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(RESEARCH ARTICLE)

Exploring the optical properties of MnO_2 nanoparticles doped PVP for optoelectronics devices

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Abstract

Numerous applications for optical technologies used the nanocomposites. The purpose of this work is to create novel kinds of polymer nanocomposites and analyze their optical characteristics. The polyvinyl pyrrolidone (PVP)/ manganese oxide nanoparticle (MnO_2NPs) nanocomposites were created. Various content of PVA and MnO_2 NPs were fabricated. The optical characteristics of these nanocomposites were examined. The results demonstrate that the absorbance, coefficient of absorption, index of refractive, coefficient of extinction, dielectric constant and conductivity of PVP are raise with arise of the MnO_2NPs content. The transmittance and gap of energy are reduced with a rise of the MnO_2NPs content. The results illustrated the PVP/MnO_2nanostructures may be utilized in different photonics and optics fields.

Keywords: Nanocomposite; PVP; Optical devices; MnO_2; Optical properties

1. Introduction

Because of their numerous industrial applications, polymers are currently the focus of considerable scientific attention. The use of polymers in numerous scientific applications is necessary due to its fundamental properties, which include ease of production, low initial cost, durability, and remarkable processability [1]. Additionally, while choosing a polymer for a certain application, it is important to take into account its hydrophobic/hydrophilic balance, biocompatibility, optoelectronic behavior, chemical stability, and functionalities. The development of methods for using such materials while keeping the mentioned attributes and enhancing specific features like strength, modulus, fire performance, and heat resistance pose the biggest problems in the field of polymer research. In several cases, polymers can allow for easier shape and better manufacturing of composites [2]. According to reports, a polymer matrix can be used to create nanoparticles (NPs) since it possesses the characteristics of both the host polymer matrix and the visiting nanoparticles [3]. Dopants can be added to polymers to change their electrical and optical characteristics as needed. Additionally, these polymers have a reputation for being top-notch hosts. It is crucial to understand that the dopant alters the polymer's structure and therefore its properties because the field of polymer additives has received significant interest in today's materials research. Since the nature of the dopant and how it interacts with the polymer are what primarily determine how the characteristics of the polymer change, the dopant significantly improves the properties of the polymer when compared to pure polymers [4]. We can now produce novel nanoscale materials with unique electrical and optical properties that are very unique from those in their bulk state because to advancements in nanoscience and nanotechnology. The size-dependent characteristics of the nano materials were utilized in a variety of electrical and optical devices [5]. Synthetic polymers that are biodegradable, biocompatible, non-toxic, and simple to produce, like polyvinyl pyrrolidone (PVP), have many applications in biomedicine, engineering, and technology. When employing the solution casting method, this polymerase produces exceptionally optically clear films and is water-soluble. Since this polymer film has strong electrical insulation and a low permittivity, it is frequently used as a flexible dielectric material in the manufacture of organic thin-film transistors and optoelectronic devices. [6]. These hydrophilic polymers are

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frequently used as binders and capping agents in the creation of advanced composite materials because the hydroxyl (-OH) functional polar groups found in the chain backbone of PVP, from strong interactions with a variety of inorganic nanofillers [7]. A possible component for electrochemical lithium-ion batteries is manganese oxide (MnO_2). Through the easy insertion and extraction of lithium, high performance in electrochromic devices has also been improved. Additionally, catalysis employs thin layers of manganese oxide and as substrates in the growth of magnetic oxide perovskite materials [8]. The ability of manganese to modify its valence state underlies these uses for manganese oxide thin films. There are several valence states of manganese oxide, including MnO (Mn^{+2}), Mn_3O_4 ($Mn^{+2.67}$), Mn_2O_3 (Mn^{+3}), and MnO_2 (Mn^{+4}) [9]. The field of applicability is determined by the valence state. For instance, MnO_2 is a catalytic substance utilized in oxidation-reduction reactions as well as an electrode in lithium-ion batteries. Finally, Mn_3O_4 ($Mn^{+2.67}$) is a possibility for window applications due to its desirable electrochromic features, such as the ability to change optical transmittance in the visible spectrum in response to an applied voltage [10]. The composites materials have been extensively employed in the various approaches like aerospace, military equipment's, protective garments, sensors, safety, automotive, optical and electronics devices. On the other hand, these applications fields incessantly demand extra characteristics and purposes like flame retardation, elevated mechanical characteristics, chemical resistance, electrical conductivity, environmental stability, UV resistance, water repellency, radar absorption, magnetic field resistance, etc. [11-15]. In this work, we report to prepare and investigation of the optical characteristic of PVP/MnO_2 nanocomposites to use in opto-electronics devices.

2. Experimental Method

The water-soluble synthetic polymers PVP (Mol. Wt. 20,000 g/mol, purity 99.99 percent, and melting point 230°C) can be acquired from (Central Drug House, Ltd, Company).The manganese oxide (MnO_2NPs) were used as additive materials. PVP (100 wt. %) were mixed in 30 ml of deionized water with a magnetic stirring at 70 °C to obtain a more homogenous solution. MnO_2 NPs were added to the solution in varying weight percent (2, 4 and 6) wt. %. To create the (PVP/MnO_2) nanocomposites, the casting technique was applied. The optical characteristics of PVP/MnO_2nanostructures films were tested using spectrophotometer (UV-1800⁰A-Shimadzu).

The coefficient of absorption (α) is planned by [17]:

$$\alpha = 2.303 \left(\frac{A}{d}\right) \qquad \text{........ (1)}$$

Which: A is the absorbance and d is the thickness. The gap of energy isgivenby [18]:

$$(\alpha h\nu)^{1/m} = C\left(h\nu - E_g\right) \qquad \text{... ... ...(2)}$$

which C is constant, hυ is the photon energy, E_g is the gap of energy, m = 2 and 3 to indirect transition of allowed and forbidden.

The index of refractive (n) is defined by[19]:

$$n = \frac{1+\sqrt{R}}{1-\sqrt{R}} \qquad \text{............(3)}$$

which R is the reflection.The coefficient of extinction (k) is determinedby[20]:

$$k = \frac{\alpha\lambda}{4\pi} \qquad \text{..................... (4)}$$

whichλ is the wavelength. The dielectric constant parts: real (ε_1), and imaginary (ε_2) are givenby[21]:

$$\varepsilon_1 = n^2 - k^2 \qquad \text{.............................. (5)}$$

$$\varepsilon_2 = 2nk \qquad \text{......................................(6)}$$

Theconductivity of optical (σ_{op}) is definedby[22].

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

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3. Results and discussion

The variation of absorbance of PVP/MnO_2nanostructures films are demonstrated in fig.(1). The absorbance intensity of PVP rises when the MnO_2NPs content rises, this is due to rise in the charge carriers density lead to increase in the absorbance values[23-25], while in fig.(2) the transmittance will reduce.

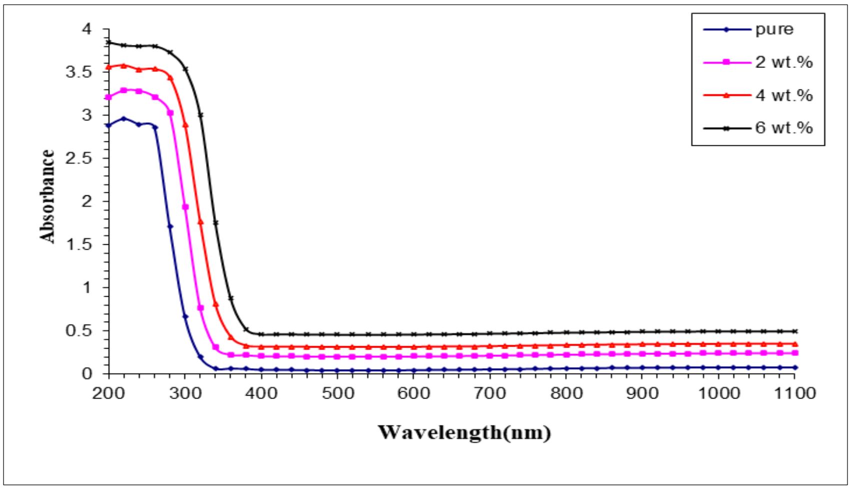

Figure 1 Absorption spectra of PVP/MnO_2nanostructures films

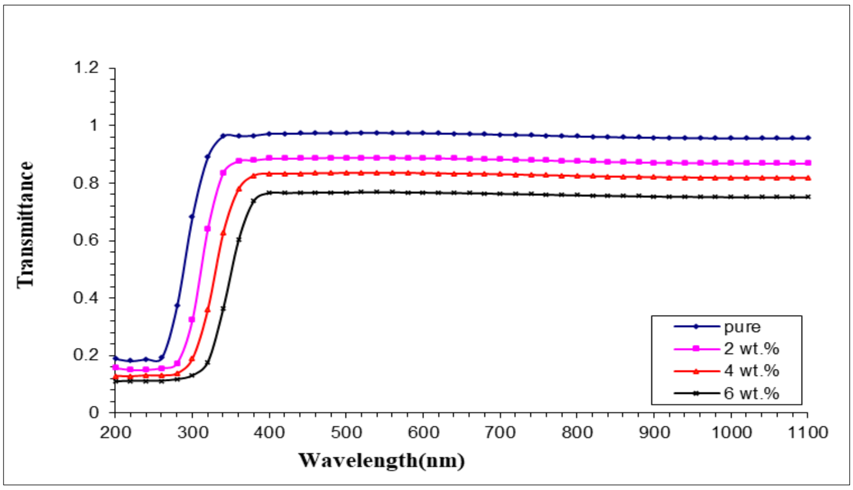

Figure 2 Transmission spectra of PVP/MnO_2nanostructures films

The coefficient of absorption (α) is useful to know the transition nature. The α values of PVP/MnO_2nanostructures films as a function with wavelength are demonstrate in fig. (3). from this Figure, the α values$<10^4$ cm^{-1} which indicates to the indirect transition. Figs. 4 and 5 illustrate the energies gaps values of PVP/MnO_2nanostructures films of allowed and forbidden transitions. The E_g value reduces with rise in theMnO_2NPs content which relate to create of levels in the band gap lead to reduce in the$E_g$values [26-29].

Figs. (6,7) explain the extinction coefficient and refractive index of PVP/MnO_2nanostructures films. The values of k and nof PVP rise when the MnO_2NPs content increases, these behaviors due to rise in the light scattering and absorbance [30,31].

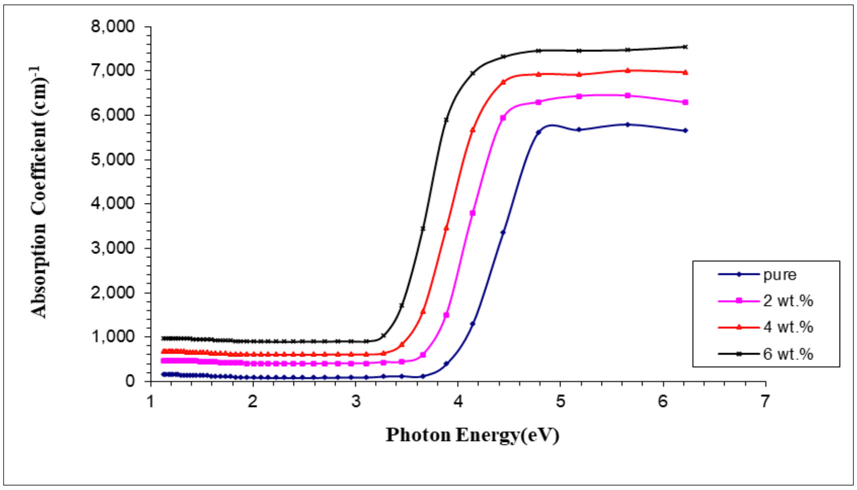

Figure 3 Values of αfor PVP/MnO_2nanostructures films

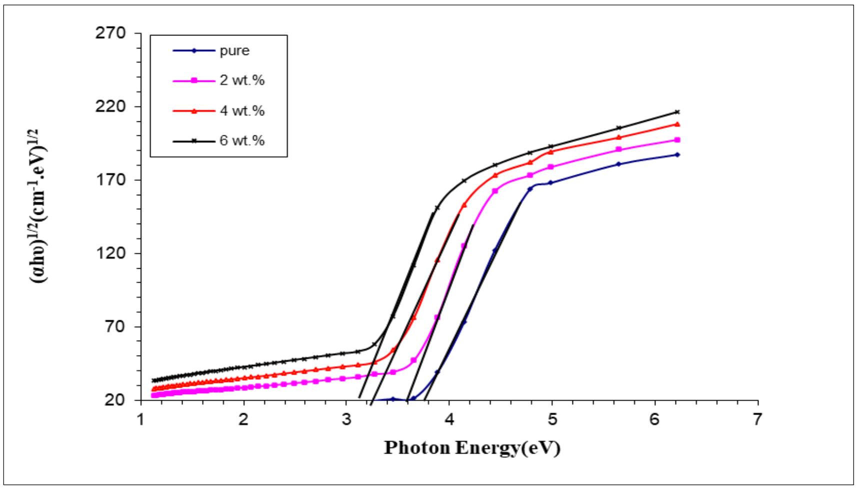

Figure 4 Gaps of energies values of PVP/MnO_2nanostructures of allowed transition

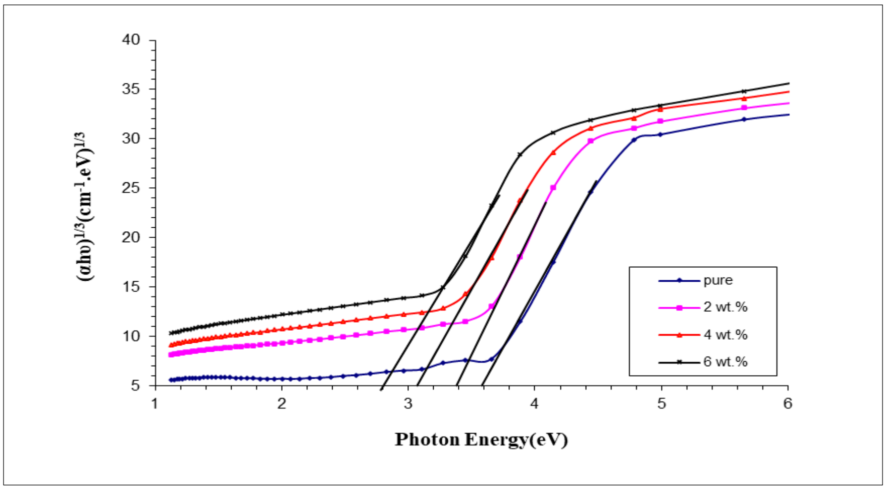

Figure 5 Gaps of energies values of PVP/MnO_2nanostructures of forbidden transition

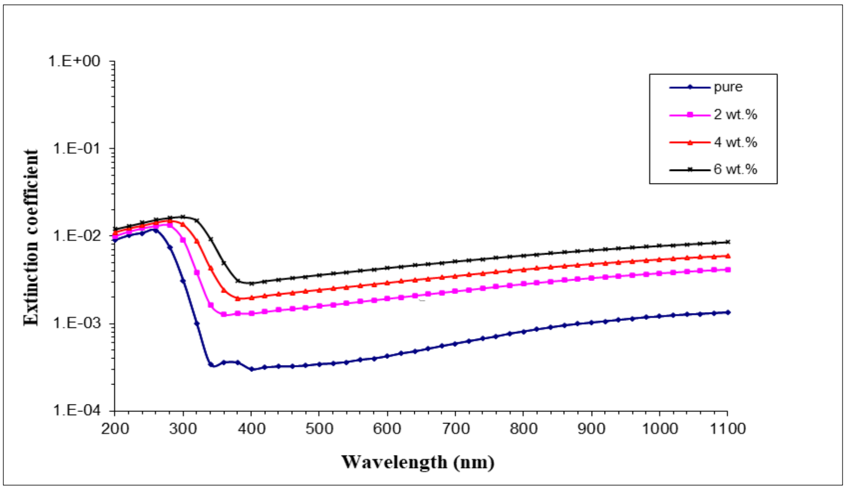

Figure 6 Extinction coefficient performance of PVP/MnO2nanostructures films

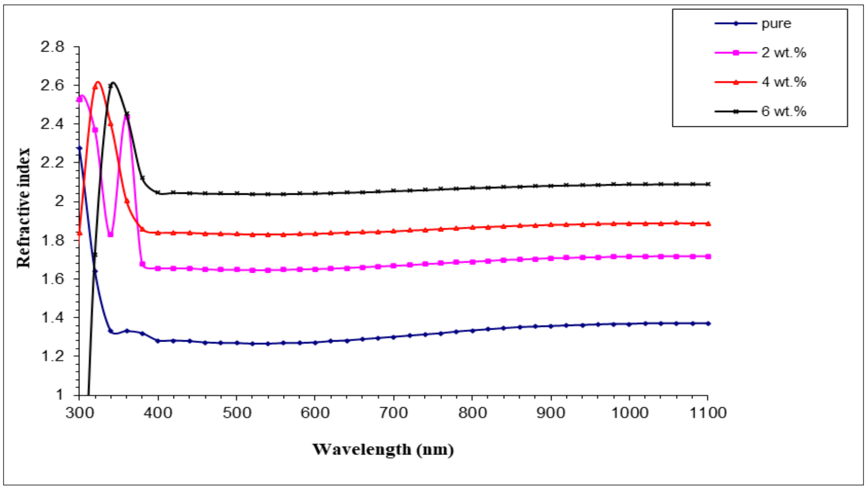

Figure 7 Refractive index performance of PVP/MnO2nanostructures films

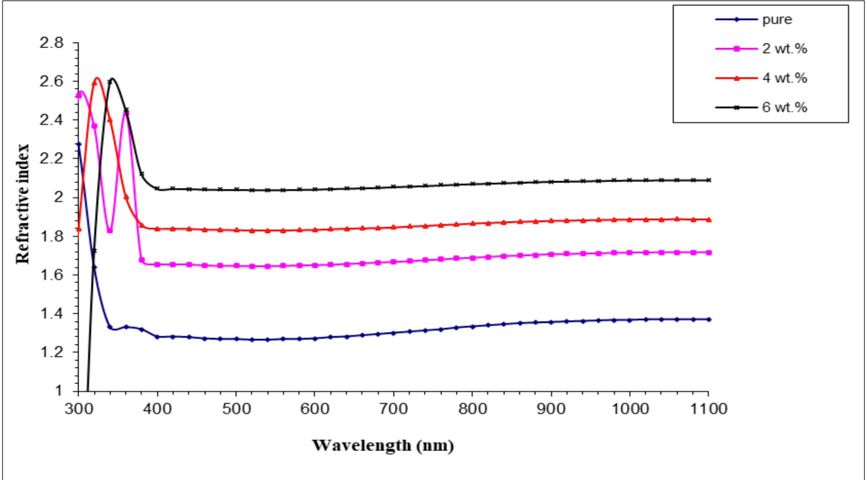

Figure 8 Variation of dielectric constant ofreal part of PVP/MnO2nanostructures

The dielectric constant of real and imaginary parts ofPVP/MnO2nanostructures films are explain in figs (8,9). From these Figures, the values of ε_1 andε_2 riseas the ratio of MnO2NPs rises which relate to rise in the n and k values [32].

The variation of optical conductivity of PVP/MnO2nanostructuresfilmswith wavelength is represented in Fig.10. The σ_{op} value of PVP/MnO2nanostructures films rises with rise in the MnO2NPs content and this behavior related to rise in the absorption and reduce in the energy gap [33,34].

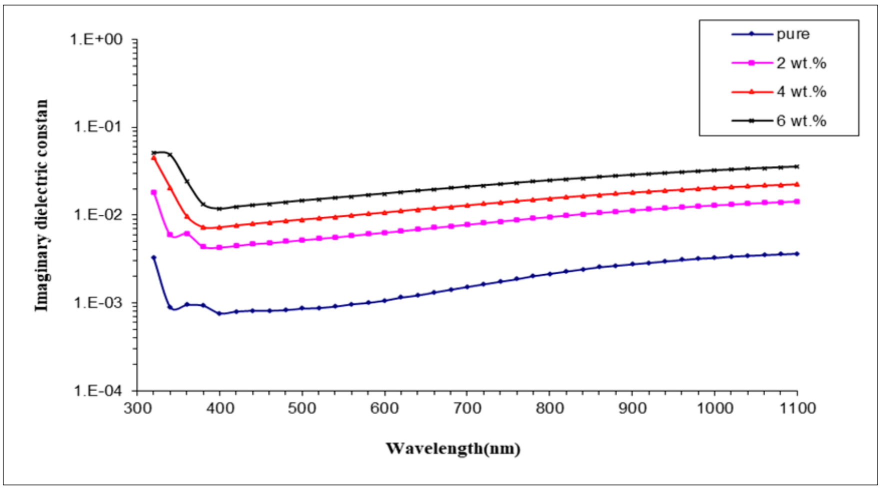

Figure 9 Behaviour of dielectric constant of imaginary part of PVP/MnO2nanostructures

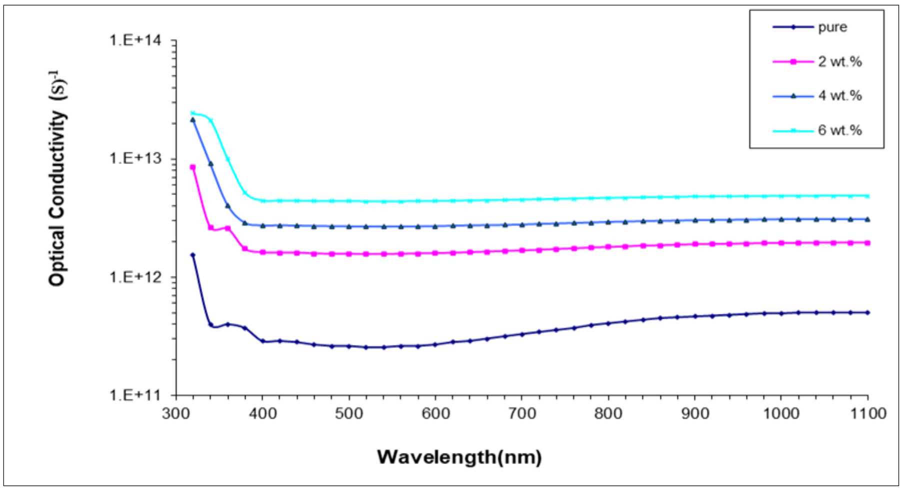

Figure 10 Influence of MnO2NPs content on optical conductivity for PVP

4. Conclusion

The absorbance of PVP rises and the transmittance reduce with rise of theMnO2NPs content. The PVP/MnO2nanocomposites have high absorbance in the UV-region. The gap of energy of polymer reduces with a rise of the MnO2NPs content. Coefficient of absorption, index of refractive, coefficient of extinction, dielectric constant for real and imaginary parts and conductivity of PVP are raise with a rise of the MnO2 NPs content. From this results illustrated the PVP/MnO2nanostructures may be utilized in different photonics and optics fields.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

No conflict of interest.

References

[1] Alibe, I. M., Matori, K. A., Sidek, H. A. A., Yaakob, Y., Rashid, U., Alibe, A. M., ... &Nasir, M. M. (2019). Effects of polyvinylpyrrolidone on structural and optical properties of willemite semiconductor nanoparticles by polymer thermal treatment method. Journal of Thermal Analysis and Calorimetry, 136(6), 2249-2268.

[2] Ajayan PM, Schadler LS, Braun PV. Nanocomposite science andtechnology. Weinheim: WILEY-VCH Verlag GmbH & Co.; 2006.

[3] Jordan J, Jacob KI, Tannenbaum R, Sharaf MA, JasiukI.Experimental trends in polymer nanocomposites—a review.MaterSciEng A. 2005;393:1–11.

[4] Alaa J. Kadham, Dalal Hassan, Najlaa Mohammad, Ahmed Hashim, Fabrication of (Polymer Blend-magnesium Oxide) Nanoparticle and Studying their Optical Properties for Optoelectronic Applications, Bulletin of Electrical Engineering and Informatics, Vol.7, No.1, (2018), DOI: 10.11591/eei.v7i1.839.

[5] D. Hegazy, M. Eid and M. Madani, "Effect of Ni Nano particles on Thermal, Optical and Electrical Behaviour of Irradiated PVA/AAc Films", Arab Journal of Nuclear Science and Applications, Vol.47, No. 1, PP.41-52, (2014).

[6] H.N. Obaid, M.A. Habeeb, F.L. Rashid, and A. Hashim, Thermal energy storage by nanofluids, Journal of Engineering and Applied Sciences, 8(5), 143-145 (2013).

[7] Mohammed, M. I. (2022). Controlling the optical properties and analyzing mechanical, dielectric characteristics of MgO doped (PVA–PVP) blend by altering the doping content for multifunctional microelectronic devices.

[8] S.S. Shahrabi, J. Barzin, P. Shokrollahi, Blood cell separation by novel PET/PVP blendelectrospun membranes, Polym. Test. 66 (2018) 94–104.

[9] Hendi, A. H. Y., Al-Kuhaili, M. F., &Durrani, S. M. A. (2016). Chemical and optical properties of MnO_2 thin films prepared by reactive evaporation of manganese. Int. J. Res. Eng. Technol, 5, 320-328.

[10] O. Nilsen, H. Fjellva˚g, A. Kjekshus, Growth of manganese oxide thin films by atomic layer deposition Thin Solid Films, 444 (2003), pp. 44–51.

[11] B. B. Burton, F.H. Fabreguette, S.M. George, Atomic layer deposition of MnO using Bis (ethylcyclopentadienyl) manganese and H2O Thin Solid Films, 517 (2009), pp. 5658-5665.

[12] Hind Ahmed, Ahmed Hashim, Fabrication of PVA/NiO/SiCNanocomposites and Studying their Dielectric Properties For Antibacterial Applications, Egypt. J. Chem., Vol. 63, No. 3, DOI: 10.21608/EJCHEM.2019.11109.1712, (2020).

[13] Kadhim K J, Agool I R and Hashim A., Synthesis of (PVA-PEG-PVP-TiO2) Nanocomposites for Antibacterial Application. Materials Focus, Vol.5, No.5, DOI: https://doi.org/10.1166/mat.2016.1371 , (2016).

[14] HayderAbduljalil, Ahmed Hashim, AlaaJewad, The Effect of Addition Titanium Dioxide on Electrical Properties of Poly-Methyl Methacrylate, European Journal of Scientific Research, Vol.63, No.2, pp.231-235, (2011).

[15] Ahmed Hashimand QassimHadi, Novel of (Niobium Carbide/Polymer Blend) Nanocomposites: Fabrication and Characterization for Pressure Sensor, Sensor Letters, Vol.15, doi:10.1166/sl.2017.3892 , (2017).

[16] Majeed Ali Habbeb, Ahmed Hashim, Abdul-Raheem K. AbidAli, The dielectric properties for (PMMA-LiF) composites , European Journal of Scientific Research, Vol. 61, No.3, pp.367-371, (2011).

[17] M. Jothibas, C. Manoharan, S. Johnson Jeyakumar, P. Praveen, Study on structural and optical behaviors of In2O3nanocrystals as potential candidate for optoelectronic devices. J Mater Sci: Mater Electron, Vol.26, pp.9600–9606, (2015), https://doi.org/10.1007/s10854-015-3623-x.

[18] T. Abdel-Baset, M. Elzayat, and S.Mahrous, Characterization and Optical and Dielectric Properties of Polyvinyl Chloride/Silica Nanocomposites Films, Int. J. of Polym. Sci., Vol. 2016, http://dx.doi.org/10.1155/2016/1707018.

[19] Shalini Agarwal, Y. K. Saraswat and Vibhav K. Saraswat, Study of Optical Constants of ZnO Dispersed PC/PMMA Blend Nanocomposites, Open Physics Journal, Vol.3, pp.63-72, (2016), DOI: 10.2174/1874843001603010063.

[20] N. Mahfoudh, K. Karoui and A. Ben Rhaiem,Optical studies and dielectric response of[DMA]2MCl4 (M ¼ Zn and Co) and [DMA]2ZnBr4, RSC Adv., Vol.11, (2021), DOI: 10.1039/d1ra03652a.

[21] A. Alsaad, A. R. Al Dairy, A. Ahmad, I. A. Qattan, S. Al Fawares and Q. Al-Bataineh, Synthesis and Characterization of Polymeric (PMMA-PVA) Hybrid Thin Films Doped with TiO2 Nanoparticles Using Dip-Coating Technique, Crystals, Vol.11, (2021), https://doi.org/10.3390/cryst11020099.

[22] Ali F Al-Shawabkeh, Ziad M Elimat and Khaleel N Abushgair, Effect of non-annealed andannealedZnO on the opticalproperties of PVC/ZnOnanocomposite films, J. of Thermoplastic Com. Mat., (2021), DOI: 10.1177/08927057211038631.

[23] NahedaHumood Al-Garah, FarhanLafta Rashid, AseelHadi, and Ahmed Hashim, Synthesis and Characterization of Novel (Organic–Inorganic) Nanofluids for Antibacterial, Antifungal and Heat Transfer Applications, Journal of Bionanoscience, Vol. 12, doi:10.1166/jbns.2018.1538 , (2018).

[24] M. A. Habeeb, A. Hashim, and A. Hadi, Fabrication of New Nanocomposites: CMC-PAA-PbO2 Nanoparticles for Piezoelectric Sensors and Gamma Radiation Shielding Applications, Sensor Letters, Vol.15, No.9, (2017), doi:10.1166/sl.2017.3877.

[25] Falah Ali Jasim, FarhanLafta, Ahmed. Hashim, Majeed Ali, Angham. G. Hadi, Characterization of palm fronds-polystyrene composites, Journal of Engineering and Applied Sciences, Vol.8 , No.5, PP. 140-142, 2013.

[26] A. Hashim, Fabrication and characteristics of flexible, lightweight, and low-cost pressure sensors based on PVA/SiO2/SiC nanostructures, J Mater Sci: Mater Electron 32, 2796–2804 (2021), https://doi.org/10.1007/s10854-020-05032-9.

[27] Ahmed Hashim, Zinah S. Hamad, Lower Cost and Higher UV-Absorption of Polyvinyl Alcohol/ Silica Nanocomposites For Potential Applications, Egypt. J. Chem., Vol. 63, No.2, DOI: 10.21608/EJCHEM.2019.7264.1593, (2020).

[28] Ahmed Hashim and Ali Jassim, Novel of (PVA-ST-PbO2) Bio Nanocomposites: Preparation and Properties for Humidity Sensors and Radiation Shielding Applications, Sensor Letters, Vol. 15, No.12, doi:10.1166/sl.2018.3915 , (2017).

[29] Hazim, A., Abduljalil, H.M. &Hashim, A. Analysis of Structural and Electronic Properties of Novel (PMMA/Al2O3, PMMA/Al2O3-Ag, PMMA/ZrO2, PMMA/ZrO2-Ag, PMMA-Ag) Nanocomposites for Low Cost Electronics and Optics Applications. Trans. Electr. Electron. Mater. 21, 48–67 (2020). https://doi.org/10.1007/s42341-019-00148-0.

[30] Ahmed Hashim, Alaa J. Kadham, AseelHadi, and Majeed Ali Habeeb, Determination of Optical Parameters of Polymer Blend/Nanoceramics for Electronics Applications, Nanosistemi, Nanomateriali, Nanotehnologii, Vol.19, No.2, (2021), https://doi.org/10.15407/nnn.19.02.327

[31] Falah Ali Jasim, Ahmed. Hashim, Angham. G. Hadi, FarhanLafta, Saba R. Salman and Hind Ahmed, Preparation of (pomegranate peel-polystyrene) composites and study their optical properties, Research Journal of Applied Sciences, Vol.8, Issue 9, PP. 439-441, (2013).

[32] Khalid Al-Ammar, Ahmed Hashim, MaithemHusaien, Synthesis and Study of Optical Properties of (PMMA-CrCl2) Composites, Chemical and Materials Engineering, Vol.1, No.3, 2013, DOI: 10.13189/cme.2013.010304.

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

[34] Ahmed Hashim, Synthesis of SiO2/CoFe2O4 Nanoparticles Doped CMC: Exploring the Morphology and Optical Characteristics for Photodegradation of Organic Dyes, Journal of Inorganic and Organometallic Polymers and Materials, Vol.31, https://doi.org/10.1007/s10904-020-01846-6 , (2021).