

Optical and Physical Properties for the Nanocomposite Poly(vinyl chloride) with Affected of Carbon Nanotube and Nano Carbon

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ABSTRACT

In this paper, the new nanocomposite thin films of carbon nanotube (CNT) and nano carbon (CN) implanted in PVC matrix were produced by casting technique. The influence of nanomaterials (CNT+CN) was studied on the optical properties and structure of PVC nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) by utilizing a microscope, AFM device, and computerized diffused reflectance of UV-Visible. The energy gap, absorption coefficient, reflectance, extinction factor, refractive index, and urbach energy have been studied. The reflectance and transmittance of the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) were decreased compared with blank PVC after being dispersed (CNT+CN) in the PVC matrix. The dielectric constant and conductivity of nanocomposite thin films also increased after adding nanomaterials (CNT+CN). The direct energy gap and indirect energy gap were decreased for the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) compared with the energy gap of blank PVC, where, urbach energy of nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) increased after addition the nanomaterials (CNT+CN) to the PVC matrix. The SEM images were used to show the shape of carbon nanotube (CNT) and nano carbon (CN). The surface topography was tested by the AFM device and it found the roughness of the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) were increased compared with the blank PVC. The application of nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) was used in many applications like optical clarity, high mechanical strength, and thermal gas barrier. Prog. Color Colorants Coat. 16 (2023), 331-345© Institute for Color Science and Technology.

1. Introduction

The production of plastic is vastly utilized in communication cable packaging, medical fields, food packing, and in many fields due to outstanding their mechanical and chemical resistance with lightweight and lower cost [1]. Poly(vinyl chloride) is the one type of

plastic that is used as a polymer in many research applications, it has a simple modification, cheap thermoplastic, economic formation, and flame retardancy, thereby used in thin films [2]. Therefore, PVC at high temperatures is unsteady out of the application in molding, consequently, the addition of reinforcement

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material to be stabilized and through the processing [3]. The reinforcement materials such NPs as titanium oxide (TiO_2), chromium oxide (Cr_2O_3), cobalt oxide (Co_3O_4), nickel oxide (NiO), copper oxide (CuO), graphene (Gr), multi-walled nanotube (MWNT), carbon nanotube (CNT), and carbon nano (CN) are added to polymer structure enhanced its properties via preparing new nanocomposite of polymer PVC, that it is used in optical clarity, high mechanical strength, thermal gas barrier [4-7].

In the present work, the nanocomposite thin films of PVC are reinforced by carbon nanotube (CNT) and carbon nano (CN), which is regarded as a nanofiller material inside the PVC matrix. So, the single-walled carbon nanotube (CNT) has extraordinary properties that are utilized in many applications as a nanofiller in the nanocomposite, when adds to the PVC structure and gives it electrical transport properties and high thermal stabilization [8, 9]. MWCNT was used in PVC matrix that dissolved in THF to study the effect of thermal, electrical, and dispersion within the PVC structure [10]. The nanocomposite-MWCNTs were synthesizes and dissolved in THF and cast as a film, where the addition of MWCNTs increased the electrical conductivity for these nanocomposite thin films due to the change in PVC structure and penetrate MWCNTs within PVC lattice [11]. Likewise, PVC-nanocomposite thin films have been prepared with various contents of MWCNTs, these thin films are hit by plasma irradiation to give a fine dispersion of MWCNTs within the PVC matrix. the resulting thin films gained good AC electrical conductivity, thermal stability, and a good dielectric constant layer [12, 13]. But regarding of carbon nano (CN) is used in the present work with carbon nanotube (CNT) to improve the structure of PVC. The thin films which were fabricated give nanocomposite good electrical conductivity with high absorption.

The present work aims to fabricate thin films consisting of PVC-CNT, PVC-CN, and PVC-CNT-CN and study the effect of CNT and CN on the PVC structure to show the optical properties of these films, compared with blank PVC. These thin films with nanomaterials improved the absorbance, refractive index, energy gap, dielectric constant, and urbach energy. To our knowledge, there is no one using carbon nano (CN) with PVC. the SEM device was used to show the shape of carbon nanotube (CNT) and nano carbon (CN). The nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) are used in many

applications like optical clarity, high mechanical strength, and thermal gas barrier.

2. Experimental

2.1. Materials

The material of pure PVC bought from Turkey, Istanbul (PetKim Petrokimya), carbon nanotube, and carbon nano have been synthesized in the lab.

2.2. Synthesis carbon nanotube and nano carbon

The carbon nanotube (CNT) and carbon nano (CN) were synthesized in the lab. Primely, preparation of carbon nanotube (CNT) by taking 1 g of reeds with 3 g from NaOH (1:3 wt. %), they were mixed and put in the furnace at 550 °C for 1 h, every 1 min raise the temperature 10 °C, at this degree the calcination has happened. The output was cooled at room temperature and washed with hot water many times using Hcl to normalize the pH degree (pH=7) and get rid of NaOH, then the wetted mass was left to dry at 80 °C for 12 h. Secondly, the same method above was used to produce nano carbon (CN), but the difference was in burning the reeds with NaOH at 700 °C for 3 h in the furnace. A scheme (1) shows the synthesis of carbon nanotube (CNT) and carbon nano (CN) in different temperatures of calcination.

2.3. Preparation thin film

The PVC nanocomposite thin films were prepared in these steps. In step one, the blank PVC thin film was produced with 1 g of PVC in 100 mL of THF to be 1 % wt. of the mixture. The mixture is blended with a stirrer and raised the temperature to 75 °C, then the solution is poured into the glass template. In step two, the nanocomposite thin film of (PVC+CNT) was prepared by taking 0.05 g from carbon nanotube (CNT) added to the PVC mixture and blended by a stirrer and then in a sonication device to dissolve the CNT with the mixture. Finally, in step three, the nanocomposite thin film of (PVC+CN) was prepared at the same method by taking 0.05 g from the carbon nano (CN) to the PVC mixture. The nanocomposite thin film (PVC+CNT+CN) was prepared by taking (0.025CNT+0.025CN) with a PVC mixture. All these nanocomposite films were poured into a glass template 40 μm thick and were left under vacuum circular glass, to protect these thin films from any environmental effect. Scheme 2 shows the preparation of

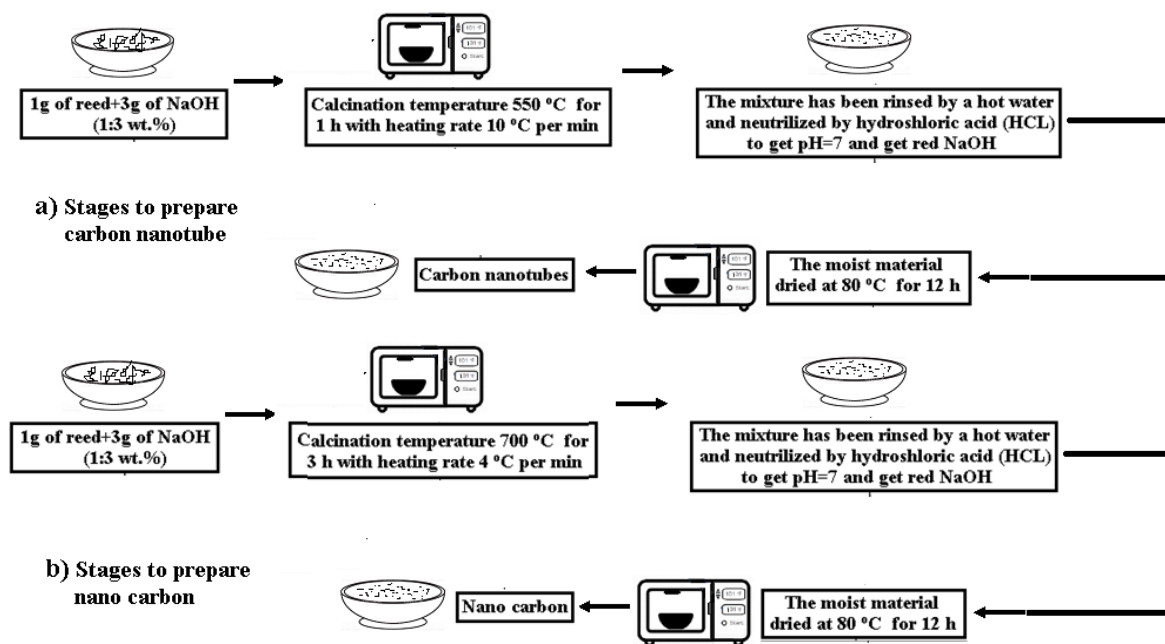
synthesis the nanocomposite thin films of PVC with CNT and CN.

2.4. Characterization techniques devices

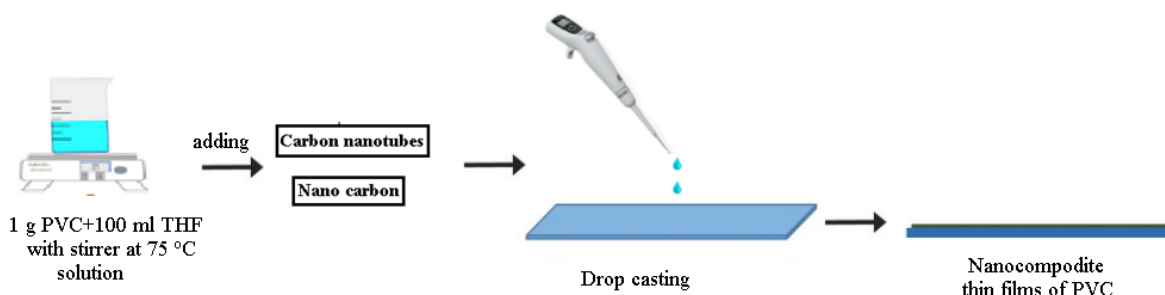
The samples were inspected by the reflectance device Avantes (DH-S-BAL-2048, UV-Visible Spectro-2048) in the wavelength range (250-1300 nm) for 0.5 step wavelength. The microscope image MK 1000 and MEIJI equipped is inspected with central processor controller with INSTEC hot stage, that was connected to Lumenera color, that have 20x magnifying powers.

It used for signify the morphology of the surface. The AA2000 AFM device is employed to assign the particles size of roughness for the blank PVC and PVC-CNT, PVC-CN, PVC-CNT-CN nanocomposite thin films.

The scanning electron microscopy (SEM) S50 with a low vacuum (3 nm at 30 kV SE) was used to show the shape after burned, where the carbon nanotube after calcination at 550 °C shown in Figure 1a and nano carbon after calcination at 700 °C shown in Figure 1b.



Scheme 1: Described the stages to synthesis: a) carbon nanotubes (CNT) and b) nanocarbon (CN).



Scheme 2: Synthesis the nanocomposite thin films of PVC with carbon nanotube (CNT) and carbon nano (CN).

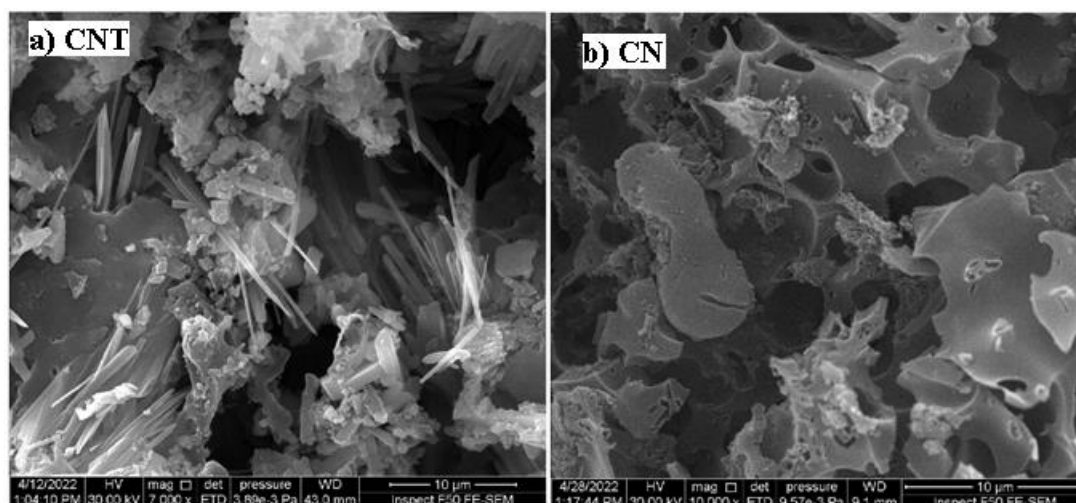


Figure 1: The images of a) carbon nanotube (CNT) and b) nano carbon (CN).

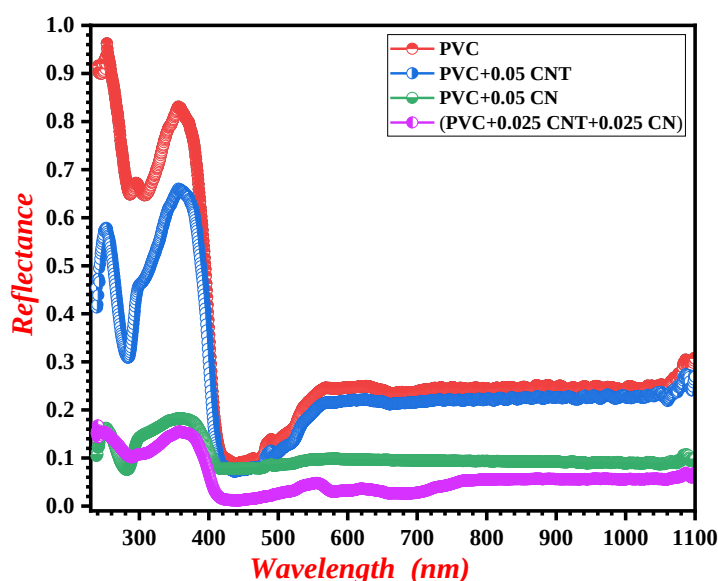


Figure 2: Reflectance variation with wavelength for the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN).

3. Results and Discussion

3.1. Reflectance of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN)

The reflectance of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN) can be shown in Figure 2. Figure 2 shows the variation of reflectance with wavelength for the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN), it can see the curves of reflectance initiated from a high value in the UV region and declines to a lower value in the visible region. Therefore, after the visible region ($400 \leq \lambda \leq 600$), all curves of reflectance

are continued invariant when shifted to a higher wavelength. The best nanocomposite thin film is PVC-CNT-CN has a lower value of reflectance compared with other curves and blank PVC [14, 15].

3.2. Absorption coefficient of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN)

The absorption coefficient (α) of nanocomposite thin films was studied between 250-1300 nm of the incident wavelength. The variation of absorption coefficient (α) with the wavelength of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN)

can be shown in Figure 3.

The absorbance coefficient (α) of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN) is calculated from equation 1 [15-17]:

$$\alpha = 2.303 * \frac{A}{t} \dots \quad (1)$$

Where (α) absorbance coefficient (cm^{-1}), (A) absorbance value, (t) coating thickness (cm).

It is obvious from Figure 3 that the absorption coefficient (α) increases as a content of nanoparticles (CNT+CN) is founded in the PVC matrix, because these nanoparticles improves the matrix of PVC and

drives to increase in the absorption after the absorption edge between the wavelength range ($500 \leq \lambda \leq 600$) of the thin films. Thereby, all the absorption coefficient curves have high absorption after doping PVC with (CNT+CN) [18].

3.3. Transmittance of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN)

The transmittance of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN) are demonstrated in Figure 4.

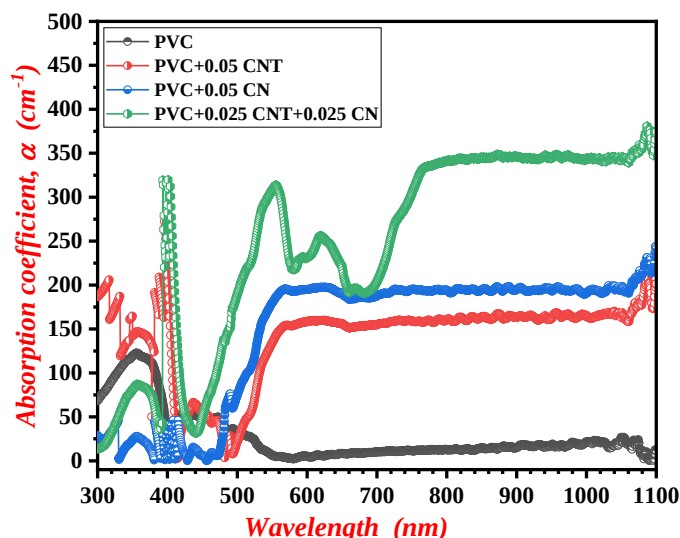


Figure 3: Absorbance coefficient variation with wavelength for the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN).

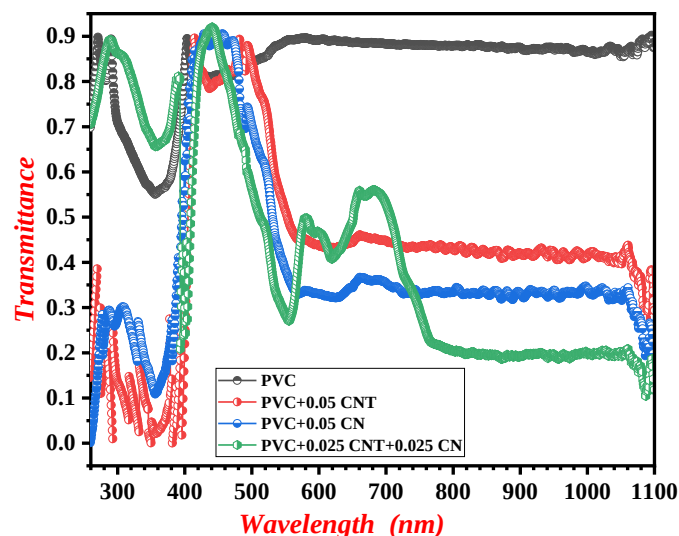


Figure 4: Transmittance variation with wavelength for the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN).

It can be seen from Figure 4 that the transmittance of the blank PVC is 90 %, but the other curves that doped with nanoparticles (CNT+CN) decreased to be lower value when is shifted to a higher wavelength. This due to existence of nanoparticles (CNT+CN) in the PVC matrix. Also, can see from Figure 4 the interference of nanoparticles inside the PVC decreased the transmittance and be about 20 % for the nanocomposite thin film PVC-CNT-CN, which is be the best thin film compared with other curves [19].

3.4. Refractive index of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN)

The propagation of the wavelength inside the thin films is displayed by the refractive index, therefore, the refractive index depends on the reflectance. Then, it is computed from equation 2 [20]:

$$n = \left[\frac{1+R}{1-R} \right] + \sqrt{\frac{4R}{(1-R)^2} - k^2} \dots \quad (2)$$

Where (n) refractive index, (R) reflectance, and (k) extinction factor. The refractive index (n) is displayed in Figure 5 of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN).

Figure 5 shows the refractive index of nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN), it is obvious that the refractive index (n) increases to be maximum value in the UV region. Then decreases in the visible region and be continuous invariant along the wavelength shifted to higher values. The refractive index increases from value 1.5 to 2.5 at ($\lambda=600$ nm), the increasing in refractive index (n) for all the curves have nanoparticles of (CNT+CN) compared with blank PVC, this due to the density of (CNT+CN) nanoparticles packed in PVC structure [21].

3.5. Extinction factor of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN)

The important factor that demonstrates the light loss during the absorption and scattering inside the thin films called by extinction coefficient (k). it is computed from equation 3 [22]:

$$k = \frac{\alpha \lambda}{4\pi} \dots \quad (3)$$

Where, (λ) wavelength (cm), (α) absorption coefficient (cm^{-1}).

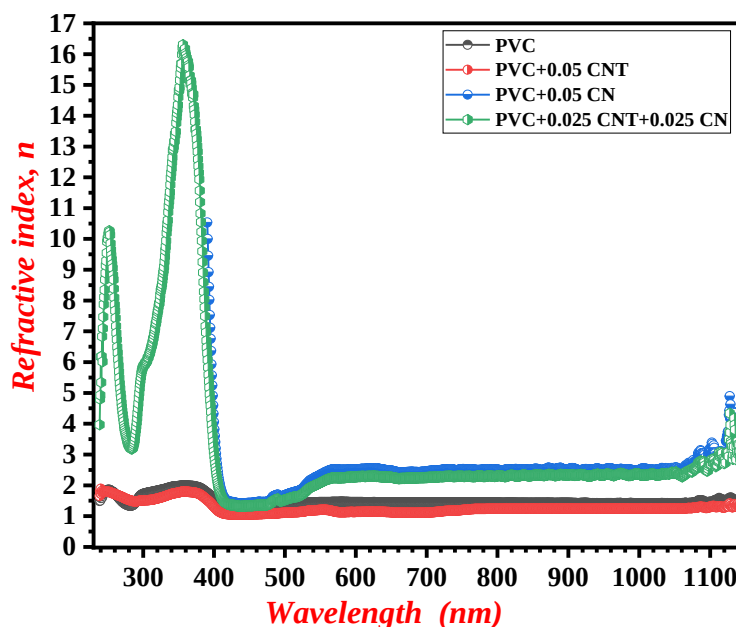


Figure 5: Refractive index variation with wavelength for the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN).

Therefore, it can be seen from Figure 6 the extinction factor (k) for the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN), inside these thin films, the CNT and CN were implanted within the PVC matrix to dope PVC and minimize losses of absorption and scattering inside nanocomposite thin films.

Also, from Figure 6 the extinction factor (k) for all curves of the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) have low values of extinction factor (k), this is attributed to finding the nanoparticles inside the PVC matrix which is lead minimizing the loss in absorption and scattering [23, 24].

3.6. Dielectric constant (real and imaginary) of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN)

The dielectric constant (ϵ) is correlated to the electronic framework of the nanocomposite thin films and denotes to the density of localized states in the gap, the dielectric constant for the real ϵ' and imaginary ϵ'' can be computed directly from the equation 4 [25]:

$$[(\epsilon) = \epsilon'(\omega) + i\epsilon''(\omega)] \quad (4)$$

The dielectric constant (ϵ) dependent on (n) and (k) parameters and can be computed equation 5 [25]:

$$\begin{bmatrix} \epsilon' = n^2 - k^2 \\ \epsilon'' = 2nk \end{bmatrix} \dots \quad (5)$$

Furthermore, both the real ϵ and imaginary ϵ are shown in Figures 7 and 8 of the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN). Figure 7 shows the real dielectric constant ϵ for the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) to exhibit its values various with the wavelength.

Figure 7 shows the variation of real dielectric constant (ϵ) with the wavelength for the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN), where the real dielectric constant for these thin films increases when added the (CNT+CN) to the PVC matrix, this increase lead to form many local states in the gap. Therefore, the doping changes the electronic structure of PVC [26]. Similarly, Figure 8 shows the variation of imaginary dielectric constant with the wavelength for the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN).

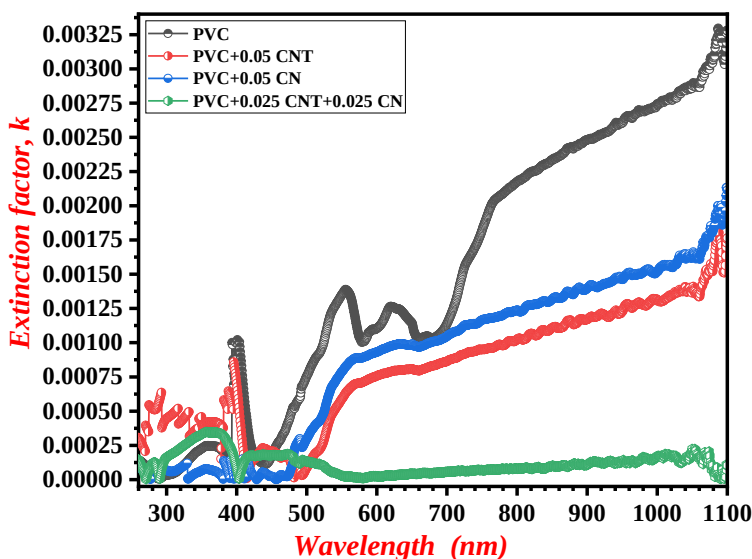


Figure 6: Extinction factor variation with wavelength for the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN).

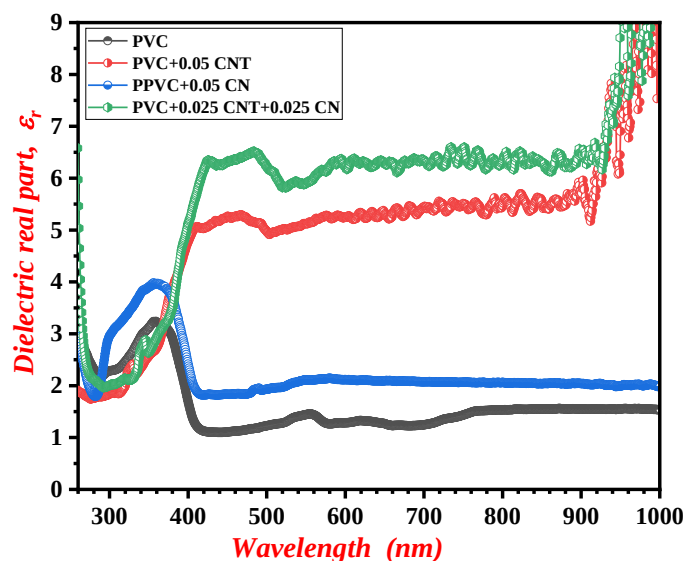


Figure 7: Real dielectric constant variation with wavelength for the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN).

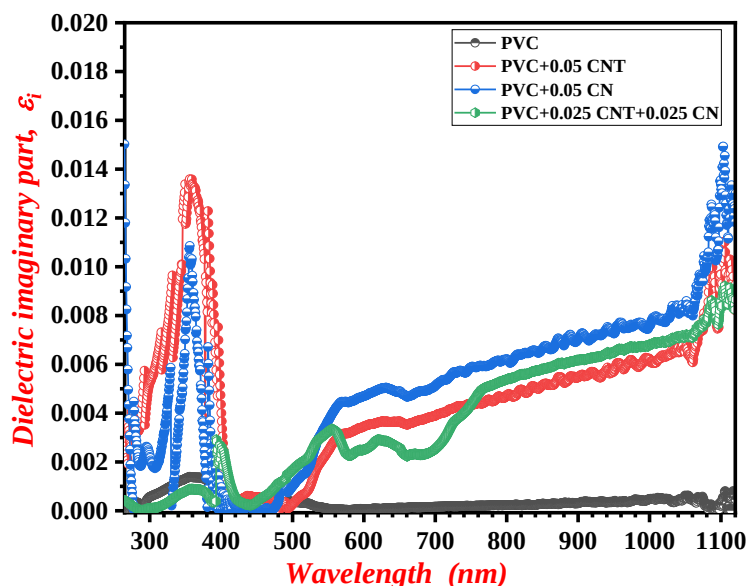


Figure 8: Imaginary dielectric constant variation with wavelength for the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN).

It can be seen from Figure 8 the imaginary dielectric constant for the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN), whereas, its high values in the UV region is attributed to the effect of polarization that decrease when the wavelength shifted to higher values. Thereby, the addition of (CNT+CN) lead to increase the imaginary dielectric constant due to change in the electronic structure in PVC matrix [26].

3.7. Optical conductivity of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN)

The photon energy when incident on the surface of the thin films will excited the charge carriers and diffused between the structure. This diffusion will caused transfer these charge carriers from valence band to the conduction band. Then, the optical conductivity is computed by the equation 6 [27]:

$$\sigma = \frac{\alpha n c}{4\pi} \dots \quad (6)$$

Where (σ) optical conductivity (S^{-1}), (n) refractive index, (c) light speed (3×10^{10} cm/s), and (α) absorbance coefficient (cm^{-1}).

Figure 9 shows the optical conductivity various with the wavelength for the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN). In overall, it is shown that the optical conductivity increasing when the wavelength increases. the influence of the wavelength is clear to excite the electrons and lead to increase the optical conductivity as shown in Figure 9. Therefore, the addition of (CNT+CN) to the PVC matrix increase optical conductivity, which lead to increase charge carriers and make easy transition of electrons through the bands [28].

3.8. Optical energy gap of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN)

The gap between the valence band and conduction band is called the energy gap and it has been studied via Tauc's relation, equation 7 [29]:

$$\alpha h\nu = B (h\nu - E_g)^n \dots \quad (7)$$

Where (B) constant, (E_g) energy gap, and (n) power to the transition type ($n=2$ for direct transition and $n=0.5$ for indirect transition, respectively) [30, 31].

Thereby, to get the values of energy gap by taking the square of ($\alpha h\nu$) with ($h\nu$) as shown in Figures 10 and 11 for the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN). Figure 10 shows the direct energy gap for the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN), it can be obtained by intercept the linear line of extrapolating to x-axis when the value of ($\alpha h\nu$) zero ($y=0$).

It can be shown from Figure 10 that the direct energy gap of blank PVC thin film is 4.6 eV, and for the nanocomposite thin film (PVC-CNT) is become 3.0 eV, where decreased after added carbon nanotube (CNT). The direct energy gap of nanocomposite thin film (PVC-CN) is become 3.4 eV, after addition carbon nano (CN). And then, for the nanocomposite thin film (PVC-CNT-CN) is become 2.9 eV, where after addition the hybrid nanomaterials (CNT+CN) to the PVC matrix, there is a decreasing in the energy gap to a lower value. Therefore, when added the nanomaterials to the PVC matrix are changed the structure and grant it the conductivity. All values of energy gap for the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) are listed in table 1 [32]. Likewise, Figure 11) shows the indirect energy gap for the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) to obtain these values.

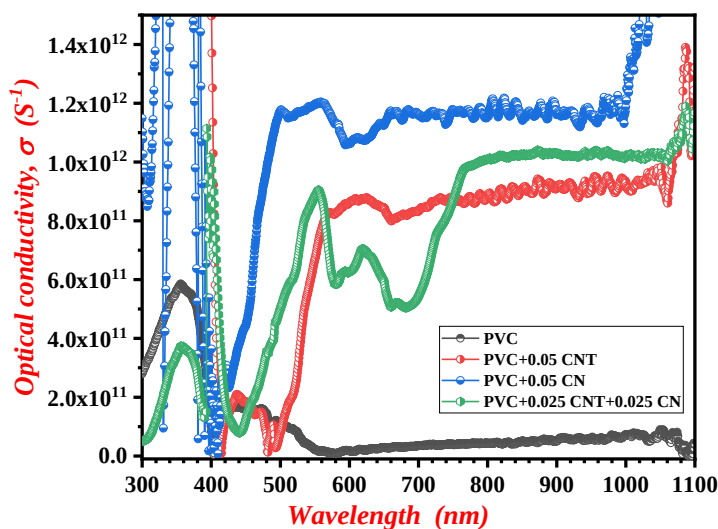


Figure 9: Optical conductivity variation with wavelength for the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN).

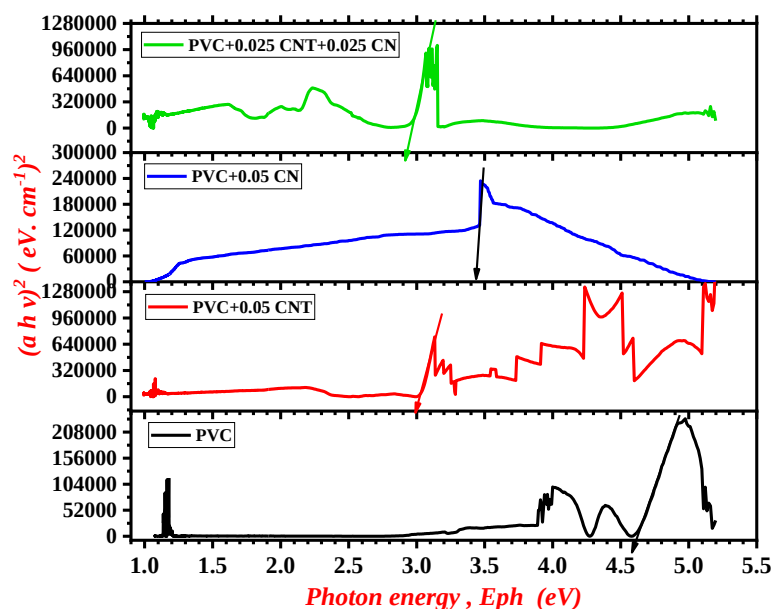


Figure 10: Energy gap variation with wavelength for the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN).

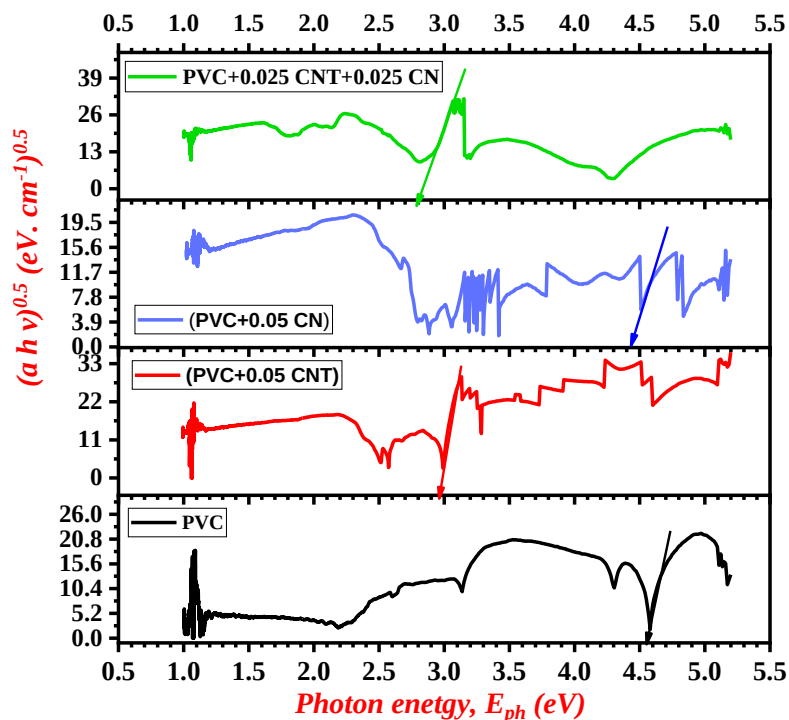


Figure 11: Energy gap variation with wavelength for the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN).

It can show from Figure 11 that the indirect energy gap of blank PVC thin film is 4.55 eV, and for the nanocomposite thin film (PVC-CNT) is become 2.95 eV, where decreased after added carbon nanotube (CNT). The indirect energy gap of nanocomposite thin

film (PVC-CN) is become 4.4 eV, after addition carbon nano (CN), this value is become higher from direct band gap value due to irregular mixing in this region. And then, for the nanocomposite thin film (PVC-CNT-CN) is become 2.8 eV, where after addition the hybrid

nanomaterials (CNT+CN) to the PVC matrix, there is a decreasing in the energy gap to a lower value. Therefore, when added the nanomaterials to the PVC matrix are changed the structure and grant it the conductivity. All values of energy gap for the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) are listed in Table 1 [32].

3.9. Urbach energy of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN)

The urbach energy (ϵ_u) is happened due to absorb the photon energy, this absorption caused a formation of localized states in the gap due to the electrons movement which lead increase the degree of disorder in the gap of the nanocomposite. Then, equations 8 is used to compute urbach energy [30, 32]:

$$\alpha = \alpha_o \exp \frac{h\nu}{E_u} \dots \quad (8)$$

By modified equation 8, the get (Eq. 9):

$$\ln \alpha = \ln \alpha_o + \frac{h\nu}{E_u} \quad (9)$$

Where, (α_o) constant.

Figure 12 shows the urbach energy variation with photon energy for the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN). From Figure 12 shows the urbach energy is plotted against photon energy, and gets the reciprocal of the slope for the curves that formed in Figure 11 to give the value of urbach energy. It can see from Figure 12 that urbach energy is increased from 2.240-8.190 eV for the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN), this obvious that urbach energy increased when added the nanomaterials (CNT+CN) to the PVC matrix. Also, the degree of disorder is increased when the value of urbach energy increases [33, 34]. The values of urbach energy are listed in Table 1.

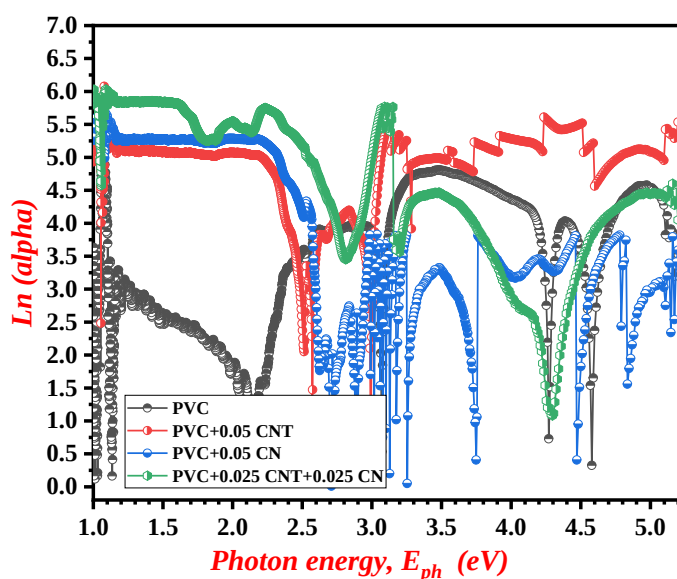


Figure 12: Urbach energy variation with wavelength for the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN).

Table 1: shows the values of direct energy gap, indirect energy gap, and urbach energy.

No.	Parameters	Blank PVC (eV)	PVC+0.05CNT (eV)	PVC+0.05CNT (eV)	PVC+0.025CNT +0.025CN (eV)
1	Direct transition of (E_g) (eV)	4.6	3.0	3.4	2.9
2	Indirect transition of (E_g) (eV)	4.55	2.95	4.4	2.8
3	Urbach energy (E_u) (eV)	2.240	8.190	1.126	1.386
4	(α_o) constant (cm^{-1})	7.925	177.151	634.603	853.035

4. Microscope images of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN)

The microscope images analysis was utilized to assign the form of thin film morphology and distribution of nanomaterials (CNT+CN) in the PVC matrix. Figure 13 exhibits the microscope images for the blank PVC and the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN). It was noticed that the (CNT+CN) nanomaterials have collected as a spherical shape. Where, Figure 13a shows the blank PVC image is clear. Figure 13b shows the nanocomposite thin film of PVC+CNT and the carbon nanotube (CNT) takes a form agglomerates of spherical shape in the thin film. Figure 13c shows the nanocomposite thin film of PVC+CN and the nano carbon takes a form agglomerates as a spherical shape also, but is smaller than the spherical shape in PVC+CN thin film. Figure 13d shows a homogeneous mixing of carbon nanotube with nano carbon distributed in PVC matrix [35].

5. AFM test of the nanocomposite thin films (blank PVC, PVC-CNT, PVC-CN, and PVC-CNT-CN)

Figure 14 a, b, c, and d shows the topography of the surface in 3D and 2D for the blank PVC and the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) by the AFM device.

The blank PVC thin film surface shows in Figure 14a is fine and has small roughness 1.07 nm. Figure 14b shows the nanocomposite thin film of PVC+CNT has a high roughness; its value 3.09 nm is greater than the blank PVC thin film. Figure 14c shows the nanocomposite thin film of PVC+CN has a higher roughness; its value 3.30 nm is greater than from the blank PVC thin film and the nanocomposite thin film of PVC+CNT. While, Figure 14d shows the nanocomposite thin film of PVC+CNT+CN has a lower value of roughness is 1.22 and greater than the blank PVC thin film [36].

Table 2: AFM test for blank PVC, PVC+CNT, PVC+CN, and PVC+CNT+CN nanocomposites thin films.

No.	Composite	Number of figures	Roughness average (nm)	Root mean square of roughness (nm)
1	Blank PVC	14a	1.07	1.49
2	PVC+CNT	14b	3.09	4.08
3	PVC+CN	14c	3.30	4.57
4	PVC+CNT+CN	14d	1.22	1.79

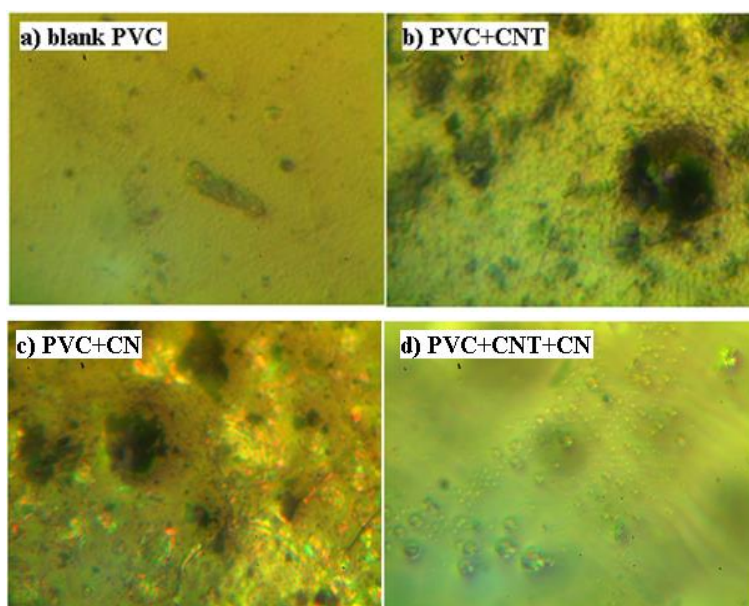


Figure 13: Images for the nanocomposite thin films a) blank PVC, b) PVC-CNT, c) PVC-CN, and d) PVC-CNT-CN).

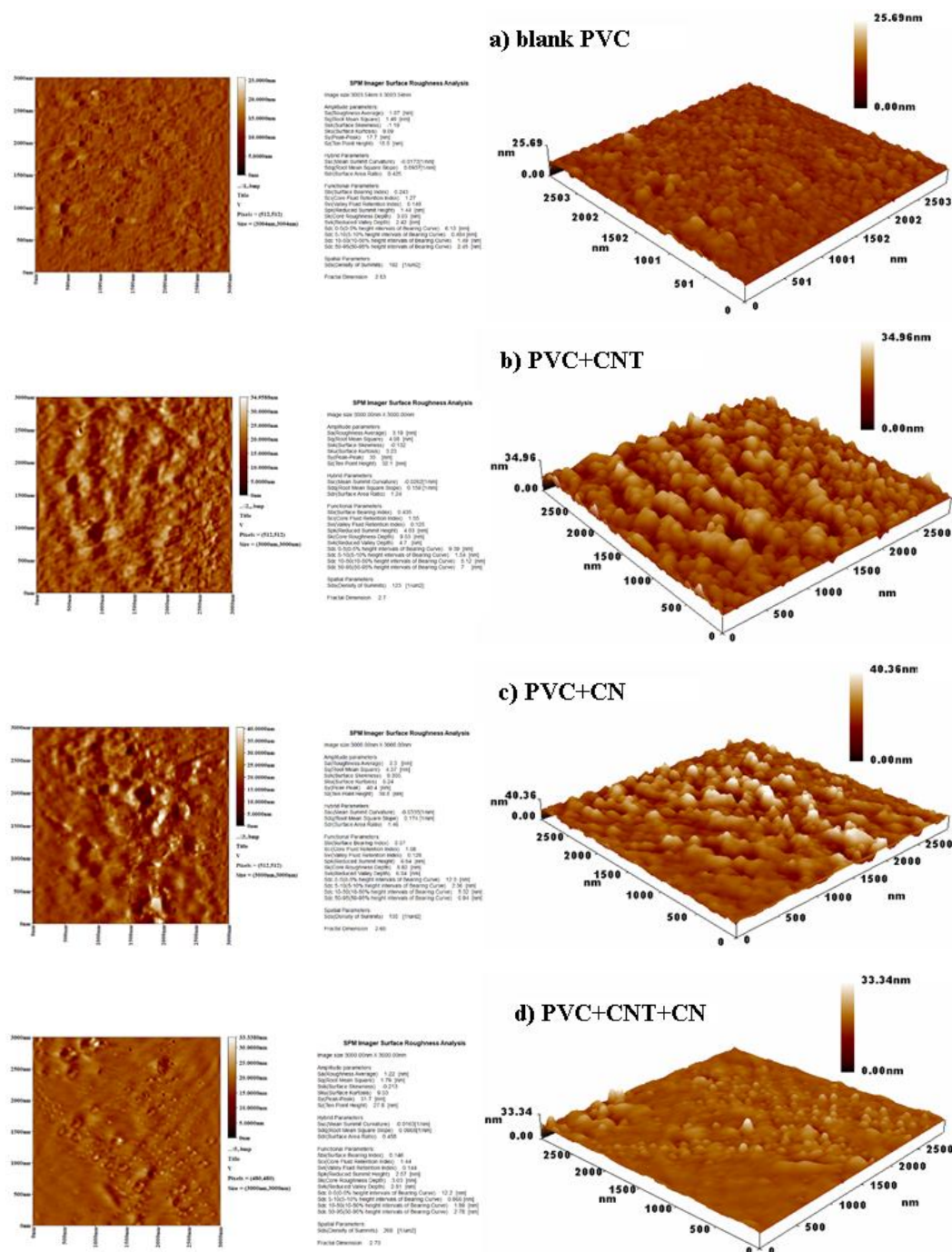


Figure 14: 3D and 2D pictures display the average roughness and root mean square for: a) blank PVC, b) PVC-CNT, and c) PVC-CN, and d) PVC+CNT+CN.

4. Conclusion

The PVC nanocomposite thin films have been made by casting technology, they containing carbon nanotube (CNT) and nano carbon (CN) in PVC matrix to change their structure. The impact was done in the structure of PVC nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) by adding nanomaterials (CNT+CN). The optical properties were studied for the

blank PVC and nanocomposite thin films by using computerized diffused reflectance of UV-Visible. The absorption coefficient, reflectance, extinction factor, optical density, and refractive index of optical properties have decreased, and the reflectance with transmittance were decreased of the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) compared with blank after dispersion of (CNT+CN) in

PVC matrix. The conductivity and dielectric constant were increased of nanocomposite thin films after adding nanomaterials. The diminish direct energy gap from 4.6 eV for the blank PVC to 2.9 eV of nanocomposite thin film, and there is a diminish in an indirect energy gap from 4.55-2.8 eV. The Urbach energy was increased of nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) after adding the nanomaterials (CNT+CN) to the PVC matrix from 2.240 eV to 8.190. The configuration of the carbon nanotube (CNT) and nano carbon (CN) was appeared by SEM images, and the AFM images shows a fine surface of the of nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN). The surface

roughness has been increased from 1.07 nm for the blank PVC to 3.30 nm of nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN) after adding the nanomaterials to the PVC matrix. The applications were used in many applications like optical clarity, high mechanical strength, thermal gas barrier of the nanocomposite thin films (PVC-CNT, PVC-CN, and PVC-CNT-CN).

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