World Journal of Advanced Research and Reviews

eISSN: 2581-9615 CODEN (USA): WJARAI

Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://wjarr.com/

(Research Article)

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Effect of WC nanoparticles addition on optical properties of CMC for photo-detectors devices

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World Journal of Advanced Research and Reviews, 2023, 17(01), 1194–1201

Publication history: Received on 12 December 2022; revised on 24 January 2023; accepted on 26 January 2023

Article DOI: https://doi.org/10.30574/wjarr.2023.17.1.0147

Abstract

In this paper, nanostructures from carboxymethyl cellulose (CMC) /tungsten carbide nanoparticles (WC NPs) were fabricated. The WC NPs was added to polymer by various weight ratios are (1.5, 3 and 4.5) wt. %. "The optical characteristics" of CMC/WC nanostructures were tested. The optical results exhibited the absorbance of CMC is raised with rising of the content of WCNPs. The gap of energy of CMC polymer reduces with a rise of the content of WCNPs. The optical constants such as "coefficient of absorption, coefficient of extinction, index of refractive", dielectric "constants for real and imaginary part"and conductivity of CMC varied with a rise of the weight ratios of WC NPs.

Keywords: CMC; Nanocomposites; Optical properties; WC

1. Introduction

When combined with a polymer, organic/inorganic hybrid substances provide incredibly appealing and flexible fields. Because they combine the benefits of organic polymers' ductility, dielectric properties, and flexibility with those of inorganic materials increased thermal stability, rigidity, and strength as well as their higher refractive index and harder surface, nanocomposites of organic and inorganic materials have a wide range of applications [1]. There has to be more investigation into how nanoparticles affect the characteristics of a polymer matrix in order to more accurately predict the final properties of the composite. Recently, composites of polymer and ceramic filler have drawn attention because of their appealing electronic and electrical properties. Potential applications include sensos, window and packaging of electronic[2].Composites with polymer matrix display distinct characteristics and include found ever-increasing fields as engineering components and structures in land transportation, electricalandelectronics, aviation, aerospace,military, sensors, marine,UV resistance, sports and recreational industries [3-7].Carboxymethyl cellulose "(CMC) "is a linear polysaccharide of anhydro-glucose" that is "an anionic, water-soluble"cellulose derivative. 1,4-Glycosidic linkages link the repeating units together. Only a few anionic carboxymethyl groups (i.e., -CH2COOH) in the CMC structure, which replace some of the "presentof hydroxyl groupsin the pure "infrastructureof cellulose ", are the primary molecular difference between CMC and cellulose [8, 9]. CMC and its composites, for instance, are frequently used in the biomedical fields of tissue engineering, bone-tissue engineering, wound dressing,creation of artificial organs or and diagnosis of various diseases[10].Due to its exceptional characteristics, including a "high melting point", excellent hardness, low friction coefficient, strong "resistanceof oxidation ", and "superior electrical conductivity", tungsten carbide (WC) has potential applications. The substance has been used with success in the ""hydrogen evolution reaction" (HER), solar cells, and as an efficient catalyst for the oxygen reduction reaction and electro-oxidation of methanol [11]. Because it is inexpensive, has a high catalytic activity, is selective, and has good thermal stability under testing. Additionally, WC is more resistant to acidic solutions and operates at greater temperatures. For direct alcohol fuel cells, it demonstrated resistance to CO poisoning, resulting in a prolonged catalytic life[12,13]. This paper aims to explain the effect of WC NPsadding on optical characteristics of CMC for photo-detectors devices.

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2. Material and methods

Films of carboxymethyl cellulose (CMC) doped withtungsten carbide (WC) were created viacasting method. CMC film was created by dissolving 1gm of this polymer in 50 ml of deionized water at room temperature with magnetic stirrer for half an hour. The nanocomposites films were created by adding WC NPs to a CMC solution with concentrations of (1.5, 3 and 4.5) wt.%. The optical characteristics of nanocomposites films were tested using "spectrophotometer (UV-1800^{0}A-Shimdzu)".The coefficient of absorption (α) is calculated by [14]:

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

Which: "A is the absorbance and d is the thickness. The gap of energy is given by" [15]:

$$(\alpha h v)^{1/m} = C(hv - E_g) \quad \text{..........(2)}$$

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 [16]:

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

which"R is the reflection.The coefficient of extinction (k) is determinedby" [17]:

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

which"λ is the wavelength. The dielectric constant of real and imaginary parts: real (ε_1), and imaginary (ε_2) are given by"[18]:

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

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

The conductivity of optical (σ_{op}) is defined by [19].

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

3. Results and discussion

Fig. (1)"display the absorbance of a CMC/WC nanocomposites with a wavelength range of 200-1100 nm. The absorption of CMC rises with rise the WC NPs content which due to the free electron absorb the light of incident hence the transmittance will decrease as shown in Fig.2. This result is agreement with" [20-22].

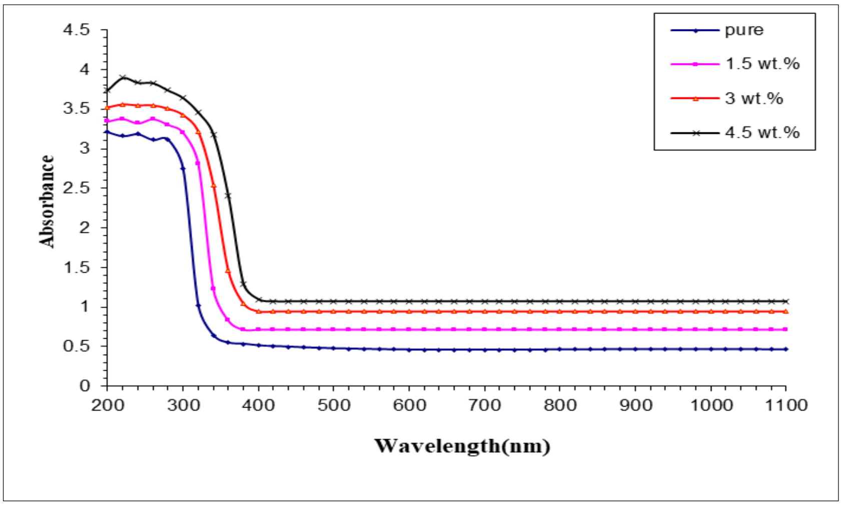

Figure 1 Influence of WC NPs on the absorbance of CMC

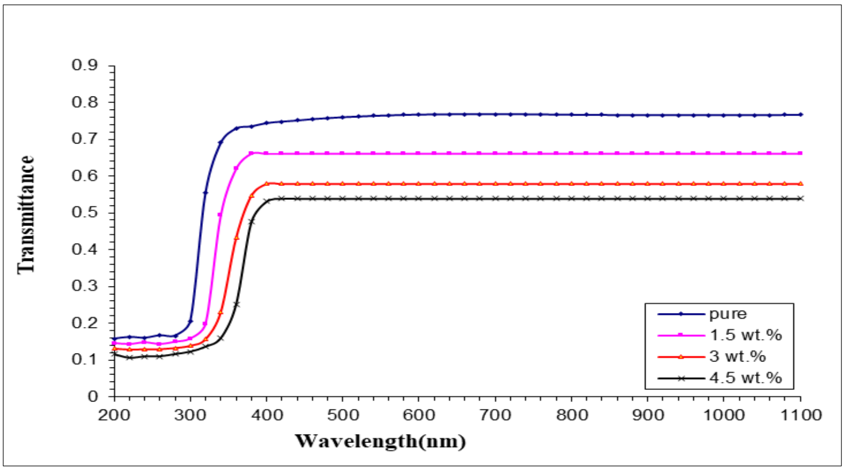

Figure 2 Optical transmittance of CMC/WC nanocomposites

The coefficient of absorption of CMC/WC nanostructures with energy of photon are demonstrate in fig.(3). When the WC NPs content rises, the α rise. The improve of α is indicatea rise in light absorbance [23]. The nanostructures have an indirect gap of energy when the value of α is less than 10^4 cm^{-1}.

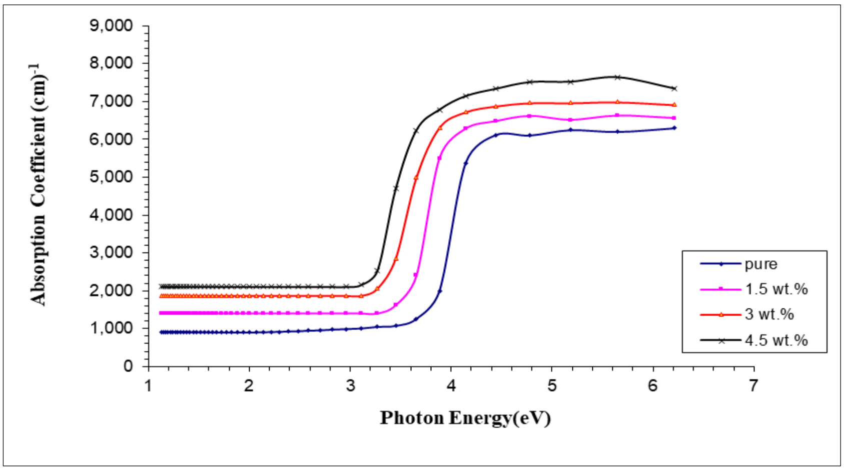

Figure 3 Absorption coefficient of CMC/WCnanocomposites versus photon energy

By plotting $(\alpha h\upsilon)^{1/2}$ and $(\alpha h\upsilon)^{1/3}$againsthvas shown in figs.(4,5), the energy of gap was calculated. The gap of energy fortheallowed reduced from 3.6 eV for the CMC to 2.9eV for the for 4.5wt.%WC NPs and from 3.4 eV for the CMC to 2.6eV for CMC 4.5wt.% WCNPsgap of for the forbidden. The creation of localstates in the band gap cause to reduce the gap of energy [24]. The value gap of energy isdemonstratedinTable (1)."

Table 1 Gap of energy values of CMC/WCnanocomposites

WC NPs wt.%	Eg(eV)	
	allowed	forbidden
0	3.6	3.4
1.5	3.4	3.1
3	3.1	2.8
4.5	2.9	2.6

The extinction coefficient for CMC/WC nanostructure is demonstrate in Fig.(6). The Krises as the content of WC NPs rises. This result attributed to the improvement of the coefficient of absorption when the added of WCNPs. This result agrees with [25].

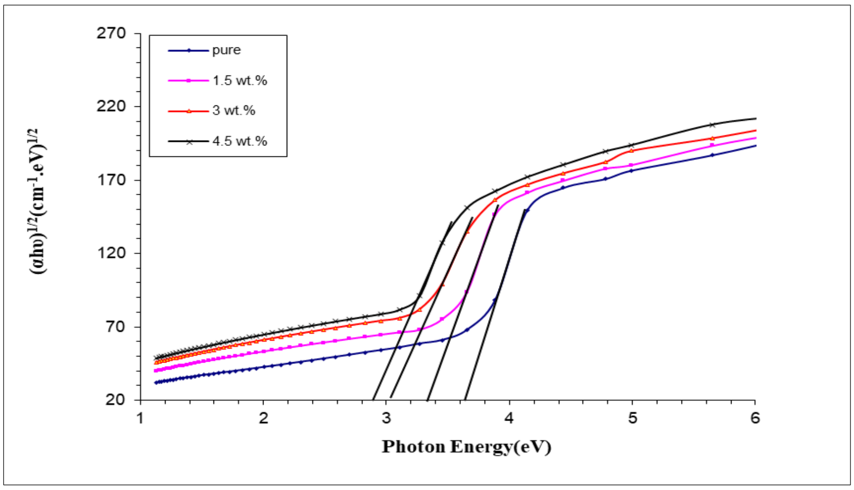

Figure 4 $(\alpha h\upsilon)^{1/2}$ versus hv of CMC/WC nanocomposites

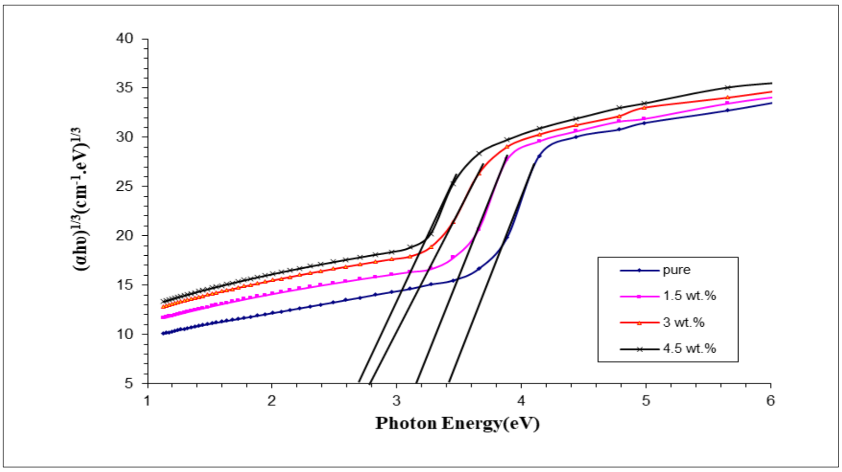

Figure 5 $(\alpha h\upsilon)^{1/3}$ versus hv ofCMC/WCnanocomposites

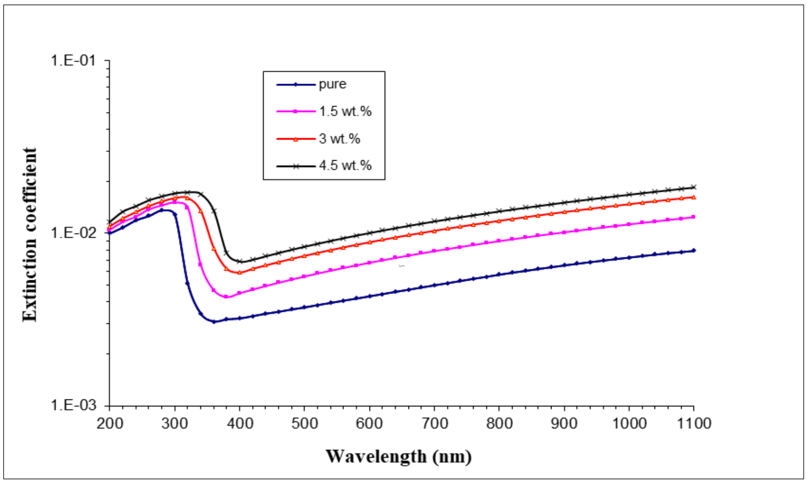

Figure 6 Extinction coefficient for (CMC/WC) nanocomposites

The refraction index of (CMC/WC) nanostructure with wavelength is demonstrate in Fig. (7). The index of refractive inclines to rise as the rises of WC NPs content in the CMC polymer. This result due to rise of WC NPs content, the density of the nanostructure rises [26].

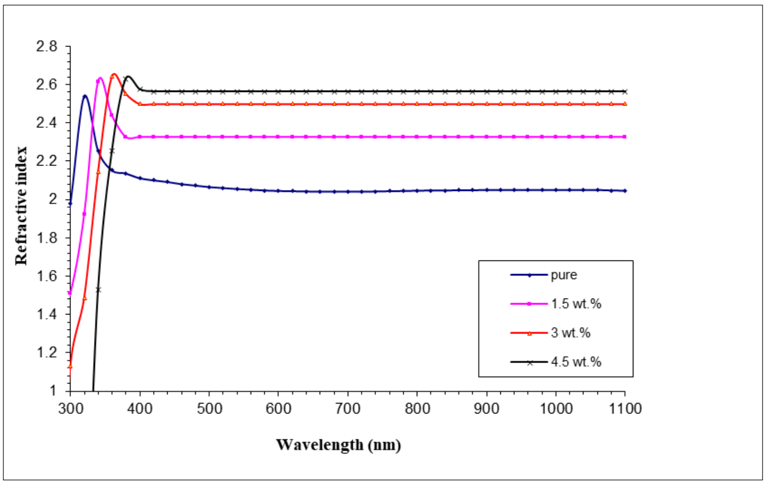

Figure 7 Refraction index of (CMC/WC) nanocomposites versus wavelength

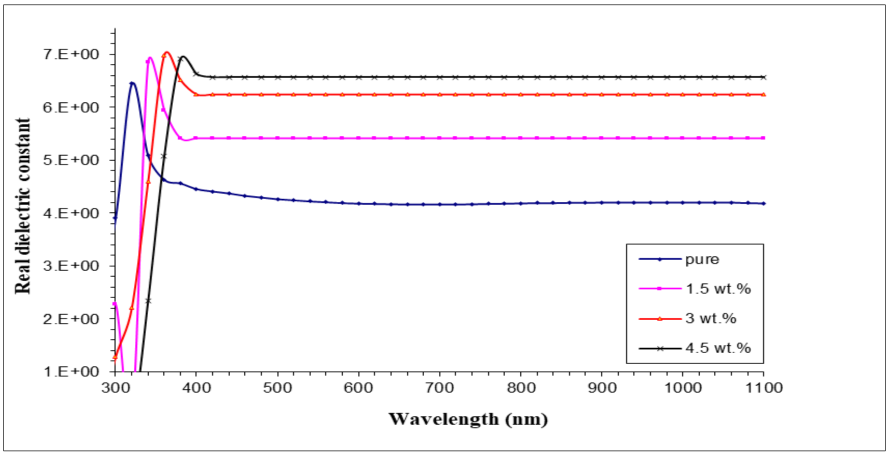

Figure 8 Variation of (ε_1) versus wavelength

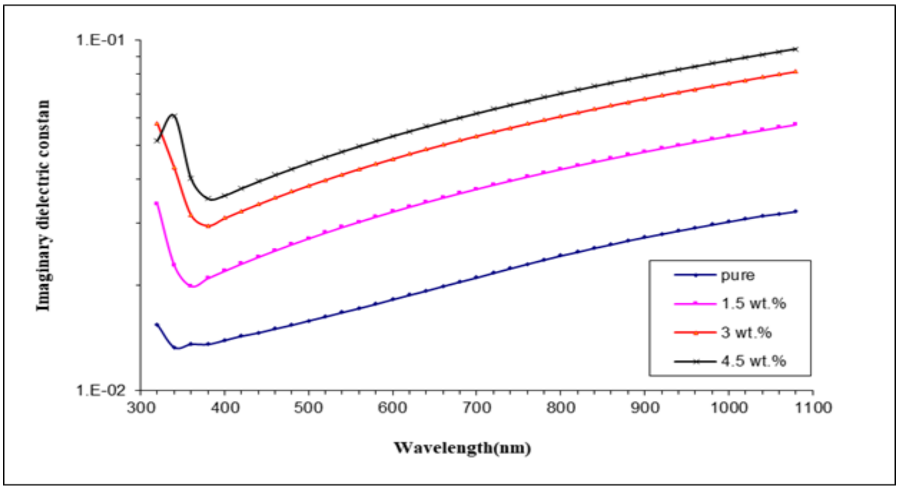

Figure 9 Variation of (ε_1) versus wavelength

The variance of (ε_1) with wavelength is demonstrate in fig.(8). Since of the low value of K^2, the dielectric constant of real rises as the n values rise when the content of WC NPs rises. The variation in ($\varepsilon_{2)}$ with wavelength is demonstrate in Fig.(9). Since the relation between α and K, it is clear that ε_2 is dependent on K values that differ with the coefficient of absorption. This result is agreeing with [27].

Fig. (10) Demonstrate the conductivity of optical of CMC/WC nanostructure versus of wavelength. The conductivity of optical of CMC increases as the WC content increases which indicate to create of local states in the E_g[28].

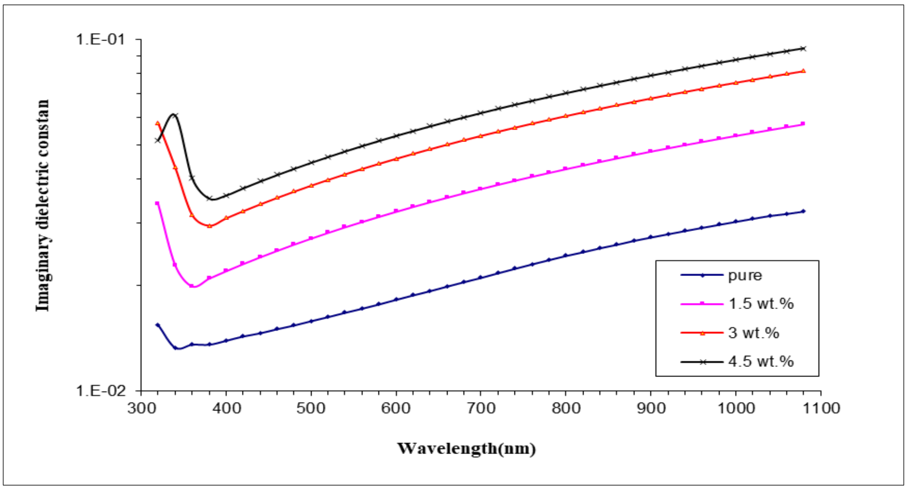

Figure 10 Optical conductivity of CMC/WC nanocomposites versus wavelength

4. Conclusion

The results demonstrated that adding various content of WC NPs improved the optical characteristics of CMC. The absorbance and optical constants (coefficient of absorption, coefficient of extinction, index of refractive, dielectric constants for real and imaginary and conductivity) of CMC increased with a rise in weight percentages of WCNPs. The gap of energy (E_g) of CMC decreases with the increase of the content of WCNPs. The optical results demonstrated that the CNC/WC nanocomposites might be utilized for a variety of optoelectronic applications.

Compliance with ethical standards

Acknowledgments

Acknowledgment to University of Babylon.

Disclosure of conflict of interest

No conflict of interest.

References

[1] 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.

[2] 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 MatériauxAvancés-Journal of Composite and Advanced Materials, Vol. 32, No. 4, pp. 205-209. https://doi.org/10.18280/rcma.320406.

[3] Heinze, T.; Pfeiffer, K. Studies on the synthesis and characterization of carboxymethylcellulose. Angew. Makromol. Chem. 1999, 266, 37–45.

[4] Su, J.-F.; Huang, Z.; Yuan, X.-Y.; Wang, X.-Y.; Li, M. Structure and properties of carboxymethyl cellulose/soy protein isolate blend edible films crosslinked by Maillard reactions. Carbohydr. Polym. 2010, 79, 145–153.

[5] Rahman, M., Hasan, M., Nitai, A. S., Nam, S., Karmakar, A. K., Ahsan, M., ... & Ahmed, M. B. (2021). Recent developments of carboxymethyl cellulose. Polymers, 13(8), 1345.

[6] 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).

[7] Ahmed Hashim, Hayder M. Abduljalil, Hind Ahmed, Fabrication and Characterization of (PVA-TiO2)1-x/ SiCxNanocomposites for Biomedical Applications, Egypt. J. Chem., Vol. 63, No. 1, DOI: 10.21608/EJCHEM.2019.10712.1695, (2020).

[8] 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).

[9] 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).

[10] 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).

[11] 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).

[12] Gabhale, B., Jadhawar, A., Bhorde, A., Nair, S., Borate, H., Waykar, R., ... &Jadkar, S. (2018). High band gap nanocrystalline tungsten carbide (nc-WC) thin films grown by hot wire chemical vapor deposition (HW-CVD) method. Journal of Nano-and Electronic Physics, 10(3).

[13] Czyzniewski, A. (2003). Deposition and some properties of nanocrystalline WC and nanocomposite WC/aC: H coatings. Thin Solid Films, 433(1-2), 180-185.

[14] 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.

[15] T. Abdel-Baset, M. Elzayat, and S.Mahrous, Characterization and Optical and Dielectric Properties of Polyvinyl Chloride/Silica Nanocomposites Films, International Journal of Polymer Science, Vol. 2016, Article ID 1707018, 13 pages, http://dx.doi.org/10.1155/2016/1707018.

[16] ShaliniAgarwal, 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.

[17] 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.

[18] 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.

[19] Ali F Al-Shawabkeh, Ziad M Elimat and Khaleel N Abushgair, Effect of non-annealed and annealed ZnO on the optical properties of PVC/ZnOnanocomposite films, Journal of Thermoplastic Composite Materials, (2021), DOI: 10.1177/08927057211038631.

[20] 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.

[21] 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).

[22] 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.

[23] 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).

[24] 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.

[25] 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.

[26] 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).

[27] 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.

[28] D. Hassan, A. Hashim, Structural and optical properties of (polystyrene-copper oxide) nanocomposites for biological applications. Journal of Bionanoscience. (2018); Vol.12, Issue 3, doi:10.1166/jbns.2018.1533