Structural, electrical and optical properties of PVC/ZnTe nanocomposite thin films

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Research Article

Keywords: ZnTe nanoparticles, Hydrothermal synthesis, ZnTe/PVC nanocomposite, Thin films, Photoluminescence, Electrical resistivity

Posted Date: February 25th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-275129/v1>

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Abstract

ZnTe nanoparticles (NPs) were synthesized using hydrothermal method and then were dispersed in poly(vinyl-chloride) (PVC) to prepare hybrid PVC/ZnTe nanocomposite thin films which were deposited on glass substrates by the dip coating technique. Structural, optical and electrical properties of films were investigated by different techniques. XRD analysis revealed that synthesized ZnTe NPs have a cubic structure and a nanoscale size, while pure PVC films have a weak degree of crystallinity and exhibit a broad diffraction peak at low angles. The PVC/ZnTe nanocomposite thin films display an intense diffraction peak corresponding to the plane (220) which indicates a preferred orientation of ZnTe nanocrystallites along crystallographic axis [220]. This texture was also showed by the atomic force microscopy micrographs. The analysis by FT-IR and Raman vibrational spectroscopies confirmed the incorporation of ZnTe NPs in the PVC matrix. The ZnTe/PVC nanocomposites thin films have an optical transparency over 80 % in the visible range and an optical gap close to 4.07 eV. Discrepancies with respect to the gap of pure PVC (red shift) and bulk ZnTe (blue shift) are due to the effect of the interaction between the ZnTe NPs and the PVC matrix and also to the nanometric size of the ZnTe crystallites. Photoluminescence (PL) spectra showed an enhanced blue emission at 466 nm, a green emission at 522 nm and a strong red emission at 686 nm. Thus the incorporation of oriented ZnTe NPs induced a new optical behavior of the PVC polymer matrix. Electrical measurements indicate a decrease of electrical resistivity of PVC/ZnTe nanocomposites as ZnTe NPs concentration increases.

Keywords ZnTe nanoparticles. Hydrothermal synthesis. ZnTe/PVC nanocomposite. Thin films. Photoluminescence. Electrical resistivity.

1 Introduction

The insertion of inorganic ZnTe NPs in polymers can induce significant evolution in their behavior by the modification of their mechanical, electrical and optical properties [1]. The characteristics of the resulting nanocomposite material depend on the experimental method of fabrication and are function of the chemical nature and relative concentration of each component. The manufacture of nanocomposites, using

transparent polymers as host matrices and inorganic semiconductor NPs as fillers, is an area of current interest in many fields such as optics, optoelectronics and solar energy. This type of hybrid materials can benefit from the advantages of both materials: superior optoelectronic properties of polymers and high electron mobility of inorganic semiconductors [2]. In this perspective some recent works are devoted to the polymer-inorganic hybrid solar cells using NPs of

CdSe [3], TiO₂ [4] and ZnO [5], this trend is driven by the fact that polymers are technologically advantageous owing to the ease and flexibility of devices fabrication process.

The Poly(vinyl-chloride) (PVC) is one of the most versatile polymers, its transparency in the visible domain makes it suitable for hosting inorganic semiconductor NPs having an optical activity in the visible range. The Zinc telluride (ZnTe) semiconductor has a band gap energy $E_g = 2.25$ eV (~ 550 nm) [6], which makes it promising for application as a purely green light-emitting diode. The II–VI semiconductors can be easily doped n-type, but resist to p-type doping, the most notable exception is ZnTe which easily allows p-type doping [7]. Therefore, the incorporation of ZnTe NPs in PVC matrix may lead to a hybrid nanocomposite with new interesting optical properties. However the challenge in the manufacture of such nanocomposites lies in the search for an approach to optimize the interaction between guest semiconductor NPs and the host polymer to ensure the production of materials with high quality and adapted to the desired application.

In a heterojunction between a polymer and a semiconductor such as in the PVC/ZnTe system, electrons can diffuse without difficulty from the polymer to the semiconductor. When the polymer is irradiated with photons of energy larger than the band gap electron-hole pairs are generated and electrons can be injected into the conduction band of the semiconductor and can move along the

nanoparticle network to be finally collected via an electrical contact in photovoltaic devices. The nature of the charge transfer process depends on the optical properties of the two materials as well as the surface properties of the semiconductor NPs [8].

The present work is focused on the study of the structural, optical and electrical properties of the PVC/ZnTe nanocomposite thin films and the energy transfer between the PVC polymer and the ZnTe NPs. The investigation was carried out using PVC/ZnTe nanocomposite thin films deposited on glass substrates by the dip-coating method. Furthermore, for checking the quality of synthesized ZnTe NPs and prepared PVC/ZnTe thin films a structural characterization was performed by X-ray diffraction, AFM microscopy and also by FT-IR and Raman spectroscopy. The optical and electrical performance have been demonstrated by measurement of optical absorption, photoluminescence and electrical resistivity.

2 Experimental section

2.1 Synthesis of ZnTe nanoparticles

The ZnTe NPs were synthesized by the hydrothermal method, which was earlier described by [9]. In a typical synthesis 0.67 g of zinc powder (90 %), 1.32 g of tellurium powder (99.999 %) and 6.41 g of NaOH (96 %) were mixed in 40 ml of distilled water. The obtained mixture was placed into a 50 ml Teflon-lined stainless steel autoclave which was heated in an oven with a heating rate of 5° C/min and maintained at 120°C for 4 h. Then the autoclave was cooled down to room

temperature naturally. The as-formed powder was washed with distilled water and ethanol several times then it was collected by centrifugal sedimentation. Finally, the obtained product was dried at 70°C for 8 h to get purple powder.

2.2 Preparation of PVC/ZnTe nanocomposite thin films

The synthesized ZnTe NPs were used as filler and were embedded in the polymer matrix of PVC to fabricate the PVC/ZnTe nanocomposite. The thin films of PVC/ZnTe nanocomposite were prepared according to the following procedure. The PVC (1 g) was dissolved in 20 ml of tetrahydrofuran (THF) solvent using a magnetic stirrer. ZnTe NPs with different concentrations (10%, 15%, 20% and 25% weight) were added to the mixture of PVC-THF and the whole was stirred until getting a clear and homogeneous solution. The glass slides used as substrate were washed with ethanol and thoroughly rinsed with distilled water. Thin films were deposited onto substrates by dip-coating technique. The substrates were dipped several times and the pulling speed was ranged from 0.5 to 1 cm/min in order to control the thickness of films. After each immersion, the films were dried at 40°C for 10 minutes. The thickness of obtained films, measured by a profilometer, was found around 800 nm. All experiments were performed at ambient pressure and room temperature. In order to highlight the characteristics of the thin films of the PVC/ZnTe nanocomposites, the elaborated samples have been subjected to structural,

optical and electrical characterization by several complementary techniques.

2.3 Characterization techniques

The structural study of the deposited thin films of PVC/ZnTe nanocomposites was performed on aX'pert PRO PANalytical X-ray diffractometer using $\text{CuK}\alpha$ radiation ($\lambda=1.54059 \text{ \AA}$). The spectra were recorded in the angle range $2\theta=10^\circ\text{-}110^\circ$. The surface morphology was examined with an atomic force microscope AFM Asylum research (MFP-3DSPM). The chemical analysis by Fourier transform infrared spectroscopy in attenuated total reflection (ATR) mode was carried out using a JASCO FT-IR 6300 spectrophotometer. To determine the vibrational modes of structure of ZnTe NPs, Raman spectra were recorded using a Senterra-Bruker spectrometer with a 473 nm laser wavelength as excitation source. The optical properties were investigated by the UV Visible spectroscopy using a Shimadzu UV-3100 PC Spectrophotometer. The photoluminescence spectra were recorded at room temperature with a Horiba Yvon Fluoro Max 4P fluorometer using a xenon flash lamp (power 150 w and excitation wavelength 415 nm) and a 3 nm aperture for the excitation source and the emission detector. The electrical resistivity of the samples was measured by the four-point technique.

3 Results and discussion

3.1 XRD analysis

The figure 1 shows the XRD pattern of as-synthesized ZnTe NPss. The spectrum

depicts a polycrystalline structure and the analyze of angular positions and intensities of diffraction peaks (Table 1) shows that all peaks are related to the cubic phase of ZnTe (space group $F\bar{4}3m$) according to the JCPDS File 15-0746. The well-resolved profile of the peaks testifies to the good crystallinity of the ZnTe particles. Furthermore, the ZnTe crystallite sizes are estimated using Scherrer's formula (1) [10].

$$D = \frac{0.9\lambda}{\beta \cos \theta} \quad (1)$$

Where λ is the wavelength of X-Ray (0.154059 nm), β is the FWHM (full width at half maximum) of diffraction peak, θ is the diffraction angle and D is the size of crystallites.

The crystallite size values related to the diffraction planes are reported in Table 1, it can be seen that all the ZnTe crystallites have a nanometric size which is in the range 20.83 – 57.19 nm

Fig. 1 XRD pattern of as-synthesized ZnTe nanoparticles

Table 1 The crystallite size values of ZnTe nanoparticles

In Figure 2, are presented the XRD patterns of pure PVC and prepared PVC/ZnTe nanocomposite thin films. The spectrum of pure PVC shows only a broad and weak peak at around $2\theta = 24.36^\circ$ which is characteristic of the PVC polymer [11]. This observation indicates that the PVC matrix has a very low

degree of crystallinity. In the case of PVC/ZnTe nanocomposite thin films, the intensity of this peak decreases more when the concentration of ZnTe NPs increases indicating a decrease of the crystallinity of PVC which leads to more amorphicity of the PVC matrix [12]. The spectra, corresponding to the PVC/ZnTe nanocomposite thin films, displayan intense diffraction peak at the angular position $2\theta=41.93^\circ$ and a weak peak at $2\theta=91.19^\circ$ which correspond respectively to the plane (220) and its harmonic (440) of cubic structure of ZnTe (Table1). In addition, a very small peak corresponding to the (111) plane is observed at $2\theta=25.33^\circ$. This result means that the ZnTe NPs exhibit a certain texture and have a preferred orientation along the [220] crystallographic axis perpendicular to the surface of substrate. On the other hand the absence of extra peaks indicates that there was no chemical reaction in the solution during the fabrication of PVC/ZnTe nanocompositesand therefore no formation of a new phase. Thus the method used for the preparation of our samples makes possible the fabrication of hybrid nanocomposite thin films with textured NPs dispersed in a polymer matrix. This texture is an advantage especially in the case of anisotropic physical properties such as optical properties.

Fig 2 XRD patterns of pure PVC and PVC/ZnTe nanocomposite thin films

3.2 FT-IR analysis

Figure 3 shows the infrared transmittance spectra (400- 4000 cm^{-1}) of elaborated pure

and 10, 15, 20 and 25 wt.% ZnTe filled PVC thin films. The main characteristic vibration frequencies of PVC are observed at 1332, 1005 and 760 cm^{-1} and are respectively associated with C-H bending of $-\text{CH}_3$, $-\text{CH}_2$ rocking [13] and C-Cl stretching [14]. Further bands are observed at 1739 cm^{-1} and 1566 cm^{-1} , they were assigned to C=C stretching in the dichlorinated alkenes and to C=C stretching in the monochlorinated alkenes [15]. The band at 1424 cm^{-1} is attributed to the CH_2 scissors vibration [16] and that at 1252 cm^{-1} is due to CH_2 wagging [17]. One note that there are some discrepancies in the frequencies of PVC infrared bands, which may be related to the degree of crystallization, to the length of the polymeric chains and their interpenetration. One can also see that the intensity of bands is significantly influenced by ZnTe filling and it decreases with increasing ZnTe NPs concentration. The effect of the ZnTe filling level on the relative intensity of the bands can help to estimate the structural deformation of PVC chains [18].

Fig 3 FT-IR Transmittance spectra of pure PVC and ZnTe/PVC nanocomposite thin films

The other bands observed in the range (2000-3000 cm^{-1}) are located at 2365, 2854, 2922 and 2968 cm^{-1} . The two last bands are respectively associated to asymmetric and symmetric stretching of CH_2 and the band at 2854 cm^{-1} has been correlated with stretching vibration of C-H bond [19]. The band at 900 cm^{-1} has been related to syndiotactic

structure and is attributed to rocking vibration groups [20]. The band at 617 cm^{-1} is assigned to out of plane OH bending [20]. Finally the weak bands appearing around 2365 cm^{-1} are due to the attraction of CO_2 from the atmosphere [21].

The FTIR spectra of PVC/ZnTe nanocomposites display no shift in the bands compared with that of the pure PVC, suggesting a very weak interaction in terms of chemical bonding between PVC and ZnTe NPs [22].

3.3 Raman spectroscopy

The recorded Raman spectra of the PVC/ZnTe nanocomposite thin films are shown in Fig 4. The power and wavelength of used laser are 15 mW and 473 nm respectively. From spectra we can note vibration modes with frequencies in the range 40 to 1650 cm^{-1} . Low frequency modes at 42, 75, 120, 357 and 447 cm^{-1} are related to ZnTe NPs as reported in earlier works [23,24]. The vibration mode frequencies at 566, 614, 631 and 694 cm^{-1} are in agreement with that previously established by many authors for the C-Cl bond in the PVC polymer with non-crystalline phase [25]. The observed bands at frequencies 792, 996, 1095 and 1165 cm^{-1} are due to the presence residual molecules of THF solvent used in the preparation of films [26,27]. Others vibration modes associated to the PVC polymer are located at 1316, 1425 and 1650 cm^{-1} , they are related to the vibrations of C-H bond [18,28,29].

Furthermore we can note the increase of intensity of peaks when the concentration of ZnTe NPs increases. For the peaks corresponding to ZnTe it is known that the Raman intensity is proportional to the concentration of ZnTe in the material, while for the peaks corresponding to the C-Cl bond of PVC the intensity increases because the degree of crystallinity of PVC matrix decreases [25] when the concentration of ZnTe NPs increases as was observed on the XRD patterns (Fig. 1). The intensity of peaks related to the THF solvent increases probably due to increase of THF molecules trapped between the chains of the PVC polymer and the ZnTe NPs.

Fig 4 Raman spectra of the PVC/ZnTe nanocomposite thin films

3.4 AFM Analysis

Additional information on the structural properties of PVC/ZnTe nanocomposite thin films can be deduced from AFM analysis. The topography of their surface and the distribution of ZnTe particles have been investigated using Fig 5 (a and b) which respectively show three-dimensional (3D) and two-dimensional (2D) topographic images of the surface of the films. Aggregates of ZnTe particles are clearly visible on the surface of the films, they are of different sizes and are randomly dispersed. Also, it can be observed from Figure 5b that the ZnTe particles have a flattened shape with side faces oriented along the pulling direction of the films. This remark confirms the result of XRD analysis concerning the preferred orientation of ZnTe

crystallites along the crystallographic axis [220]. On the basis of this result, it can be stated that the elaboration method used for the preparation of the thin films of studied ZnTe/PVC nanocomposites makes it possible to have a common orientation for all the ZnTe crystallites incorporated in the PVC polymer matrix. This feature can be considered as an advantage in specific applications

Fig 5 Topographic images of the surface of the PVC/ZnTe nanocomposite thin films,
a) three-dimensional (3D)
b) two-dimensional (2D)

3.5 Optical properties

3.5.1 UV-Visible Transmittance

Fig 6 Optical transmittance spectra of pure PVC and PVC/ZnTe nanocomposite thin films

The Figure 6 shows spectra of optical transmittance, in the UV-Visible domain, for pure PVC and PVC/ZnTe nanocomposite thin films. In the visible range the transmittance of pure PVC is around 90 % and it decreases to reach 80 % for the PVC/ZnTe nanocomposite thin films when the concentration of ZnTe NPs increases up to 25 wt%. This reduction of transmittance is caused by the scattering of the visible light at the interface between PVC matrix and ZnTe NPs. At wavelengths greater than 500 nm, spectra display an approximately constant transmittance, while at short wavelengths a steep absorption edge is observed around 325 nm but with a slight red shift when ZnTe NPs concentration increases. Similar results

were observed for PVC/CuO [11], PVC/ZnO [30], PVC/SnO₂ [27], PVC/CdO [31] and Cr₂O₃/PVC[32].

The red shift is due to changes in length and stacking of PVC chains caused by the incorporation of ZnTe NPs which was confirmed by the amorphicity of PVC films revealed by the X-ray analysis (Fig 2). On the other hand, the evolution of the FT-IR and Raman spectra as a function of the concentration of ZnTe NPs (Fig 4 and Fig 5) indicates a change in the vibration modes of the molecules of the PVC/ZnTe system and consequently leads to a different optical behavior.

3.5.2 UV-Visible Absorbance

The fundamental absorption is related to the electron transition from the valence band to the conduction band and can be used to find out the nature and value of the optical band gap. The value of the gap of polymers and particularly of PVC depends on some parameters such as degree of purity, temperature, degree of crystallinity, nature of used solvent as well as defects and strains in the material which generally lead to red shift of the gap. Therefore the incorporation of additives, like ZnTe NPs, in the PVC polymer can significantly modify its optical properties. Most polymers absorb light in the UV region, this absorption is related to transitions between electronic energy levels of the bonds within these materials. For the PVC polymer, usually, two electronic transition bands appear in the UV wavelength region at around 286 and 197 nm [27,33], which respectively are allotted to $\pi-\pi^*$ electronic

transition associated to unsaturated C=O bond which was observed in FT-IR spectra at around 1739 cm⁻¹ and to C-Cl bond observed at 760 cm⁻¹ [14,22,34]. The intensity and position of these absorbance bands are often influenced by the structural state of the polymer [35].

The optical absorption spectra, in the UV-Visible range, of elaborated PVC/ZnTe nanocomposite thin films are shown in Figure 7. The band at 197 nm is shifted to 249 nm because of the low degree of crystallinity of films (Fig 2) which leads to the formation of localized states [14] and consequently we observe an absorbance band extended from around 200 to 300 nm

[35-37]. The observed slight red shift of the absorption edge at around 325 nm for the PVC/ZnTe films compared to that of pure PVC film can be attributed to the interaction due to the hydrogen bond between the Zn²⁺ ions at the surface of ZnTe NPs and the adjacent -OH group of PVC [20]. The small offset of the absorption edge makes it possible to deduce a weak interaction between the PVC matrix and the ZnTe NPs.

Also one can see that overall the absorption increases with increasing the concentration of ZnTe NPs. Moreover in the visible range appears an absorption band at 445 nm which is mainly due to the electronic interband transitions in ZnTe semi-conductor NPs (Fig 7). The gap energy value for the bulk ZnTe crystal was reported as 2.25 eV (~550 nm) [6] this blue shift is due to the well known quantum confinement effect due to the nanometric size of ZnTe crystallites (Table 1).

Moreover, spectra of PVC/ZnTe nanocomposites with higher concentrations 20 and 25 wt% of ZnTe NPs show additional low intensity absorption band at around 570 nm, it is assigned to defects in the ZnTe NPs like an excess of oxygen atoms which can occur during the synthesis process [38].

Fig 7 Optical absorption spectra of pure PVC and PVC/ZnTe nanocomposite thin films

To determine the band gap energy of PVC/ZnTe nanocomposite samples, the Tauc relation (2) was used [39].

$$(\alpha h\nu)^n = A(h\nu - E_g) \quad (2)$$

Where α is the absorption coefficient, A is an energy independent constant and n is equal to 2 for a direct electronic transition. The equation (1) gives the direct band gap energy (E_g), when straight portion of $(\alpha h\nu)^2$ versus $h\nu$ plot is extrapolated to the point $\alpha = 0$.

Fig 8 Optical gap of pure PVC and PVC/ZnTe nanocomposite thin films

The estimated band gap energy value (Fig 8) for the pure PVC film is 4.17 eV, it is in agreement with the value reported in the [12,40]. For the PVC/ZnTe nanocomposite films the values are close to 4.07 eV. The small difference $\Delta E_g = 0.10$ eV of gaps is related to the weak interaction between PVC matrix and the ZnTe NPs, because for fairly high concentration of doping (10-25 wt%) the formation of aggregates of ZnTe NPs is more

likely and tends to limit the surface of interaction with the PVC polymer.

The incorporation of ZnTe NPs in the PVC polymer induced a new optical behavior of the PVC/ZnTe nanocomposite which is characterized by an intermediate optical gap ($E_{g(PVC)} > E_{g(Composite)} > E_{g(ZnTe)}$) and an optical transmittance between 90 % and 80 % in the visible range.

3.5.3 Photoluminescence study

Photoluminescence spectra of both powders of PVC and ZnTe used in the fabrication of the PVC/ZnTe nanocomposite thin films are shown in Figures 9 and 10 respectively. We can note, from fig 9 that the pure PVC powder displays a strong blue emission band with maximum of intensity at 467 nm (2.65 eV). This blue emission is characteristic of PVC polymer [6,41] and is due to the PVC excimer fluorescence corresponding to $\pi^*-\pi$ transition [42]. This band presents shoulders at 480 and 492 nm which may be due to trapped energy levels created by impurities in the PVC. A second emission band appears at around 530 nm (2.33 eV), it is less intense and it belongs to the excimer phosphorescence which involves triplet excimer [42-45]. As expected the emission from the PVC polymer is dominated by excimer fluorescence [45].

Fig 9 Photoluminescence spectrum of PVC powder

While fig 10 exhibits for the ZnTe powder an intense red emission band at 686 nm (1.80 eV) and a weak blue emission band at 464

nm (2.67 eV). This later emission is close to the exciton-related near band edge emission of bulk ZnTe (2.25 eV) [22,46], but with a blue shift (0.42 eV) which is due to quantum size effect as average size of ZnTe crystallites is of nanometric scale (Table 1). Whereas the strong emission at 686 nm is owing to oxygen defects [38,46] occurring during the synthesis of ZnTe particles. This strong emission indicates a highly radiative transition and is therefore a greatly desirable characteristic for the intermediate band solar cell devices [38,46,47].

Fig 10 Photoluminescence spectrum of ZnTe powder

For the PVC/ZnTe nanocomposite thin films, the photoluminescence spectra (Fig 11) display three emission bands at around 466 nm (blue), 525 nm (green) and 686 nm (red). As for the PVC powder, one can observe the emission band at 466 nm of the excimer fluorescence [42], while irradiation of the PVC/ZnTe nanocomposites with the wavelength of 415 nm leads to the excitation of both PVC molecules and ZnTe NPs which is followed by luminescence with maximum at 466 nm. The two emissions, from PVC matrix and ZnTe NPs, overlap which gives an emission band with high intensity. The intensity of this band increases with the increase in concentration of ZnTe NPs [48] and consequently the intensity at 466 nm is highly enhanced.

The appearing of the phosphorescence band at 525 nm is owing to the formation of triplet excimers which are related to the presence of

excimers [49] as the high efficiency of energy transfer in the solid state of polymers, makes that the emitting species can be not the chromophores that were originally excited [45]. The intensity of this band (525 nm) is relatively weak but also increases with the concentration of ZnTe NPs.

Finally the intensity of the strong luminescent band at 686 nm which is owing to the oxygen defects in the ZnTe NPs is affected by the rate of ZnTe NPs and also by the energy transfer process. Thus the optical absorption band at 570 nm is consistent with the photoluminescence characteristics, and is consequently assigned to oxygen defects in ZnTe NPs [38]. The energy transfer from PVC to ZnTe crystallites occurs by the Forster mechanism as due to the spectral overlap of the PVC luminescence bands and the absorption band at 570 nm of the ZnTe crystallites [50,51]. For the relatively weak concentrations of ZnTe NPs (10 % and 15 %) the intensity at 686 nm increases with the ZnTe concentration, but for the high concentrations (20 % and 25 %) the situation is inverted because of the well-known effect of aggregation of nanometric ZnTe NPs which leads to decrease of the surface of the interface between PVC polymer and ZnTe semiconductor and limits the energy transfer. So an optimal concentration of ZnTe NPs would favor more important intensity of the PVC/ZnTe nanocomposite luminescence.

Fig 11 Photoluminescence spectra of PVC/ZnTe nanocomposite thin films

3.6 Electrical properties

The complexity and diversity of polymers make many factors involved in the mechanism of electrical transport in such materials. The problem is further complicated by the fact that the polymers are generally a mixture of polycrystalline regions in which the molecular chains are regularly folded and of amorphous regions in which the molecular chains are irregularly folded or entangled [18,52]. Among the most common polymers, PVC has a high resistivity which varies from 10^{12} to $10^{16} \Omega\text{cm}$ [53,54], it can decrease by temperature or irradiation treatment [55]. This resistivity can be also reduced by incorporating impurities in the polymer matrix [52]. The resistivity is calculated using the following relation: $\rho(\Omega\text{cm}) = 4.532 \times d(\text{cm}) \times R_{sq}$ where d is the thickness of films and R_{sq} the square resistance.

In the Table 2 are given the experimental values of electrical resistivity of elaborated PVC/ZnTe nanocomposite thin films for different concentrations of ZnTe and the Fig 12 displays the evolution of this resistivity.

Table 2 Electrical resistivity values of PVC/ZnTe nanocomposites.

Fig 12 Evolution of the resistivity of PVC/ZnTe nanocomposites as a function of ZnTe wt%

The increase of the conduction with increasing ZnTe NPs rate is owing to the charge transfer between PVC molecules and

ZnTe NPs. The electron transfer from one monomer of PVC to the other is achieved via ZnTe NPs surface which provides defects that may act as hopping sites for the charge carriers [18]. As expected, the incorporation of ZnTe NPs in the PVC polymer has considerably reduced the resistivity of the composite PVC/ZnTe, Similar results were earlier reported for the composites [52,56]. These found low values of resistivity indicate that PVC/ZnTe thin films become semiconducting in nature [12]. This characteristic gives opportunities for new applications.

4 Conclusion

The performed work is focused on the synthesis of the ZnTe semiconductor NPs by the hydrothermal method and the fabrication of PVC/ZnTe nanocomposite thin films deposited by Dip-Coating technique. The obtained results from XRD, FT-IR and Raman analysis of the films demonstrate the mutual influence of both components (PVC matrix and ZnTe NPs) on the structural properties of the PVC/ZnTe nanocomposites. The optical characterization revealed that the prepared PVC/ZnTe nanocomposite thin films exhibit a high transmittance, over 80 %, in the visible range. The excitation of samples by a wavelength of 415 nm leads to an enhanced blue emission at 466 nm which is owing to the overlap of PVC excimer fluorescence and the near band edge emission from ZnTe NPs. Also samples exhibit a strong red emission at 686 nm which is originated from oxygen defects present in the ZnTe NPs which are excited by the energy transfer process from

PVC to the ZnTe crystallites which occurs as due to the spectral overlap of the PVC luminescence bands and the absorption band of the ZnTe NPs. Electrical measurements show sufficiently low resistivity values, which suggests that PVC/ZnTe nanocomposites are semiconductor in nature. These characteristics mean that the elaborated PVC/ZnTe nanocomposites can be considered as potential materials for the fabrication of optoelectronic devices.

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Figures

Figure 1

XRD pattern of as-synthesized ZnTe nanoparticles

Figure 2

XRD patterns of pure PVC and PVC/ZnTe nanocomposite thin films

Figure 3

FT-IR Transmittance spectra of pure PVC and ZnTe/PVC nanocomposite thin films

Figure 4

Raman spectra of the PVC/ZnTe nanocomposite thin films

Figure 5

Topographic images of the surface of the PVC/ZnTe nanocomposite thin films, (a) three-dimensional (3D) b) two-dimensional (2D)

Figure 6

Optical transmittance spectra of pure PVC and PVC/ZnTe nanocomposite thin films

Figure 7

Optical absorption spectra of pure PVC and PVC/ZnTe nanocomposite thin films

Figure 8

Optical gap of pure PVC and PVC/ZnTe nanocomposite thin films

Figure 9

Photoluminescence spectrum of PVC powder

Figure 10

Photoluminescence spectrum of ZnTe powder

Figure 11

Photoluminescence spectra of PVC/ZnTe nanocomposite thin films

Figure 12

Evolution of the resistivity of PVC/ZnTe nanocomposites as a function of ZnTewt%

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