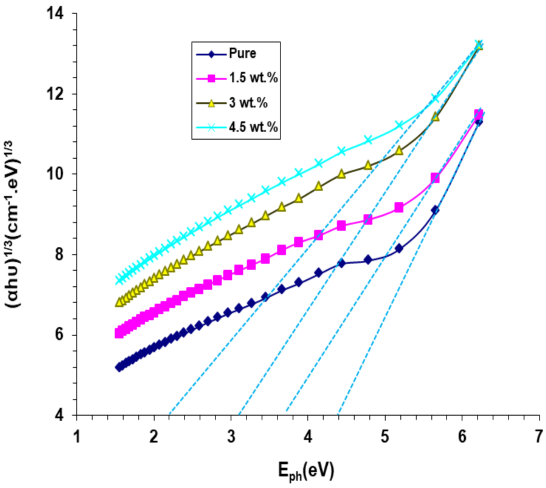

Figure 6. Refractive index values of PVA/PEG/TiN nanocomposite

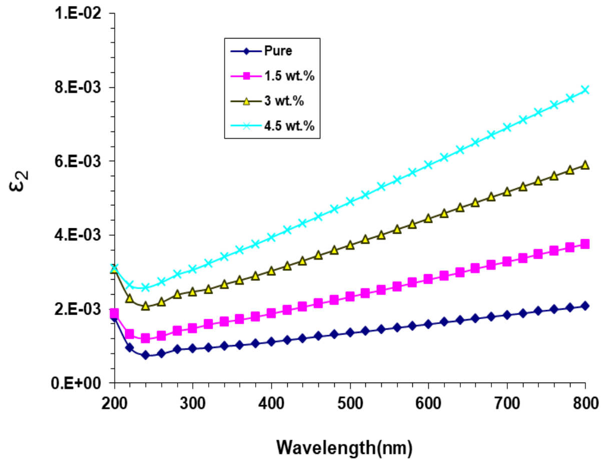

Figure 9. Imaginary dielectric constant of PVA/PEG/TiN nanocomposite

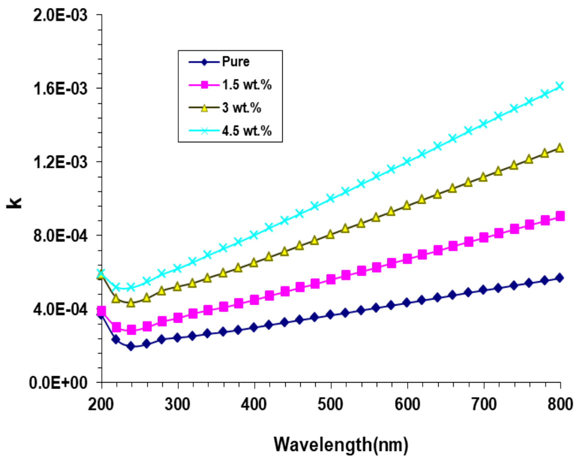

Figure 7. Extinction coefficient values of PVA/PEG/TiN nanocomposite

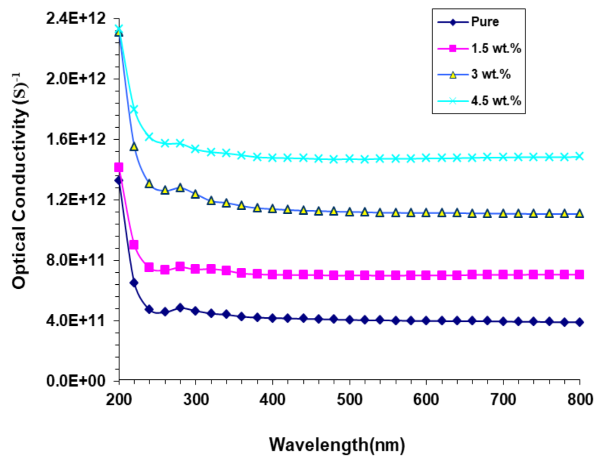

Figure 10. Optical conductivity values of PVA/PEG/TiN nanocomposite

4. CONCLUSION

This work includes manufacturing the PVA/PEG/TiN nanocomposite and examining the optical characteristics to application in optoelectronic detector. The optical characteristics of PVA/PEG/TiN nanocomposite are tested at wavelengths range (200-800) nm. When the TiN NPs content increases, the absorption increases and transmission decreases of PVA/PEG. The energy band gap is reduced when the increase in content TiN NPs. The optical factors of PVA/PEG/TiN nanocomposite are enhanced with addition of the TiN NPs content. The optical characteristics results showed that PVA/PEG/TiN nanocomposite may be employed in optoelectronic detector.

REFERENCES

[1] Heiba, Z.K., Mohamed, M.B., Ahmed, S.I. (2022). Exploring the physical properties of PVA/PEG polymeric material upon doping with nano gadolinium oxide. Alexandria Engineering Journal, 61(5): 3375-3383. https://doi.org/10.1016/j.aej.2021.08.051

[2] Bhagyaraj, S., Oluwafemi, O.S., Krupa, I. (2020). Polymers in optics. In Polymer Science and Innovative Applications. Elsevier: Amsterdam, The Netherlands, pp. 423-455. https://doi.org/10.1016/B978-0-12-816808-0.00013-5

[3] Beckers, M., Schlüter, T., Vad, T., Gries, T., Bunge, C.A. (2017). Fabrication techniques for polymer optical fibres. In Polymer Optical Fibres. Woodhead Publishing: Cambridge, UK, pp. 187-199. https://doi.org/10.1016/B978-0-08-100039-7.00006-3

[4] Loste, J., Lopez-Cuesta, J.M., Billon, L., Garay, H., Save, M. (2019). Transparent polymer nanocomposites: An overview on their synthesis and advanced properties. Prog. Polym. Sci., 89: 133-158. https://doi.org/10.1016/j.progpolymsci.2018.10.003

[5] Fréchet, J.M.J. (2005). Functional polymers: From plastic electronics to polymer-assisted therapeutics. Prog. Polym. Sci., 30(8-9): 844-857. https://doi.org/10.1016/j.progpolymsci.2005.06.005

[6] Alberto, N., Domingues, M., Marques, C., André, P. Antunes, P. (2018). Optical fiber magnetic field sensors based on magnetic fluid: A review. Sensors, 18(12): 4325. https://doi.org/10.3390/s18124325

[7] Li, W., Zhao, X., Huang, Z.H., Liu, S.X. (2013). Nanocellulose fibrils isolated from BHKP using ultrasonication and their reinforcing properties in transparent poly (vinyl alcohol) films. J. Polym. Res., 20: 210. https://doi.org/10.1007/s10965-013-0210-9

[8] Kannan, K., Guru Prasad, L., Agilan, S., Muthukumarasamy, N. (2018). Investigations on Ag_2S/PVA-PEG polymer nanocomposites: An effectual nonlinear optical material. Optik-Int. J. Light Electron Opt., 170: 10-16. https://doi.org/10.1016/j.ijleo.2018.05.078

[9] Hassen, A., El Sayed, A.M., Morsi, W.M., El-Sayed, S. (2012). Influence of Cr_2O_3nanoparticles on the physical properties of polyvinyl alcohol. J. Appl. Phys., 112(9): 093525. https://doi.org/10.1063/1.4764864

[10] Sedlařík, V., Saha, N., Kuřitka, I., Sáha, P. (2006). Characterization of polymeric biocomposite based on poly (vinyl alcohol) and poly (vinyl pyrrolidone). Polymer Composites, 27(2): 147-152. https://doi.org/10.1002/pc.20197

[11] Chuang, W., Shih, K., Hong, P. (2005). Kinetics of phase separation in poly (ε-caprolactone)/poly (ethylene glycol) blends. Journal of Polymer Research, 12(3): 197-204. https://doi.org/10.1007/s10965-004-1868-9

[12] Tang, T.E., Wei, C.C., Haken, R.A., Holloway, T.C., Hite, L.R., Blake, T.G.W. (1987). Titanium nitride local interconnect technology for VLSI. IEEE Transactions on Electron Devices, 34(3): 682-688. https://doi.org/10.1109/T-ED.1987.22980

[13] Steinmüller-Nethl, D., Kovacs, R., Gornik, E., Rödhammer, P. (1994). Excitation of surface plasmons on titaniumnitride films: Determination of the dielectric function, Thin Solid Films, 237(1-2): 277-281. https://doi.org/10.1016/0040-6090(94)90273-9

[14] Hibbins, A.P., Sambles, J.R., Lawrence, C.R. (1998). Surface plasmon polariton study of the optical dielectric function of titanium nitride. Journal of Modern Optics, 45(10): 2051-2062. https://doi.org/10.1080/09500349808231742

[15] Chen, N.C., Lien, W.C., Liu, C.R., Huang, Y.L., Lin, Y.R., Chou, C., Yang, S.Y., Ho, C.W. (2011). Excitation of surface plasma wave at TiN/air interface in the Kretschmann geometry. Journal of Applied Physics, 109(4): 043104. https://doi.org/10.1063/1.3549732

[16] Naik, G.V., Schroeder, J.L., Ni, X., Kildishev, A.V., Sands, T.D., Boltasseva, A. (2012). Titanium nitride as a plasmonic material for visible and near-infrared wavelengths. Optical Materials Express, 2(4): 478-489. https://doi.org/10.1364/OME.2.000478

[17] Hashim, A., Abduljalil, H.M., Ahmed, H. (2019). Fabrication and characterization of $(PVA\text{-}TiO_2)1\text{-}x$/ SiCx nanocomposites for biomedical applications. Egyptian Journal of Chemistry, 63(1): 71-83. http://dx.doi.org/10.21608/ejchem.2019.10712.1695

[18] Hashim, A., Abduljalil, H., Ahmed, H. (2019). Analysis of optical, electronic and spectroscopic properties of (Biopolymer-SiC) nanocomposites for electronics applications. Egyptian Journal of Chemistry. https://doi.org/10.21608/EJCHEM.2019.7154.1590

[19] Mohammed, M.K., Abbas, M.H., Hashim, A., Rabee, R.H., Habeeb, M.A., Hamid, N. (2022). Enhancement of optical parameters for PVA/PEG/Cr2O3 nanocomposites for photonics fields. Revue des Composites et des Matériaux Avancés-Journal of Composite and Advanced Materials, 32(4): 205-209. https://doi.org/10.18280/rcma.320406

[20] Hayder, N., Hashim, A., Habeeb, M.A., Rabee, B.H., Hadi, A.G., Mohammed, M.K. (2022). Analysis of dielectric properties of PVA/PEG/In2O3 nanostructures for electronics devices. Revue des Composites et des Matériaux Avancés-Journal of Composite and Advanced Materials, 32(5): 261-264. https://doi.org/10.18280/rcma.320507

[21] 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): 012012. https://doi.org/10.1088/1742-6596/1591/1/012012

[22] Asogwa, P. (2011). Band gap shift and optical characterization of PVA Capped PbO thin films: Effect of thermal annealing. Chalcogenid Lett., 8(3): 163-170.

[23] Tyagi, C., Devi, A. (2018). Alteration of structural, optical and electrical properties of CdSe incorporated polyvinyl pyrrolidone nanocomposite for memory devices. Journal of Advanced Dielectrics, 8(3): 1850020. https://doi.org/10.1142/S2010135X18500200

[24] Ahmed, H., Hashim, A., Abduljalil, H.M. (2020). Determination of optical parameters of films of $PVA/TiO_2/SiC$ and PVA/MgO/SiC nanocomposites for optoelectronics and UV-detectors. Ukr. J. Phys., 65(6): 533. https://doi.org/10.15407/ujpe65.6.533

[25] Lafta, F., Rashid, A., Hashim, Majeed, A., Razaq, S., 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.

[26] Agool, I.R., Mohammed, F.S., Hashim, A. (2015). The effect of magnesium oxide nanoparticles on the optical and dielectric properties of (PVA-PAA-PVP) blend. Advances in Environmental Biology, 9(11): 1-10.

[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., Hashim, A., Hadi, A.G., Lafta, F., Salman, S., Ahmed, H. (2013). Preparation of (pomegranate peel-polystyrene) composites and study their optical properties. Research Journal of Applied Sciences, 8(9): 439-441.

[29] 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.

[30] Ahmed, H., Hashim, A. (2021). Lightweight, flexible and high energies absorption property of PbO_2 doped polymer blend for various renewable approaches. Transactions on Electrical and Electronic Materials, 22: 335-345. https://doi.org/10.1007/s42341-020-00244-6

[31] Hazim, A., Abduljalil, H.M., Hashim, A. (2020). Structural, spectroscopic, electronic and optical properties of novel platinum doped ($PMMA/ZrO_2$) and ($PMMA/Al_2O_3$) nanocomposites for electronics devices. Transactions on Electrical and Electronic Materials, 21: 550-563. https://doi.org/10.1007/s42341-020-00210-2

[32] Hazim, A., Abduljalil, H.M., Hashim, A. (2020). Analysis of structural and electronic, properties of novel ($PMMA/Al_2O_3$, $PMMA/Al_2O_3$-Ag, $PMMA/ZrO_2$-Ag, PMMA -Ag) nanocomposites for low cost electronics and optics applications. Trans. Electr. Electron. Mater., 21: 48-67. https://doi.org/10.1007/s42341-019-00148-0

[33] Hazim, A., Abduljalil, H.M., Hashim, A. (2021). Design of PMMA doped with inorganic materials as promising structures for optoelectronics applications. Trans. Electr. Electron. Mater., 22: 851-868. https://doi.org/10.1007/s42341-021-00308-1

[34] Hazim, A., Abduljalil, H.M., Hashim, A. (2020). First principles calculations of electronic, structural and optical properties of (PMMA–ZrO_2–Au) and (PMMA–Al_2O_3–Au) nanocomposites for optoelectronics applications. Transactions on Electrical and Electronic Materials, 22: 185-203. https://doi.org/10.1007/s42341-020-00224-w

[35] 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

[36] 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

[37] Hashim, A., Hamad, Z. (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

[38] Hashim, A., Hamad, Z. (2018). Novel of (niobium carbide-biopolymer blend) nanocomposites: Characterization for bioenvironmental applications. Journal of Bionanoscience, 12(4): 488-493. https://doi.org/10.1166/jbns.2018.1551

[39] Upadhyay, V.S., Dubey, S.K., Singh, A., Tripathi, S.R. (2014). Structural, optical and morphological properties of PVA/ Fe_2O_3 nanocomposite thin films, IJCPS, 3(4): 43-48.

[40] Hashim, A. (2021). Enhanced morphological, optical and electronic characteristics of WC NPs doped PVP/PEO for flexible and lightweight optoelectronics applications. Optical and Quantum Electronics, 53: 478. https://doi.org/10.1007/s11082-021-03100-w

[41] Hassan, D., Hashim, A. (2018). Preparation and studying the structural and optical properties of (poly-methyl methacrylate-lead oxide) nanocomposites for bioenvironmental applications. Journal of Bionanoscience, 12(3): 346-349. https://doi.org/10.1166/jbns.2018.1537

[42] Hashim, A. (2021). Synthesis of SiO_2/ $CoFe_2O_4$ nanoparticles doped CMC: Exploring the morphology and optical characteristics for photodegradation of organic dyes. Journal of Inorganic and Organometallic Polymers and Materials, 31: 2483-2491. https://doi.org/10.1007/s10904-020-01846-6

[43] Hassan, D., Hashim, A. (2018). Structural and optical properties of (polystyrene-copper oxide) nanocomposites for biological applications. Journal of Bionanoscience, 12(3): 341-345. https://doi.org/10.1166/jbns.2018.1533