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Research Article

Characterization and evaluation of thin films of a polymer reinforced with nanoparticles using the spin coating technique

Abstract

Thin films of the polymer, polyvinylpyloridate, reinforced with zinc-nickel ferrite nanoparticles (Zn0.5Ni0.5Fe_2O_4) and prepared using the technique of spin coating is the central theme of presentation and discussion in this research paper. The zinc-nickel ferrite nanoparticles were used to reinforce a thin film of the chosen polymer and for varying concentrations. The prepared thin films were transparent and consequently studied for the purpose of selection and use in applications specific to the domain of photonics. Optical characterization of samples of the as-synthesized thin films was done using different spectroscopy techniques. Optical density of the as-prepared thin films was obtained using a ultra-violet (UV) spectrophotometer. The reinforcing effect was observed from the emission spectra that was obtained using the fluorescence spectrophotometer. Also, Fourier transform infrared spectroscopy (FTIR) of the reinforced thin films of the chosen polymer was obtained and compared with the unreinforced pure polymer and did reveal an observable change in both the peak value and intensity of the peak. X-ray diffraction (XRD) analysis revealed a noticeable difference in both intensity and crystallization of the thin films of the reinforced polymer. Scanning electron microscopy observations revealed a morphological change of the thin films. Roughness of the sample surface was studied with the help of images obtained from an atomic force microscope (AFM). The present research study technique of spin coating was done properly and successfully.

With a gradual increase in the number of reinforcing nanoparticles in the polymer matrix we did observe an increase in Optical Density using UV-Visible spectroscopy. An increase in the Optical Density is beneficial for attaining an improvement in anti-reflection response. This study helped establish the effect of nanoparticle reinforcements on optical properties while concurrently establishing the need for selection and use of thin films for applications in the field of photonics.

Keywords: UV-Vis, X-ray diffraction, photoluminescence

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Abbreviations: SEM, scanning electron microscope; AFM, atomic force microscopy; FTIR, fourier transform infrared spectroscopy

Introduction

Photonics is all about the science of light. The technology behind controlling, generating and detecting light waves, or photons, is often referred to as photonics. Photonics involves a wide range of wavelength ranging from the gamma rays to the radio waves, and includes infrared, Ultra-Violet (UV), and the X-rays. The science behind photonics essentially includes a study and understanding of the following: (i) emission, (ii) transmission, (iii) amplification, (iv) deflection, (v) detection by optical instruments and components, (vi) lasers and the other sources of light, (vii) electro-optical instrumentation, and (viii) fiber optics.

Polymers are organic materials in solid form and essentially consists of a large number or network of monomers, which are often linked to each other in both a prescribed and repetitive manner. In the domain of electrical engineering, the thin polymer transistors have over the years seen gradual improvements resulting thereby in low cost, more flexible electronics and a large area. In RF-ID [radio frequency identification] tags, the common developments recently made and rapidly emerging in the areas of ink-jet printing, active-matrix display and integrated circuits. Typical materials chosen and used as the dielectric organic gate material consists of spin coated polyvinylpyloridate (PVP), which is doped, or reinforced, with Zn0.5Ni0.5Fe_2O_4 nanoparticles. The solid polymer electrolytes, i.e., salt dissolved in a polymer matrix often suffer from slow polarization response. Cross linked ultra-thin polymer films have shown an appropriate value of capacitance, which often exceeds that of the conventional polymer insulators and ceramics that have conventionally been chosen for use in organic thin film transistors. A few of the polymer films like the bi-axially oriented polypropylene provide high electrical insulation. This makes them an ideal candidate for selection and use as a dielectric in capacitors and other electronic components. Also, they can be used both as a sealant and as an encapsulant. Solar cells for the emerging generation of electronic equipment are also being fabricated using polymer thin films.

In this present research study, optical properties of chosen thin film samples of a polymer nano composite were determined, studied and analyzed using spectroscopy techniques. The optical parameters were also determined from Optical Density and the effect and/or influence of doping, or reinforcement, was systematically studied and established. Introducing nanoparticles, that is Zn0.5Ni0.5Fe_2O_4, to a polymer matrix will tend to alter the physical properties of the various techniques that have been used to prepare polymer films, the spin coating method was chosen and used primarily because it is an effective and simple technique while concurrently offering low manufacturing cost. A previous study by Wang and co-workers described the use of multiple drop casting for preparing inorganic films that were doped with organic compounds for selection and use in photonic devices. To check the overall uniformity of the thin film samples, both atomic force microscopy (AFM) and optical microscopy (OM) was used and the images are provided to help establish the morphology and degree of roughness. The scanning electron microscope (SEM) observations did reveal a noticeable change in morphology of the thin film surface. Results are compared with those obtained in earlier studies.[1-10]

Experimental techniques

The spectroscopy technique, where electromagnetic radiation is used for getting information about structure and property of a material was used for characterization of the thin film samples.[11] The prepared thin film samples were studied using the following: (i) a UV-Visible, (ii) Fourier transform infrared (FTIR) spectroscopy, and (iii) fluorescence spectrophotometer. The ultra-violet (UV)-visible spectrophotometer [Model: Shimadzu UV Visible Spectroscope] study was carried out at the BMS Institute of Technology [Bangalore-560064, India] and provided the spectra for the chosen three thin films and pure polyvinylpyloridate. The Fourier transform infrared (FTIR) spectroscopy [Model: Perkin Elmer FTIR] study was carried out at the BMS Institute of Technology [Bangalore-560064, India]. The FTIR did reveal an observable change in functional group of the thin films of the as-synthesized polymer nano composite. The photoluminescence [Model: FP-8300 Jarko] study was carried out at Mysore University [Mysore- 570005, India]. Fluorescence spectroscopy was done for the purpose of analyzing fluorescent properties of the chosen thin film samples.

The x-ray diffractometer (XRD) used [Model: Type D8 XRD] was carried out at the Ramaiah Institute of Technology [Bangalore-560054, India] and did reveal a change in intensity and an overall improvement in crystallinity of the as-synthesized nano composite. The scanning electron microscope [Model: Tescan Vegan 3] observations were carried out at the BMS College of Engineering [Bangalore-560019, India] and did reveal a change in morphology of the chosen polymer [PVP] and the engineered polymer nano composites. The Atomic Force Microscope (AFM) observations help in revealing overall roughness of the sample surface of the three chosen thin films of the as-synthesized polyvinylpyloridate nano composite.

Materials and methods

Material

Polyvinylpyrrolidone is a non-ionic water-soluble polymer with a chemical formula of $[C_9H_9NO]$ n with a structural configuration shown in Figure 1. Polyvinylpyrrolidone is commonly referred to by the name polyvidone and made from the monomer N-vinylpyrrolidone. The chosen polymer is a synthetic polymer consisting of linear 1-vinyl-2-pyrrolidinone groups and essentially amorphous in nature. The chosen polymer has good adhesiveness coupled with film producing capability. In a liquid solution, this specific polymer has good wetting properties, which makes it an ideal candidate for selection and use as a coating. Besides, the chosen polymer has acceptable tensile properties, hygroscopic in nature, and resistance to both oil and grease thereby making it resistant to chemicals. Hygroscopic means it has the ability to absorb moisture that is present in the surrounding environment. Further Polyvinylpyrrolidone (PVP) has high tensile strength coupled with an ability to emulsify. It was bought from Sigma-Aldrich [India] and had the following properties: (i) starting density of $1.2 g/cm^3$, (ii) melting point of 150°C, and (iii) refractive index of 1.65. The polymer was procured in the powder form. The method of solution combustion was used for preparation of nanoparticles used in this research study.

Preparation of Zinc Ferric oxide

Firstly, we measure the required amount of $Zn\,(NO_3)^2$, $Fe\,(NO_3)^3$, and ODH (oxidative dehydrogenation).

(a) Amount of $Zn\,(NO_3)^2 = 2.97$grams

(b) Amount of $Fe\,(NO_3)^3 = 8.08$grams

(c) Amount of ODH (Oxidative Dehydrogenation) = 4.7257grams

The above chemicals were thoroughly mixed in a glass beaker. A magnetic stirrer was used for mixing the solution at a speed of 550rpm and at a temperature of 300°C. To this solution mixture was added 25 ml of distilled water and the resultant mixture was gently stirred using a magnetic stirrer. We did observe a smoldering flame and it took 20 minutes to complete the reaction. The reaction can be expressed as follows:

$$Zn\,(NO_3)^2 + 2\,Fe\,(NO_3)^3 \quad \rightarrow \quad ZnFe_2O_4 + 8CO_2 + 12N_2 + 12H_2O$$

Doping or reinforcing with Ni+

Here we are adding Ni+ ions from a Ni nitrate solution having different concentration. That is, x = 0.1, 0.3, 0.5, and 0.7 to get a different concentration of nanoparticles in the chosen polymer. In Table 1 is provided the different concentration of the ZnFe oxides and ODH.

Table 1 Table of different concentration of ZnFe oxide and ODH

Ni-Nitrate(gm)	Fe Nitrate(gm)	Zn Nitrate(gm)	ODH(gm)	ZnNiFeO Nanoparticle
2.616	8.08	0.2974	4.722	$Zn0.1Ni0.9Fe_2O_4$
2.0346	8.08	0.8922	4.722	$Zn0.3Ni0.7Fe_2O_4$
1.4542	8.08	1.487	4.722	$Zn0.5Ni0.5Fe_2O_4$
0.8719	8.08	2.0818	4.722	$Zn0.7Ni0.3Fe_2O_4$
0.29	8.08	2.677	4.722	$Zn0.9Ni0.1Fe_2O_4$

Production of the thin films

Starting with different concentration of the ZnNiFe nanoparticles, we opt to use 0.5% of the nanoparticles for synthesis of the polymer nano composites. To start with both the beaker and measuring tube were thoroughly cleaned. The cleaned equipment was subsequently dried in an oven. Precision weigh three portions of 0.10 mg of the PVP granules using a weighing balance. Precision weigh three portions of 0.05 mg ZnNiFe (0.5%) nanoparticles, 0.10 mg ZnNiFe (0.5%) nanoparticles and 0.15 mg ZnNiFe (0.5%) nanoparticles. Mix the chosen proportions thoroughly in three beakers to get three PVP nano composites. Measure out 10 ml of dimethylformamide and gradually added to the three beakers containing the PVP nano composites. The beaker was then covered after placing a magnetic bead that was wrapped in aluminum foil and placed on a magnetic stirrer. The temperature of the stirrer can vary between 45°-75°C and

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the speed was set at 700-900rpm. The solutions were allowed to stir for full 60 minutes. Here we are using the method of spin coating for preparing the polymer thin films. The spin coater [Model: EZ Spin A1 Spin Coater] used was carried out at the BMS Institute of Technology [Bangalore-560064, India]. To begin with the spin coater was calibrated. Vacuum was subsequently switched on and the spinner was thoroughly cleaned using acetone and then placed in the spin coater. Program was done for a speed of 600 rpm for 10 seconds and saved. Using a dipper 3-to-4 drops of the nano composite solution was then dipped on to a glass substrate. The spinner was put into operation in accordance with the program saved. After 10 seconds, the spinner was turned off. Thin film of the chosen polymer, i., PVP, was then left to evaporate for about 15 minutes and subsequently placed in an air-tight container. The above procedure was repeated for the other two thin films of the chosen polymer nano composite.

Results and discussion

Fourier Transform Infrared [FTIR] results

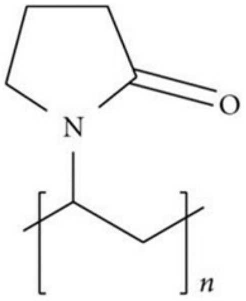
The Fourier transform infrared (FTIR) region is divided into two distinct regions. These are (i) the finger print region, and (ii) the functional group region. The finger print region is useful for the purpose of identification of the as-synthesized compound while the functional group region is used for identification of the functional groups in the compound. The FTIR spectrum was recorded for a frequency range of 4000-400 cm^{-1}. The thin films that were prepared using the spin coating technique are often affected by the solvent used. Even if the solvent used has evaporated, both the temperature and chemical properties of the solvent used will always exert an influence on the spin coated thin films[12-17] The fingerprint region is from 600 to 1400 cm^{-1} and the functional group region is from 1400 to 4000 cm^{-1}. Results of the FTIR for both pure polyvinylpyloridate polymer and as-synthesized nano composites [i.e., polyvinylpyloridate + ZnNiFe nanoparticles] for different ratios of the ZnNiFe nanoparticles is shown in Figure 1. The amount of polymer used was constant and 0.10 g for the three thin films while the amount of ZnNiFe nanoparticles used was 0.5 g, 0.10 g and 0.15 g. The FTIR was conducted in the mid-IR region, that is from 4500 cm-1 and 400 cm-1, for the four chosen and studied thin films, i.e.:

(i) pure polyvinylpyloridate (Figure 2),

(ii) PVP ZnNiFe-1 [0.10g of polymer and 0.5g of Nanoparticles] (Figure 3),

(iii) PVP ZnNiFe-2 [0.10g of polymer and 0.10g of Nanoparticles] (Figure 4), and

(iv) PVP ZnNiFe-3 [0.10g of polymer and 0.15g of Nanoparticles] (Figure 5).



$(C_6H_9NO)_n$

Figure 1 Molecular structure of the chosen polymer polyvinylpyloridate.

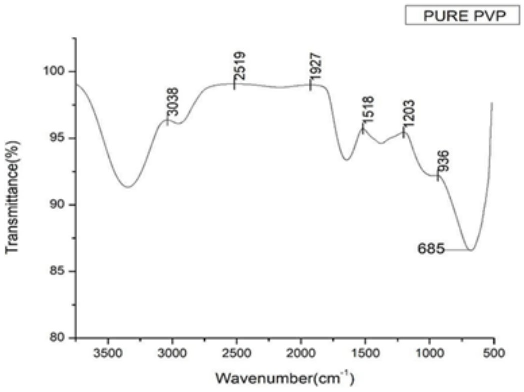


Figure 2 Fourier transform infrared (FTIR) spectra for pure polyvinylpyloridate.

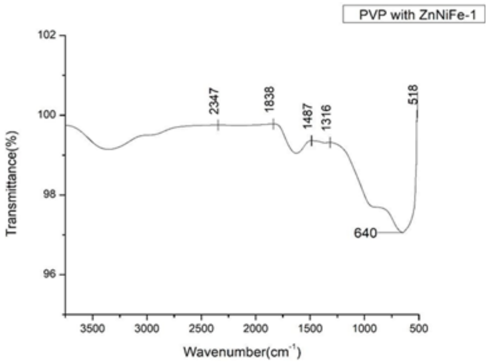


Figure 3 FTIR spectra for the polyvinylpyloridate + ZnNiFe -1.

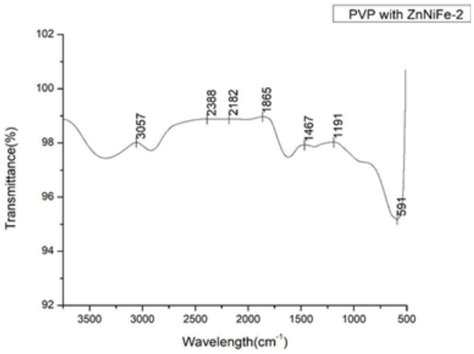


Figure 4 FTIR spectra for the polyvinylpyloridate + ZnNiFe-2.

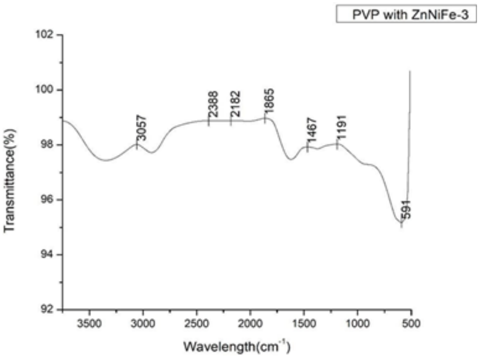


Figure 5 FTIR spectra for the polyvinylpyloridate + ZnNiFe-3.

In Figure 6 is clearly shown the regions having different wavelength peaks for the PVP + ZnNiFe nano composites and for different ratios of the nanoparticle reinforcement.[18-25]

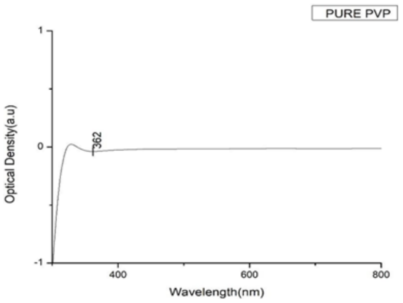


Figure 6 UV-Visible spectroscopy graph for the pure polymer PVP.

Table 2 Fourier transform infrared (FTIR) table for the polyvinylpyloridate nano composites

Wavenumber (nm^{-1})	Functional groups
3038,3057	-OH stretch, alcohols
2519,2388,2347,	C-H stretch, alkane
2182	$-C \equiv C-$ stretch, alkynes
1927,1838,1865	C=O stretch, carbonyl group
1518,1487,1467	CH bend, alkanes
1191,1203,1316	CN stretch, aliphatic amines
936	OH bend, carboxylic acid
685,640	OCN bending
518,591	Fingerprint region

UV Visible Spectroscopy

UV-Visible spectroscopy was conducted for finding and/or establishing the peak Optical Density of: (i) pure polymer, (ii) pure ZnNiFe nanoparticles, and (iii) polymer + ZnNiFe nano composites. Basically UV-Visible spectroscopy was used to determine how much the chosen material absorbs light. The results of UV-Visible spectroscopy for both the chosen polymer, i.e., polyvinylpyloridate, and the engineered polyvinylpyloridate + ZnNiFe nano composites for different ratios of the ZnNiFe nanoparticles, [i.e., 0.10 g of polymer that is constant for the 3 thin films and 0.5 g ZnNiFe nanoparticles, 0.10 g ZnNiFe nanoparticles, and 0.15g of ZnNiFe nanoparticles] are shown in Figure 6 to Figure 9. The graphs for the four chosen thin films are

(i) Pure polyvinylpyloridate (Figure 6).

(ii) PVP + ZnNiFe-1 [0.10g of polymer and 0.5g of nanoparticles] (Figure 7).

(iii) PVP + ZnNiFe-2 [0.10g of polymer and 0.10g of nanoparticles] (Figure 8), and

(iv) PVP + ZnNiFe-3 [0.10g of polymer and 0.15g of Nanoparticles] (Figure 9).

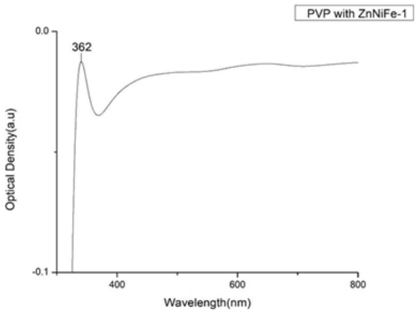


Figure 7 UV-visible spectroscopy graph for the polyvinylpyloridate + ZnNiFe nanocomposite-1.

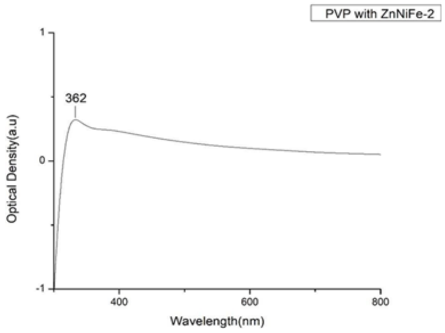


Figure 8 UV-visible spectroscopy graph for the polyvinylpyloridate + ZnNiFe nanocomposite-2.

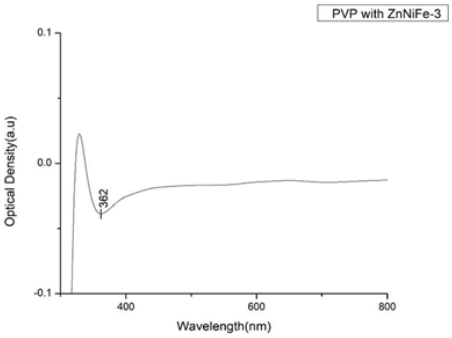


Figure 9 UV-Visible spectroscopy graph for the polyvinylpyloridate + ZnNiFe nanocomposite-3.

We observe the Optical Density to not appreciably change with variation of nanoparticle reinforcement content in the chosen polymer matrix. The Optical Density was essentially the same and 362nm for the examined thin films.

Photoluminescence results

Fluorescence (FL) emission spectroscopy was used to determine nature of the sample and to concurrently study imperfection-related emission. The fluorescence (FL) intensity and peak wavelength depends on the conjoint and mutually interactive influences of the following: (i) nature of synthesis, (ii) solvent used, (iii) starting materials used, (iv) processing time, and few other competing factors. The graphs resulting from photoluminescence study are shown for the following:

(i) Pure PVP (Figure 10).

(ii) Pure Zn0.5Ni0.5Fe$_2$O$_4$ nanoparticles (Figure 11), and

(iii) PVP Nano composite (Figure 12).

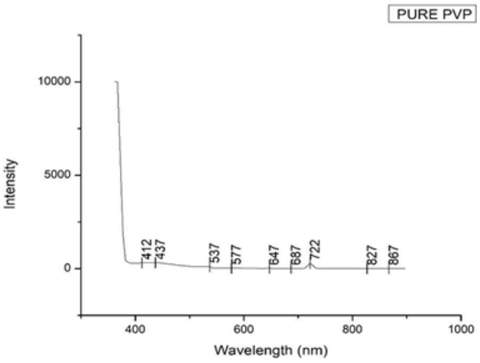


Figure 10 Photoluminescence graph for the chosen polymer PVP.

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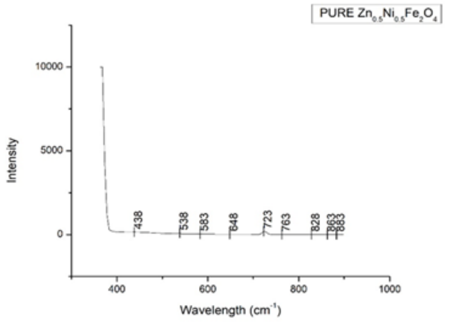


Figure 11 Photoluminescence graph for the $Zn_{0.5}Ni_{0.5}Fe_2O_4$.

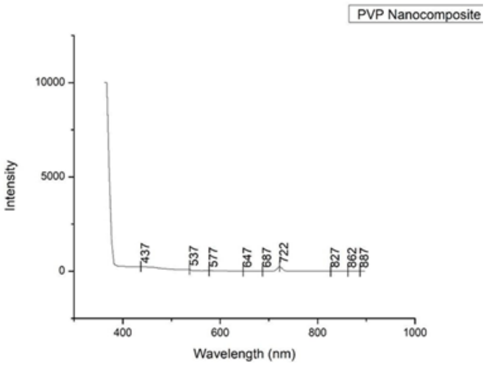


Figure 12 Photoluminescence graph for the PVP nano composite.

We have taken an optimum wavelength range of 300 cm^{-1} to 500 cm^{-1} for our consideration. For pure PVP the peak intensity was at 412, and for pure Zn0.5Ni0.5Fe_2O_4 nanoparticles it was at 438. By reinforcing, or doping, the chosen polymer with ZnNiFe nanoparticles we observed an increase in intensity. The peak intensity for the PVP nano composite was 437. The Photoluminescence intensity is directly proportional to the concentration of molecules. Hence, we observe than when the reinforcing, or doping, is done properly there does result a noticeable increase in intensity. This makes the engineered polymer nano composite to be a potentially viable candidate for selection and use in a spectrum of opto- electronic applications.[26-35]

X-ray Diffractions [XRD] results

From Figure 13 we can conclude that the pure polyvinylpyloridate (PVP) polymer is essentially amorphous in nature, The ZnNiFe nanoparticles are crystalline in nature as we observe the sharp and distinct peaks in the graphs. When we combine both the polyvinylpyloridate polymer and ZnNiFe nanoparticles, resulting in the polyvinylpyloridate + ZnNiFe nano composites, we did observe higher peaks when compared to the pure nanoparticles. This suggests that the occurrence and presence of crystallinity has increased by a combination of the chosen PVP polymer with ZnNiFe nanoparticles and is shown in Figure 13.

Atomic Force Microscopy (AFM) results

The atomic force microscope (AFM) images were taken to study roughness of the thin film surface. Since the films were prepared using the spin coating technique, the thickness is noticeably less than that of dip casting film. Consequently, the roughness is less when compared one-on-one with the dip coating film that has a thickness of the order of nanometers. The figures provided are 3-D images of

(i) Pure Polyvinylpyloridate (Figure 14), and

(ii) Polyvinylpyloridate nano composite (Figure 15).

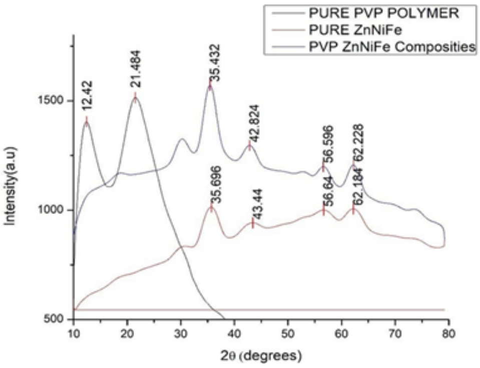
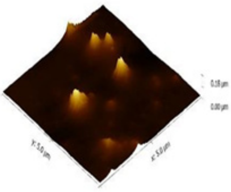


Figure 13 XRD Graph of the chosen PVP polymer with and without ZnNiFe nanoparticles.



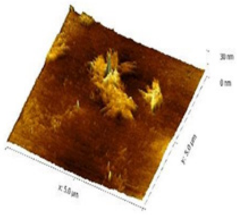


Figure 14 AFM 3-D image of pure PVP

Figure 15 AFM 3-D image of the PVP nano composite.

The figures reveal that by doping, or reinforcing, with nanoparticles of Zn0.5Ni0.5Fe_2O_4 we observe roughness of the thin films to decrease while concurrently showing overall smoothness of the thin films for the chosen polymer and the engineered polymer nano composite. By observing the images, we conclude that the thickness decreases due to the addition of nanoparticles. This observation is consistent for thin film of pure PVP the thickness is 0.16μm and for thin films of the PVP nano composite the thickness is 30nm.

The surface texture or morphology of the as-prepared thin films is shown in Figure 16 and Figure 17. Morphology of the pure polymer film was found to be grainy texture whereas morphology of the polymer nano composite thin film was less grainy when compared one-on-one with the pure polymer (PVP). We did observe a noticeable change in the grain structure of pure PVP [with a grain size = 143nm] and the engineered PVP nano composite [with a grain size = 12.5nm]. This sheds light on the effect of reinforcing the chosen polymer (PVP) with ZnNiFe nanoparticles.

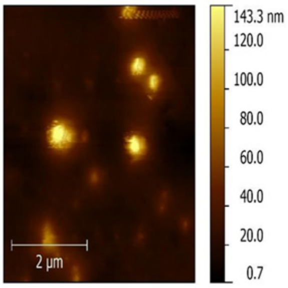


Figure 16 AFM morphology of the pure PVP.

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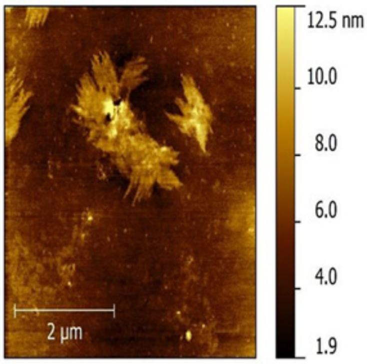

Figure 17 AFM morphology of the PVP nano composite.

Scanning electron microscopy observations

The scanning electron microscope images of pure polyvinylpyloridate polymer, pure ZnNiFe nanoparticles and the polyvinylpyloridate + ZnNiFe nano composite did reveal an observable change in morphology of the grains. Size of the polymer polyvinylpyloridate was 50µm, as shown in Figure 18. Grain size of the ZnNiFe nanoparticle was 500nm, as shown in Figure 19. The difference in grain size is evident from these two figures. The observed change in morphology when nanoparticles are added to the chosen polymer (PVP) is shown in Figure 20. The grain size is around 1µm. We also observe from that for pure PVP it is essentially granular in structure with a lot of spacing, or less networking like structure, between the particles. However, for the pure nanoparticle it is a networked structure with marginal evidence of gaps between the particles. When we reinforce, or dope, the chosen polymer (PVP) with nanoparticles, we did observe a network-like structure with minimum gaps between the particles. The network is more pronounced than the structure observed for pure PVP and pure nanoparticles.

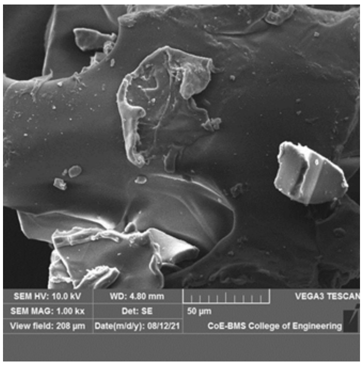

Figure 18 Scanning electron micrograph of pure polyvinylpyloridate.

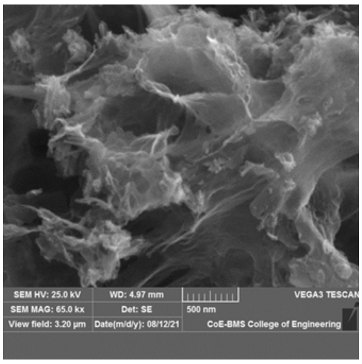

Figure 19 Scanning electron micrograph of pure $Zn_{0.5}Ni_{0.5}Fe_2O_4$.

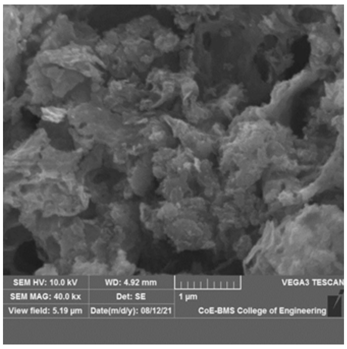

Figure 20 Scanning electron micrograph of the polyvinylpyloridate + $Zn_{0.5}Ni_{0.5}Fe_2O_4$ nano composite.

Conclusion

In the research present study, the polymer polyvinylpyloridate along with nanoparticles of ZnNiFe were used to form the polyvinylpyloridate + ZnNiFe nano composite using the technique of spin coating. Following are the key findings and/or observations.

- Thin films of the polymer nano composite were formed on glass slides.
- Characterization of the test sample, i.e., thin film, was done using the spectroscopy techniques of (i) FTIR spectroscopy, and (ii) UV-Visible spectroscopy.
- Results of the pure polymer and polymers nano composite are compared. FTIR was used for enabling vibration at the molecular level. By using FTIR we observe a 50 - 65% change in the functional group from pure polymer to the polymer nano composite. This helps us to conclude that the technique of spin coating was done properly and successfully.
- With a gradual increase in the number of reinforcing nanoparticles in the polymer matrix we did observe an increase in Optical Density using UV-Visible spectroscopy.
- An increase in the Optical Density is beneficial for attaining an improvement in anti-reflection response. The anti-reflection property is utilized to essentially suppress losses due to reflection when light propagates from one medium to another medium. This enables in increasing non-linear refractivity, which is a change in the refractive medium index depending on the material used.
- X-ray diffraction (XRD) revealed crystallinity of the polymer nano composite when compared one-on-one with the actual polymer, which is amorphous. By observing the graphs for the addition of fine nanoparticles to the chosen polymer (PVP) we observe crystallinity based on the peaks in the graph. This is clearly indicative of an overall improvement in crystallinity.
- Scanning electron microscopy observations was used to see a change in morphology of the grains coupled with an interaction of the nanoparticles with the particles.[36-39]

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None

Conflicts of interest

The author hereby declares of having not conflict of interest in this article.

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References

1. Almusawe AJ, Hassen TF, Rahman MA, et al. Linear optical properties of bromocresol green dye doped poly methyl methacrylate thin films. *Iraqi Journal of Science***.** 2018;59(1B):299–306.
2. Giridharan S, Shankar P. Optical characterization of PMMA doped with an organic polymer. *IIOABJ*. 2018;9(S1):18–25.
3. El-Bashir SM, AlSalhi MS, Al-Faifi F, et al. Spectral properties of pmma films doped by perylene dyestuffs for photo-selective greenhouse cladding applications. *Polymers*. 2019;11(3):494.
4. Cho YJ, Lee JY. Thermally stable aromatic amine derivative with symmetrically substituted double spiro-bifluorene core as a hole transport material for green phosphorescent organic light-emitting diodes. *Thin Solid Films*. 2012;522:415–419.
5. Kwang M, Abdel Rasoul A, Doan H. Controlling poly-sulfone (PSF) fiber diameter and membrane morphology for an enhanced ultrafiltration performance using heat treatment. *Results in Materials.* 2019;2.
6. Al-Kadhemy MFH, Abbas WH. Optical properties of crystal violet doped PMMA films. *Research and Reviews on Polymer*. 2013;4(2):45–51.
7. Al-Kadhemy MFH, Alwaan EM. FTIR spectrum of laser dye fluorescein doped polymer pmma films. *Research & Reviews in Polymers*. 2012;3(3):102–106.
8. Esfahani ZH, Ghanipour M, Dorranian D. Effect of dye concentration on the optical properties of red-bs dye-doped pva film. *Journal of Theoretical and Applied Physics*. 2014;8:117–121.
9. Khan MS, Qazil RA, Wahid MS. Miscibility studies of PVC/PMMA and. PS/PMMA blends by dilute solution viscometry and FTIR. *African Journal of Pure and Applied Chemistry*. 2008;2(4):041–045.
10. Melavanki RM, Muttannavar VT, Thipperudrappa J, et al. Examining the spectroscopic features and quantum chemical computations of a quinoline derivative: experimental and theoretical insights into the photophysical characteristics. *Indian Journal of Pure and Applied Physics*. 2020;58(7):503–515.
11. Chandrasekhar S, Deepa HR, Melavanki RM, et al. Quantum chemical and solvatochromic studies of biological active 1, 3, 4-thiadiazol coumarin derivatives. *Chemical Data Collections*. 2020;29.
12. Sharma K, Melavanki R, Sadasivuni KK. Quantum chemical computations and photophysical spectral features studies of two coumarin compounds. *Luminescence the journal of biological and chemical luminescence.* 2020;35(6):845–862.
13. Melavanki R, Sharma K, Muttannavar VT, et al. Quantum chemical computations, fluorescence spectral features and molecular docking of two biologically active heterocyclic class of compounds. *Journal of Photochemistry and Photobiology A: Chemistry*. 2021;404.
14. Koppal VV, Hebsur RK, Melavanki RM, et al. Solvent polarity and environment sensitive behavior of coumarin derivative. *Macromolecular symposia.* 2020;392(1).
15. Melavanki R, Muddapur GV, Srinivasa HT, et al. Solvation, rotational dynamics, photophysical properties study of aromatic asymmetric di-ketones: An experimental and theoretical approach. *Journal of Molecular Liquids*. 2021;337.
16. Melavanki R, Basanagouda MM, Mogurampelly S, et al. Computational and spectroscopic studies of biologically active coumarin-based fluorophores. *Luminescence*. 2021;36(3):769–787.
17. Melavanki R, Sharma K, Muttannavar VT, et al. Quantum chemical computations, fluorescence spectral features and molecular docking of two biologically active heterocyclic class of compounds. *Journal of Photochemistry and Photobiology A: Chemistry*. 2021;404.
18. Yoon HJ, Bang KS, Lim JW, et al. Optical properties of zirconium oxide thin films for semi-transparent solar cell applications. *Journal of Materials Science: Materials in Electronics*. 2016;27(11):11358–11365.
19. Ting YH, Liu CC, Park SM, et al. Surface roughening of polystyrene and poly (methyl methacrylate) in Ar/O_2 plasma etching. *Polymers.* 2010;2(4):649–663.
20. RC Patil, Ahmed SM, Shiigi H, et al. Investigation of some physicochemical properties of camphor sulfonic acid (CSA)–doped poly (o-anisidine) (PoAN) and CSA-doped PoAN/ABS composites. *J Polymer Sci Part A Poly Chem*. 1999;37(24):4596–4604.
21. Zaharieva J, Milanova M. Thin films for immobilization of complexes with optical properties. in modern technologies for creating the thin-film systems and coatings. *Intech Open*. 2017.
22. Koppal VV, Melavanki R, Kusanur R, et al. Analysis of fluorescence quenching of coumarin derivative under steady state and transient state methods. *J Fluorescence*. 2021;31(2):393–400.
23. Geiger C, Reichenbach J, Kreuzer LP, et al. PMMA-b-PNIPAM thin films display Conon solvency-driven response in mixed water/methanol vapours. *Macromolecules*. 2021;54(7):3517–3530.
24. Ramesh GV, Porel S, Radhakrishnan TP. Polymer thin films embedded with in situ grown metal nanoparticles. *Chem Society Rev*. 2009;38(9):2646–2656.
25. Kusanur RA, Ghate M, Kulkarni MV. Synthesis of spiro [indolo-1 5-benzodiazepines] from 3-acetyl coumarins for use as possible antianxiety agents. *J Chem Sci*. 2004;116(5):265–270.
26. Tomsho JW, McGuire JJ, Coward JK. Synthesis of (6R) and (6S)-510-dideazatetrahydrofolate oligo-γ-glutamates Kinetics of multiple glutamate ligations catalysed by folylpoly-γ-glutamate synthetase. *Organic and Biomolecular Chemistry*. 2005;3:3388–3398.
27. Ghate M, Kusanur RA, Kulkarni MV. Synthesis and in vivo analgesic and anti-inflammatory activity of some bi heterocyclic coumarin derivatives. *Euro J Med Chem*. 2005;40(9):882–887.
28. Waghmare M, Reddy KTV. Design and modal analysis of photonic crystal fiber for dispersion compensation over broadband range. *J Microwaves Optoelectronics and Electromagnetic Applications*. 2016;15:365–379.
29. Wochnowski C, Metev S, Sebold G. UV-laser-assisted modification of the optical properties of poly-methyl methacrylate. *Applied Surface Science*. 2000;154–155:706–711.
30. Yousif ME. The weak spinning magnetic force (FW) (The weak interaction). *IOSR Journal of Applied Physics.*2016;8:77–88.
31. Imad-Al-Deen, Hussein AA, Faisal Sadik. Synthesis and investigation of phenol red dye doped polymer films. *Advances in Materials Physics and Chemistry*.2016;6(5):120–128.
32. Wang C, Chen X, Chen F, et al. Organic photodetectors based on copper phthalocyanine films prepared by a multiple drop casting method. *Organic Electronics*. 2019;66:183–187.
33. Sharma K, Melavanki R, Yallur BC, et al. Optical characterization of chalcone□doped PMMA thin films for photonic applications using spectroscopic technique of drop casting method. *Macromolecular Symposia.* 2020;392(1).
34. Melavanki R, Vaijayanthimala S, Yallur BC, et al. Preparation and optical parameter characterization of two aldehyde derivative thin films for photonic applications by drop casting method. *Luminescence*. 2020;35(6):903–912.
35. Ghorpade P. Optik. *International Journal for Light and Electron Optics*. 2020;208.
36. Ghorpade SP, Melavanki RM, Patil NR. A study on the optical behavior of Dy x 3+ ion activated Sr (1□X) Y_2O_4 nanophosphors. *Macromolecular Symposia*. 2020;392(1).

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37. Ghorpade P, Nagaraj K, Raveendra Melavanki, et al. Photoluminescence TGA/DSC and photocatalytic activity studies of Dy3+ doped SrY_2O_4 nanophosphors. *RSC Advances*. 2020;10:21049–21056.

38. Sharma K, Melavanki R, Patil SS, et al. Spectroscopic behavior, FMO, NLO and NBO analysis of two novel aryl boronic acid derivatives: experimental and theoretical insights" *Journal of Molecular Structure*. 2019;1181:474–487.

39. Melavanki RM, Geetanjali HS, Thipperudrappa J, et al. Effect of hydrogen bonding and solvent polarity on the fluorescence quenching and dipole moment of 2-methoxypyridin-3-yl-3-boronic acid. *Indian Journal of Pure & Applied Physics (IJPAP)*. 2018;56(12):989–996.

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