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Lower Cost and Higher UV-Absorption of Polyvinyl Alcohol/ Silica Nanocomposites For Potential Applications

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Films of (polyvinyl alcohol- silicon dioxide) nanocomposites were prepared for UV- shielding with low cost, low weight and excellent anti-UV properties. Studying the structural and optical properties of PVA/SiO2 nanocomposites have been investigated. The experimental results showed that the absorbance (A), absorption coefficient (α), extinction coefficient (K), refractive index (n), real (ε1) and imaginary (ε2) parts of dielectric constants and optical conductivity (σop) of PVA are increased with increasing of the SiO2 concentrations. The transmittance (T) and energy band gap (Eg) decrease as a SiO2 concentrations increase. Also, te results showed that (PVA-SiO2) nanocomposites can be used for flexible solar cells, diodes and transistors applications.

Keywords: absorbance, silicon dioxide, nanocomposites, flexible , anti-UV .

Introduction

Over the last few years, increasing reports of ultraviolet aging owing to the collapse of the ozone layer have made people greatly aware of the danger to polymers from prolonged exposure to UV rays. The ultraviolet degradation of polymers is hugely important because resistance to aging, especially to UV light, is a key factor for outdoor applications. UV light, which accounts for about 7% of terrestrial sunlight, has been proven to cause aging of polymers, such as yellowing, brittleness, and even degradation. Both organic ultraviolet light stabilizers and inorganic nanoparticles have been introduced into polymer matrices to improve the UV stability of polymers. Compared with organic UV filters, inorganic nanoparticles are generally accepted as more stable and safe anti-UV agents [1]. Polymer matrix nanocomposites, which exhibit distinct physicochemical characteristics by incorporating inorganic fillers into polymer networks, have received much attention due to their various industrial applications in drug delivery, water treatment, food industry, aeronautical and aerospace structures [2]. These nanocomposites combine advantageous properties of polymers with size-tunable optical, electronic, catalytic, and other properties of semiconductor nanoparticles. Generally, the role of the polymers is to encapsulate the nanoparticles and enable better exploitation of their characteristic properties. However, polymers cannot solely be regarded as good host materials, as they can also be used to modify the surface and/ or to control the growth of nanoparticles. Surface modification could be of great importance for possible use of semiconductor nanoparticles in biomedical applications and diagnostics [3]. A hybrid material consists of soluble polymers with inorganic component with excellent mechanical, optoelectronics and dielectric properties due to the combination of the organic and inorganic components, and it can be deposited as a thin film in different substrates. Therefore, the number of contributions in the development of hybrid composites based on polymers and nanoparticles with high permittivity, low cost, and easily tunable properties, have become a hot topic in the research of materials [4]. Nanocomposites have different

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modern applications such as pressure sensors [5], piezoelectric [6,7], antibacterial [8-12], humidity sensor [13-17], thermal energy storage and release [18-22],...etc. Polyvinyl alcohol (PVA) is a biocompatible, biodegradable and non-toxic water- soluble polymer. This polymer is an excellent adhesive, has good organic solvent resistance and its resistance to oxygen passage is superior to that of any other known polymer. It is one of the few water-soluble semicrystalline polymers with good interfacial characteristics. It is widely used in the textile industry, in the packaging industry and in biomedical applications such as contact lenses, medication, orthopedic materials, tissue engineering and the manufacturing of artificial organs [23]. Silica nanoparticles are extensively studied for many applications such as photonic crystals, chemical sensors, biosensors, nanofillers for advanced composite materials, markers for bioimaging, substrate for quantum dots, and catalysts. However many interesting reports indicated the uses of silica in the formation of modern polymer composites, such as poly(butylene terephthalate) (PBT), poly(methyl acrylate) (PMA), polyethylene (PE), polypropylene (PP), polystyrene (PS), polyhydroxyethylmethacrylate (PHEMA), polyurethane (PUR), natural rubber, and acrylonitrile-butadiene elastomer (NBR) [24].

Materials and Methods

Films of polyvinyl alcohol (PVA) doped with silicon dioxide (SiO_2) nanoparticles were prepared by using casting method. The PVA solution was prepared by dissolving 1gm in 20 ml of distilled water by using magnetic stirrer for 1 hour. The SiO_2 nanoparticles were added to the PVA solution with concentrations (2, 4 and 6) wt.%. The optical properties of (PVA-SiO_2) nanocomposites were measured by using the double beam spectrophotometer (shimadzu, UV -1800^{0}A) in wavelength (240-800) nm.

The absorption coefficient (α) of nanocomposites was determined by the equation [25,26]:

$$\alpha = 2.303A/t \qquad \ldots\ldots\ldots (1)$$

Where A: is the absorbance of sample and t: the sample thickness in cm. The non-direct transition model for amorphous semiconductors is given by following equation [27,28]:

$$\alpha h\upsilon = B(h\upsilon - E_g)^r \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where B is a constant, hυ is the photon energy , E_g is the optical energy band gap, r=2,or 3 for allowed and forbidden indirect transition.

The refractive index (n) of (PVA-SiO_2) nanocomposites was calculated by using the equation [29,30]:

$$n = (1+R^{1/2})/(1-R^{1/2}) \qquad \ldots\ldots\ldots (3)$$

The extinction coefficient (k) was calculated by using the following equation [31,32]:

$$K = \alpha\lambda/4\pi \qquad \ldots\ldots\ldots\ldots (4)$$

The real and imaginary (ε_1 and ε_2) parts of dielectric constant were calculated by using equations [33,34]:

$$\varepsilon_1 = n^2 - k^2 \qquad \ldots\ldots (5)$$

$$\varepsilon_2 = 2nk \qquad \ldots\ldots (6)$$

The optical conductivity was calculated by using the following equation [35,36]:

$$\sigma = \frac{\alpha n}{4\pi} \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Results and Discussion

The variation of optical absorbance of nanocomposites as function of wavelength for different silicon dioxide concentrations is shown in Figure 1. The optical absorption analysis is an important tool to obtain optical band gap energy of crystalline and corresponds to the electron excitation from the valence band to the conduction band and can be used to determine the nature and value of the band gap. The nanocomposite showed high absorbance in UV region due to the behavior of silicon dioxide nanoparticles which are may be used as UV- shielding and low weight electronics applications . An amount of SiO_2 nanoparticles is required to reduce the value of gap energy in nanocomposites and it has different effect depending on type of polymer matrix. The insertion of the SiO_2 nanoparticles into the films of the PVA has a double effect because it increases the energy of the SiO_2 gap and decreases that of the polymer [37]. These are consistent with the results of researchers[38-40].

The effect of silicon dioxide nanoparticles concentrations on the absorption coefficient of PVA is shown in Figure 2. The absorption coefficient of polyvinyl alcohol is increased with an increase in SiO_2 nanoparticles concentrations which attribute to increase the absorbance. It can known the energy band gap from the values of absorption coefficient, which explain that the nanocomposites have indirect energy gap as shown in Figures 3 and 4 for allowed indirect and forbidden indirect transition of PVA/SiO_2 nanocompsites respectively. The figures show that the energy band gap of PVA/SiO_2 nanocomposites is decreased with the increase of SiO_2 nanoparticles concentrations which due to increase of the localized level in energy gap [41].

Figure 5 represents the variation of the extinction coefficient (k) with the incident photon wavelength of (PVA-SiO_2) nanocomposites, the variation is simple in the low energy region while it increased in the high photon energy region, this behavior may be as a result to the variation of the absorption coefficient which leads to spectral deviation in the location of the charge polarization at the attenuation coefficient due to the loses in the energy of the electron transition between the energy bands [42]. The extinction coefficient is increased with increasing of the silicon dioxide nanoparticles concentrations, this increase of extinction coefficient attributed to loss of energy for incident light because the reaction between the incident light and the molecules of the

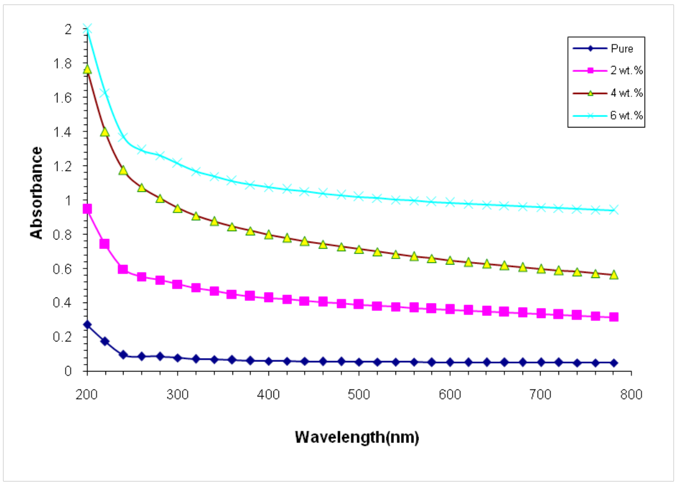

Fig. 1. Variation of optical absorbance of nanocomposites as function of wavelength for different silicon dioxide concentrations.

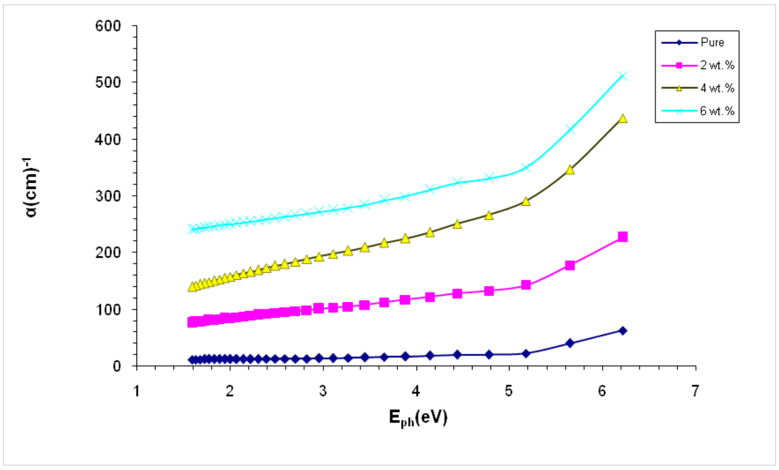

Fig. 2. Effect of silicon dioxide nanoparticles concentrations on the absorption coefficient of PVA .

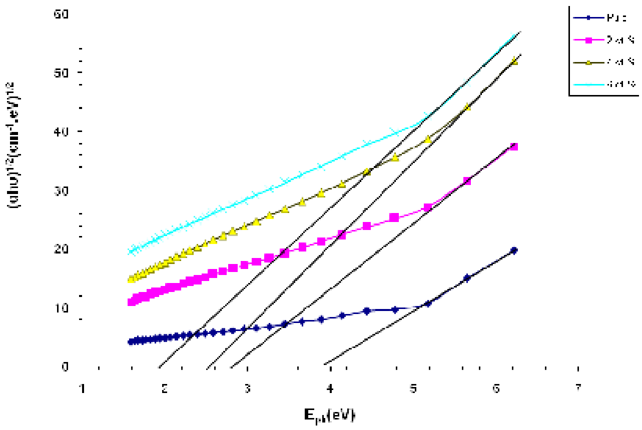

Fig. 3. Energies gaps for allowed indirect transition of PVA/SiO_2 nanocompsites.

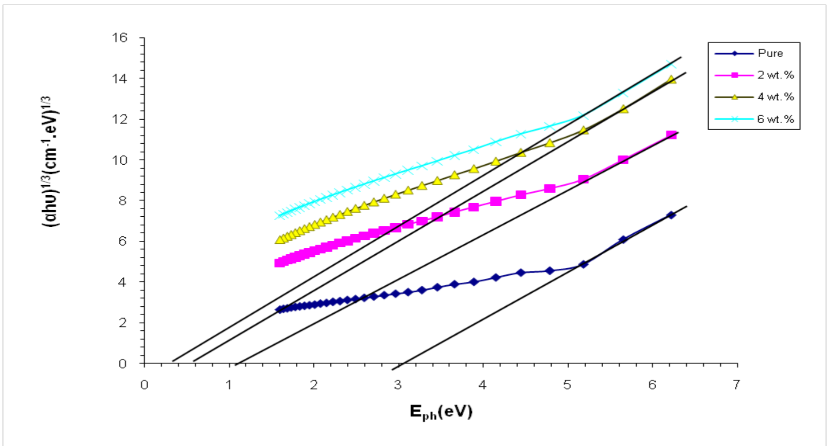

Fig. 4. Energies gaps for forbidden indirect transition of PVA/SiO_2 nanocompsites.

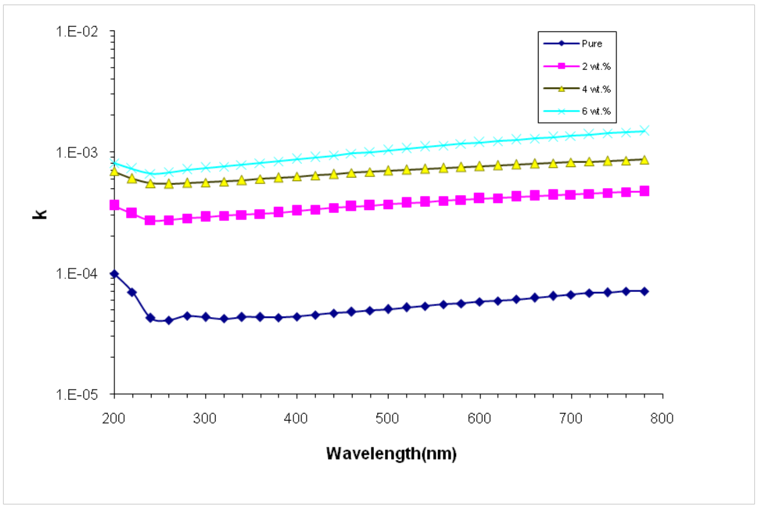

Fig. 5. Variation of the extinction coefficient with the incident photon wavelength of (PVA-SiO_2) nanocomposites.

nanocomposite [43]. Figure 6 shows the variation of refractive index (n) with photon wavelength for (PVA-SiO_2) nanocomposites, the values decrease with increasing photon wavelength. This decrease indicates that the electromagnetic radiation passing through the material is faster in the low photon energy [42]. The figure shows that the refractive index of PVA increases with the increase of the SiO_2 concentrations which is due to the increase the scattering of the light [44].

The variation of real and imaginary parts of dielectric constant for PVA/SiO_2 nanocomposites with photon wavelength are shown in Figures 7 and 8. The real and imaginary parts of dielectric constant are increased with the increase of SiO_2 nanoparticles concentrations. The increase of real and imaginary parts of dielectric constant with SiO_2 nanoparticles concentrations due to the increase of refractive index and extinction coefficient [45,46].

Figure 9 shows the variation of optical conductivity for PVA/SiO_2 nanocomposites with photon energy. From the figure, the optical conductivity of PVA increases with the increase in SiO_2 nanoparticles concentrations, this behavior attributed to increase of density and absorption coefficient [47].

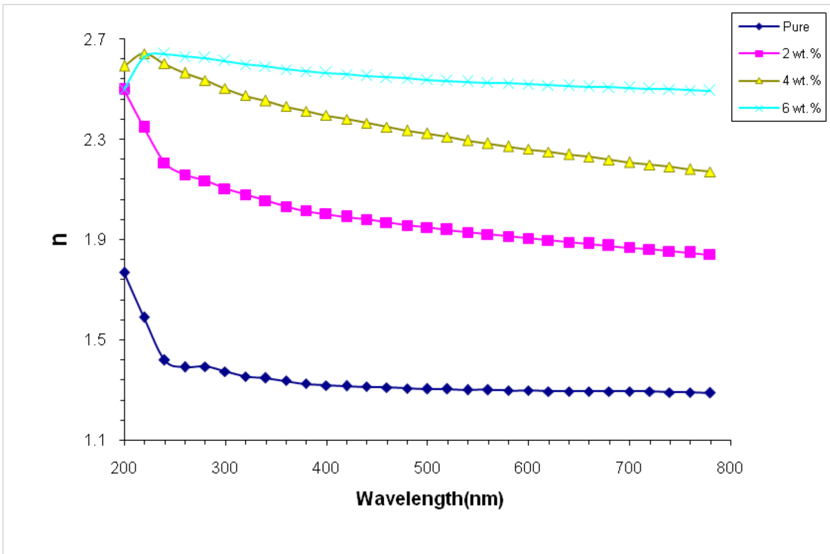

Fig. 6. Variation of refractive index with photon wavelength for (PVA-SiO_2) nanocomposites.

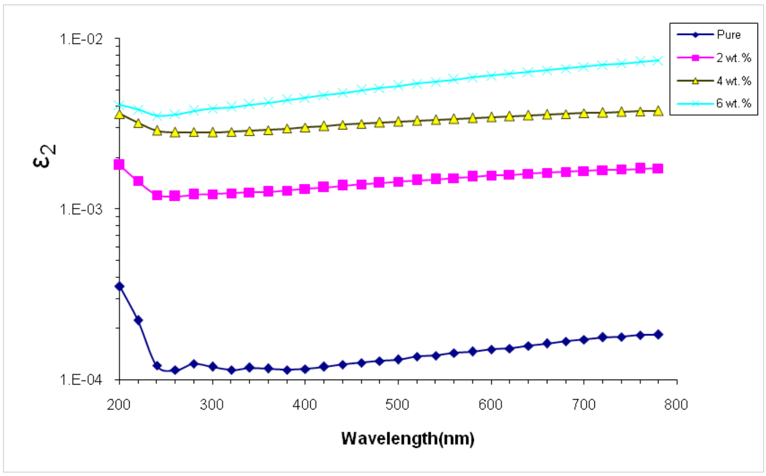

Fig. 7. variation of real part of dielectric constant for PVA/SiO_2 nanocomposites with photon wavelength.

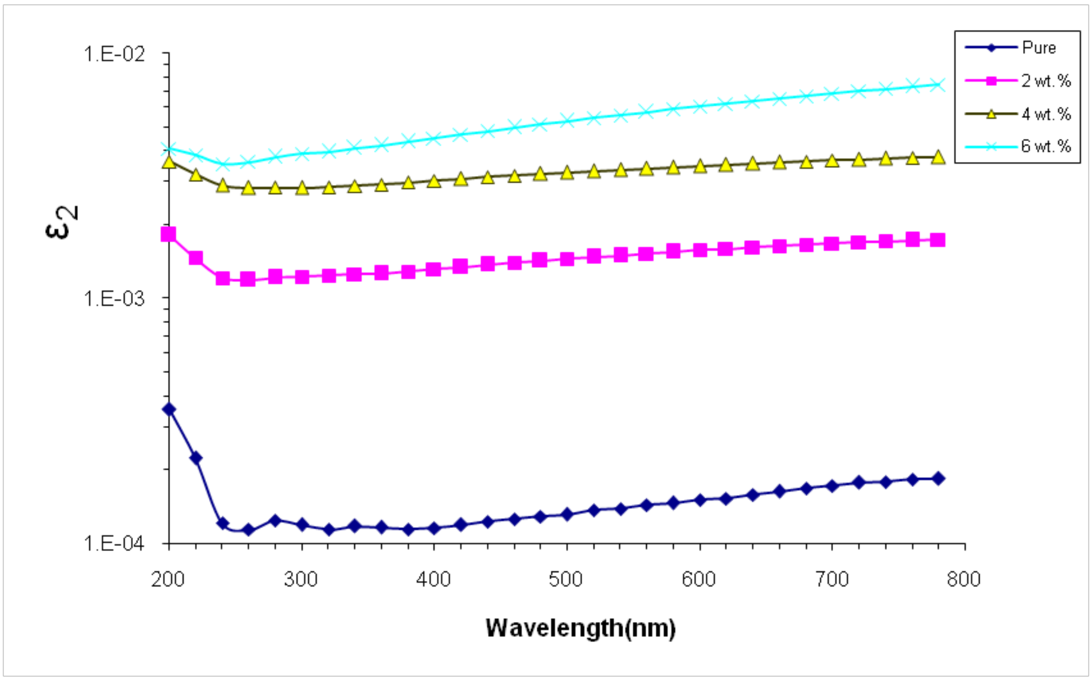

Fig. 8. Variation of imaginary part of dielectric constant for PVA/SiO2 nanocomposites with photon wavelength.

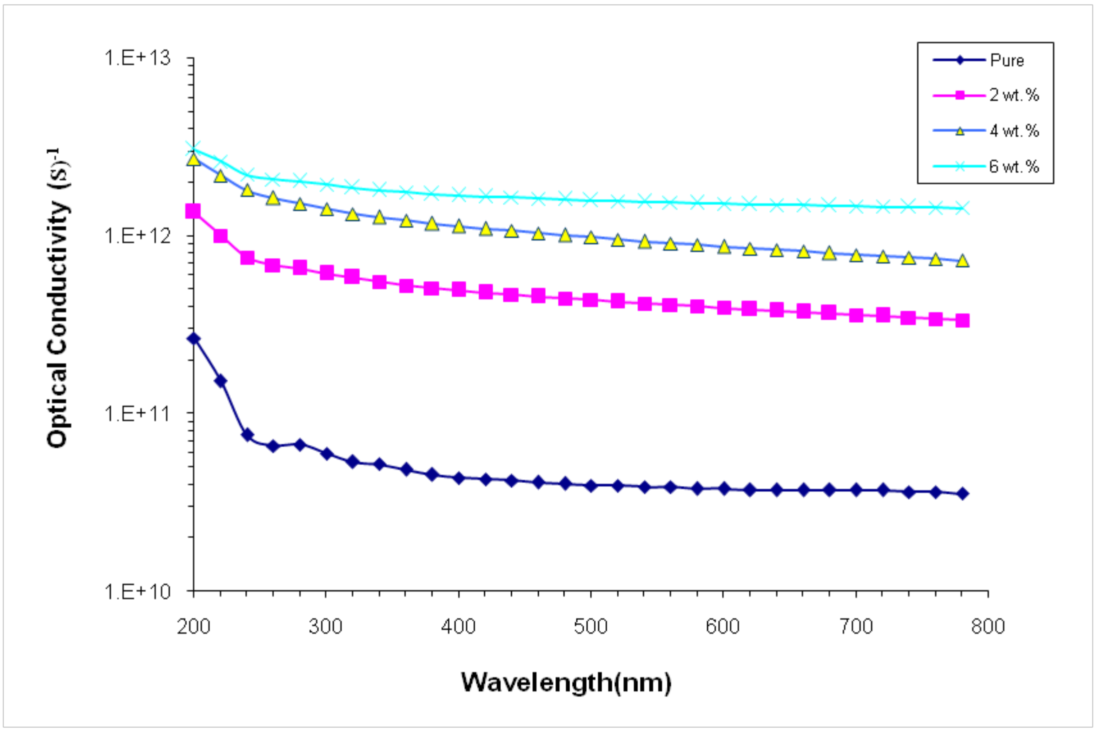

Fig. 9. Variation of optical conductivity for PVA/SiO_2 nanocomposites with photon energy.

Conclusion

1. The absorbance of polyvinyl alcohol increases and the transmittance decreases with increase in silicon dioxide nanoparticles concentrations.

2. The PVA/SiO_2 nanocomposites have higher absorbance values at UV region which are may be useful for flexible UV- shielding and electronic applications.

3. The energy band gap of PVA decreases with an increase the SiO_2 nanoparticles concentrations. The decrease of energy band gap makes the PVA/SiO_2 nanocomposites may be used for different flexible optoelectronics devices.

4. The optical parameters (absorption coefficient, extinction coefficient, refractive index, real and imaginary parts of dielectric constants and optical conductivity) of polyvinyl alcohol are increased with increase in SiO_2 nanoparticles concentrations.

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أوطئ كلفة وأعلى امتصاص للأشعة فوق البنفسجية للمتراكبات النانوية بولي فينيل الكحول/ سليكا لتطبيقات الجهد

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حضرت اغشية من المتراكبات النانوية (بولي فينيل الكحول/ ثنائي أكسيد السيليكون) كدرع واقي من الاشعة فوق البنفسجية يتميز بقلة الكلفة، وخفة الوزن وخصائص ممتازة كمضاد للأشعة فوق البنفسجية. تم دراسة الخصائص التركيبية والبصرية للمتراكبات (PVA/SiO_2) النانوية. بينت النتائج التجريبية ان الامتصاصية (A)، معامل الامتصاص (α)، معامل الخمود (K)، معمل الانكسار (n)، ثوابت العزل الحقيقي (ε_1) والخيالي (ε_2) والتوصيلية لبصرية (σ_{op}) ل PVA تزداد مع زيادة تراكيز SiO_2. النفاذية (T) وفجوة الطاقة (E_g) تقل مع مع زيادة تراكيز SiO_2. كذلك بينت النتائج ان متراكبات ($PVA-SiO_2$) النانوية يمكن ان تستخدم في تطبيقات الخلايا الشمسية المرنة، و الدايودات والترانزستورات.