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Synthesis, Optical and D.C Electrical Characterization of (Pomegranate/PVA/TiO2) Ternary-Nanocomposites, As a Window to Improve Solar Cell Performance

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Polyvinyl alcohol;
Titanium dioxide.

Abstract

This paper aims to fabricate a nanocomposite made of polyvinyl alcohol, titanium dioxide, and natural pomegranate dye that can function as a sunlight sensor for solar cells. The thin films' structural, optical and electrical properties of (Pomegranate/PVA-TiO2) were studied. Images from (FE-SEM) taken at a concentration of 0.3 weight percent revealed the structural features of the material., the surface of the (Pomegranate/PVA-TiO2) nanocomposite films demonstrations many aggregations or chucks arbitrarily dispersed of (TiO2) with grain size (47-55) nm. With an increase in natural dye content, transmittance decreases. Pomegranate dye had the most prominent peaks, measuring (76%) at a concentration of 1 ml. All optical constants, including parameters such n and k for transparency and extinction, r and i for real and imaginary dielectric constants, and electrical conductivity for optical conductivity, rise with pomegranate dye concentration. The results showed that the electrical conductivity at a concentration of (4 ml) recorded the greatest possible (6.4×10-6) (Ω.cm)-1, and the activation energy decreased with increasing concentration of pomegranate dye (0.29-0.20) eV. Then a solar cell was prepared from SnO2/Si, and the films were deposited on it, and the efficiency results were. After being coated with (Pomegranate/PVA-TiO2) nanocomposites, the efficiency (η) increased from (4.3-4.75). In addition to the increase in current (Isc) from 23 to 30 mA/cm2. The final results showed that the (Pomegranate/PVA-TiO2) nanocomposite possesses a high transmittance, low activation energy and is sensitive to light in the Vis and IR regions, making it suitable for optical application.

Introduction

One of the most promising industries is the solar cell sector. Applications that make use of thin membranes have gained a lot of attention in recent years due to their simplicity and low cost of production [1]. A nanoparticle (NP) dispersion of tin (Sn) is annealed at temperatures below 150 degrees Celsius to generate tin oxide (SnO2). Dye-sensitized and perovskite solar cells have been extensively researched, and so have their electron transport layers. The use of SnO2 as a photovoltaic

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material is promising [2]. SnO_2 was chosen to build a solar cell with an n-type SnO_2 layer and p-type silicon wafers because to its broadband gap and low reflecting index of 2 [3]. Pure silicon, which has been used as an electrical part for decades, is the most important part of a solar cell. Silicon solar panels are often called "1st generation" panels because the technology for making silicon solar cells took off in the 1950s. Silicon is used in more than 90% of the solar cells on the market [4]. PVA is a promising material with high dielectric strength, strong charge storage capacity, and electrical and optical characteristics that vary according to the dopant [5]. Titanium dioxide is notable for its wide range of uses, including paint, sunscreen, and food colouring [6]. Natural colours from plants including flowers, fruit, and leaves can be used in DSSCs [7]. One of the many factors affecting dye light absorption is the medium used to extract the dye [8] A thin-film solar cell (TFSC), also called a thin-film photovoltaic cell (TFPV), is a second generation solar cell that is made by depositing one or more thin layers, or thin film (TF) of photovoltaic material on a substrate, such as glass, plastic or metal[7]. Thin-film solar cells are commercially used in several technologies, including cadmium telluride (CdTe), copper indium gallium diselenide (CIGS), and amorphous and other thin-film silicon (a-Si, TF-Si). Film thickness varies from a few nanometers (nm) to tens of micrometers (µm), much thinner than thin-film's technology, the conventional, first-generation crystalline silicon (c-Si) solar cell, that uses silicon wafers of up to 200 µm. This allows thin film cells to be flexible, lower in weight, and have less drag. It is used in building integrated photovoltaics and as semi-transparent, photovoltaic glazing material that can be laminated onto windows[9] The most popular material utilised to create semiconductors is silicon. The outer shell of the element silicon has four electrons. A p-type semiconductor is made by adding additional elements, such as boron or aluminium, to silicon. These materials only have three electrons in their outer shell. When the additional material partially replaces some of the silicon, the location where the fourth electron would have been if the semiconductor were comprised entirely of silicon is left empty[3,8].

Experimental procedure

Materials and methods of thin polymeric films

Nano shell USA provided titanium dioxide powder that met our specifications of 20 nm particle size and 99.9% purity. It was white and quite dense, coming up about 4.23 g/cm3. The PVA came from a Chinese company called Shanghai Kaidu Industrial Development Co., Ltd., and it was a white granular polyvinyl alcohol. Once the seeds were removed from the fruit and roasted, they were the pomegranate's active component. In order to preserve the scent, pomegranate dye was removed by filtering the concentrated liquid, heating it at 77 °C, and evaporating 20% of the water. The resulting dry paste was crushed to create colour powder after being dehydrated in an oven (dryer) at 77 °C for 10 hours. In a glass beaker with 20 mL of water, 0.7 g of polyvinyl alcohol thoroughly dissolved at 85 °C. 0.3 weight percent of titanium dioxide nanoparticles were added to the pure sample that had been dissolved. Using an ultrasonic device, we combined 4 ml of pomegranate dye with 20 ml of titanium dioxide to create the samples. films with a

Materials and methods of solar cell

Sky Spring Nanomaterial, Ink Company, USA offers powdered tin dioxide with particle size (35-55) nm and high purity (99.9%). Commercially available monocrystalline p-type silicon wafers (SnO_2) have an orientation of [111] and a resistivity of 1-10.cm. Prior to film deposition, wafer silicon was cleaned and chopped into 11 cm diameter pellets. On Si wafer samples, multiple washing of distilled water were utilised, followed by gentle drying with paper towelling. Using a vacuum thermal evaporator, the p-type silicon wafer was covered with tin dioxide powder. The boat's substrate height was 17 cm and its breadth was 200 nm. Thermal evaporation technology was used to generate

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(SnO_2) films that were placed onto cleaned p-type silicon wafer substrates with constant thickness (2006 nm).

Theoretical part

By comparing the intensity of the incident rays (I_o) on the film to the intensity of the transmitting rays (I_T), we can calculate the film's transmittance (T)[10].

$$T = I_T/I_o \quad \text{........(1)}$$

Light's speed in vacuum is divided by the speed of light within the medium to yield the refractive index..

$$n = \sqrt{(4R - k^2)/(R-1)^2} - ((R+1))/((R-1)) \quad \text{.......(2)}$$

For the complex refractive index, the imaginary portion is the extinction coefficient.

$$n^* = n - ik_o \quad \text{.........(3)}$$

n: the equivalent of an actual refractive index (c/v).

The following equation gives the extinction coefficient (ko).

$$k_o = (\alpha \lambda)/(4\pi) \quad \text{.........(4)}$$

The following equation describes the real and imaginary parts of the complex dielectric coefficient[9]:

$$\varepsilon_r = n^2 - k_o^2 \quad \text{.........(5)}$$

$$\varepsilon_i = 2nk_o \quad \text{...........(6)}$$

D.C Electrical Conductivity ($\sigma_{d.c}$) ρ_{dc} is surface resistivity. The surface conductivity is the resistivity's inverse. Surface conductivity increases[11].

L, b, and t represent the sample's length, width, and thickness. Formula for activation energy (Ea) [8].

Absolute zero electrical conductivity is denoted by a value of zero, while the other variables are the Boltzman constant k, the absolute temperature T, the activation energy Ea, the thermal energy KT associated with the change in temperature measured, and the absolute temperature T [11,12]

The current-voltage (I-V) Solar cell photovoltaic performance is measured. Voc, Isc, F.F, and η are photovoltaic properties of solar cells), as in the equations below. These values were obtained using the typical conditions of 25°C cell temperature and 115 mW/cm2 incoming solar radiation [13]:

$$F.F = V_m \times I_m / V_{oc} \times I_{sc} \quad \text{..... (9)}$$

$$\eta = P_m / P_{in} \quad \text{.......... (10)}$$

Results and discussion

In figure (1), cluster and surface morphologies of (Pomegranate/PVA-TiO_2) films are studied by scanning electron microscopy (FE-SEM). As a result, the interfacial adhesion between the polymer matrix and the filler components was weak. These figures were observed When the concentration to 0.3wt.% for The top surface of the (Pomegranate/PVA-TiO_2) nanocomposite films reveals numerous aggregations or chucks of (TiO_2) nanocomposites. The images showed (48)nm [14, 15].

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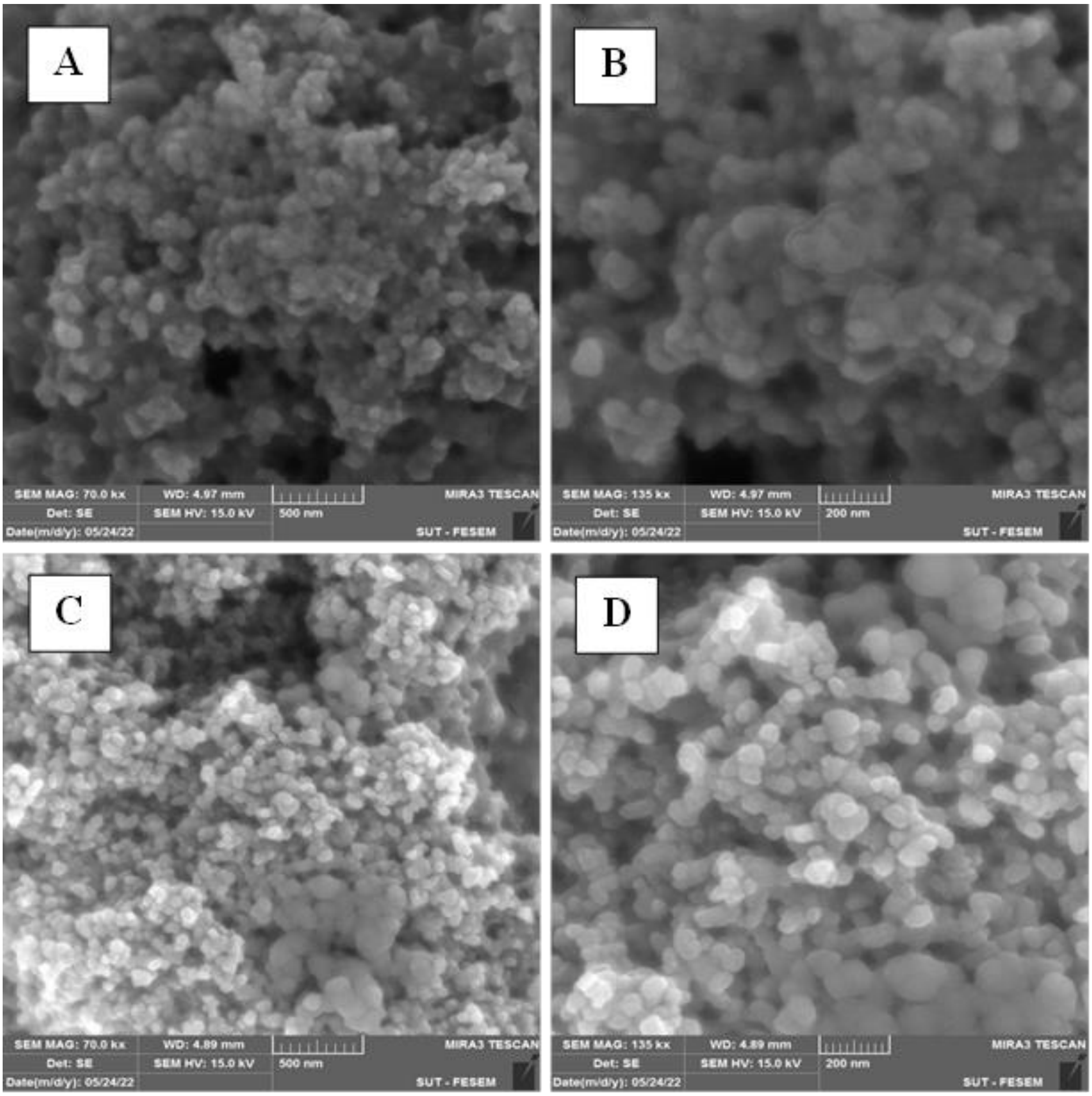

Figure 1: FE-SEM measurement of (Pomegranate/PVA- TiO2A, B) 1ml/1ml and C, D)1ml/4ml.

Figure(2) show, the maximum peaks were obtained in pomegranate dye at (76%) with a concentration of 1 ml, and that the transmittance of (Pomegranate/PVA- TiO_2) nanocomposites declines with increasing natural dye concentration. Because of their high transmittance in the visible and infrared spectrums, these thin films may find application as a window for solar cells [16] . In fig. (3), refractive index (n) increases with increasing wavelength in the ultraviolet region and then decreases with increasing wavelength in the visible and infrared regions. Also, the refractive index (n) increases with growing focus of pomegranate dye and this indicated to decrease in trancemetance. This is owing to the rise in the optical density of the material. The electronic polarization of ions and the local field inside optical materials are intimately connected to the refractive index (n) [17]. UV wavelengths have a larger attenuation coefficient than VIS and IR wavelengths, as shown in figure (4). The concentration of pomegranate dye raises the extinction coefficient. The causes are a rise in the absorption coefficient as a result of electronic transit between bonding and nonbonding molecular orbits, as well as an increase in the extinction coefficient as a result of refractive index [18]. In

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figures (5) and (6), the results observed that the real dielectric constant ε_r and the imaginary dielectric constant ε_i increase with increasing concentration of pomegranate dye [19]. Figure (7) shows the optical conductivity (σ_{op}) as a function of wavelength for Pomegranate/PVA-TiO_2 nanocomposite. The results showed that the optical conductivity (σ_{op}) increases with increasing. This is due to the increase in the *k* [20].

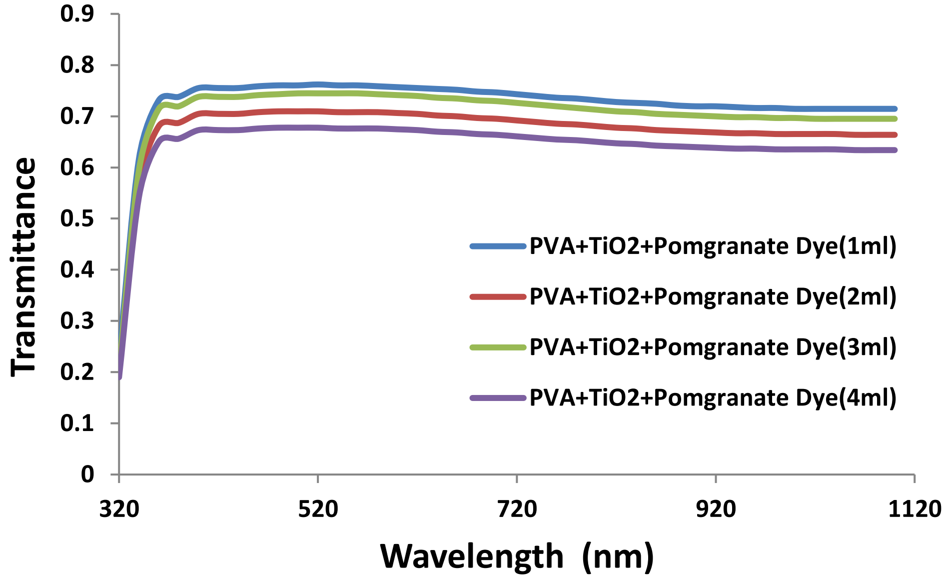

Figure 2: The transmittance (T) of (Pomegranate/PVA-TiO2) nanocomposites.

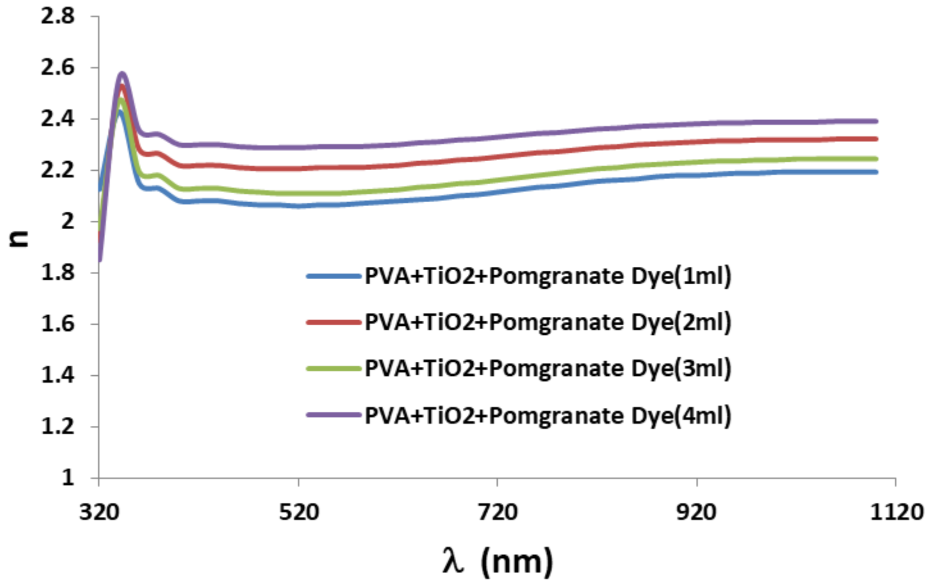

Figure 3: The refractive index (n) of (Pomegranate/PVA-TiO2) nanocomposites.

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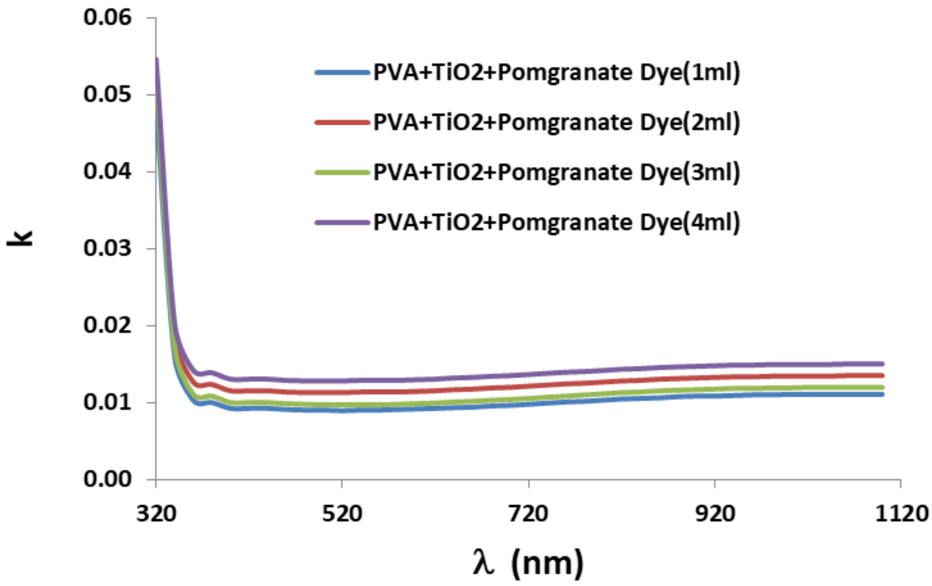

Figure 4: The Extinction coefficient (k) of (Pomegranate/PVA-TiO2) nanocomposites.

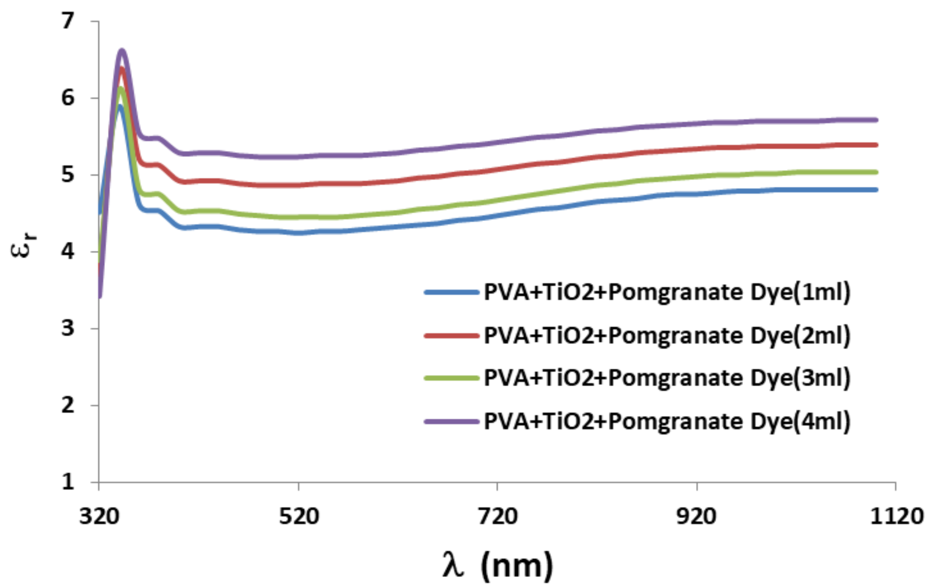

Figure 5: The Dielectric Constants (Ɛr) of (Pomegranate/PVA-TiO2) nanocomposites.

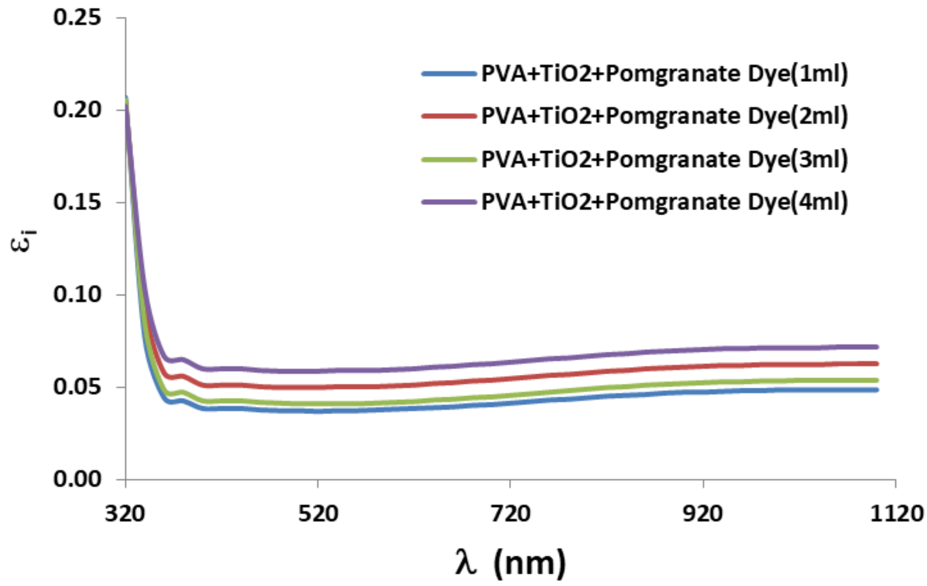

Figure 6: The Dielectric Constants (Ɛi)of (Pomegranate/PVA-TiO2) nanocomposites.

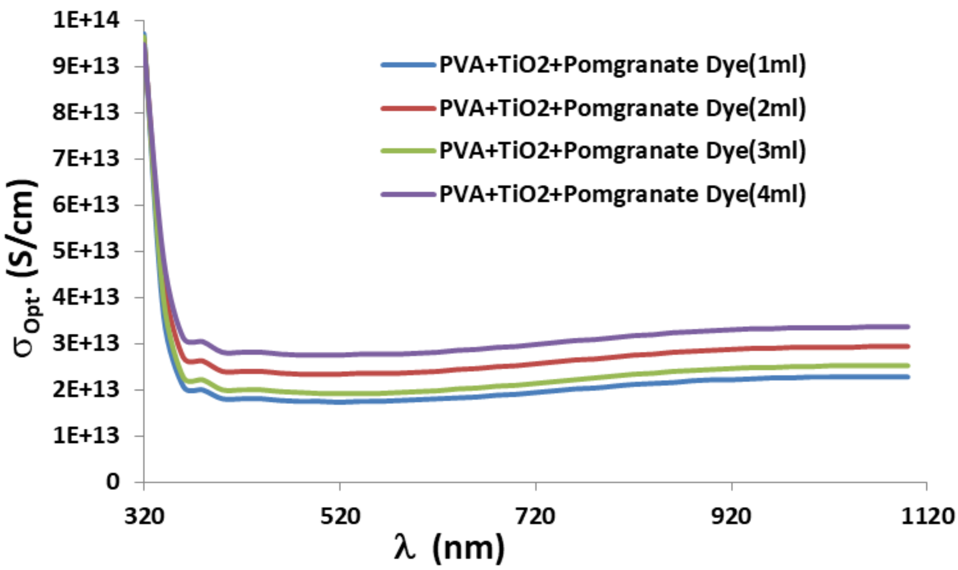

Figure 7: optical conductivity (σop) of (Pomegranate/PVA-TiO2) nanocomposites

The concentration of the pomegranate dye influences the (σ_{op}) d.c. $(W.cm)^{-1}$ electrical conductivity (Figure 8). The concentration of pomegranate dye with (PVA/TiO_2) resulted in an increase in electrical conductivity, as seen in the picture[21] The conductivity was $6.4\times10_{-6}$ $(W.cm)^{-1}$ at 4 ml. This phenomenon may be explained by electronic communication between bonding sites [22]. Also, the electrical conductivity of (Pomegranate/PVA-TiO_2)nanocomposite rises with increasing temperature. Figure 9 revealed an optimal range with an exponential or line trend when the temperature was applied from 30 to 70°C. Heating rates may affect strength of electric field or electrical conductivity of (Pomegranate/PVA-TiO_2) nanocomposite, according to the researchers, who claim that the growth in (σ_{op}) values with temperature is due to reduced drag for ions movement [23]. The activation energy is computed using equation (8), and the results prove that (Pomegranate/PVA-TiO_2) nanocomposites have activation energies ranging between (0.29-0.20) eV.

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Figure 10 depicts the relationship between the inverse absolute temperature and lnσ for (Pomegranate/PVA-TiO_2). The main reason for the decrease in the activation energies when increasing the concentration of the natural dyes is that figure 11 and Table 1 show how the dyes captured photons with lower energy by operating between the valence and conduction beams [22, 23].

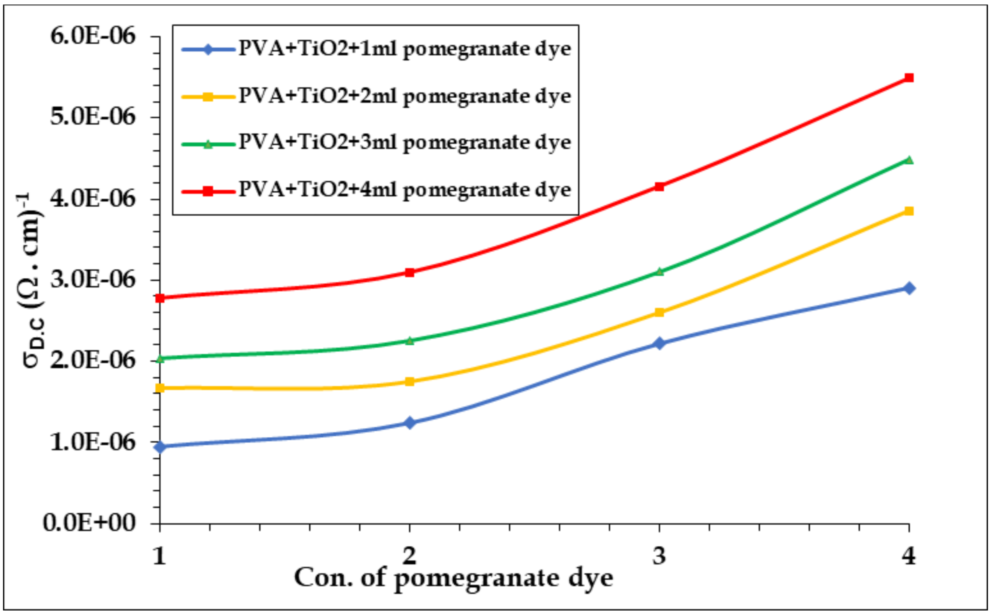

Figure 8: Variation of σD.C with concentration of pomegranate dye for (Pomegranate/PVA-TiO2) NCs.

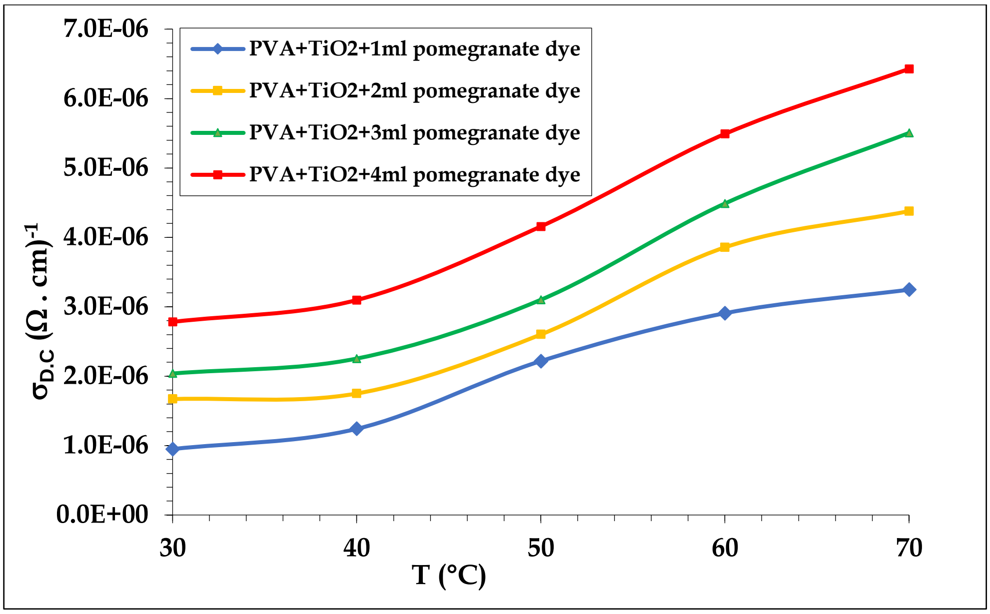

Figure 9: Variation of σD.C with T for (Pomegranate/PVA-TiO2) NCs.

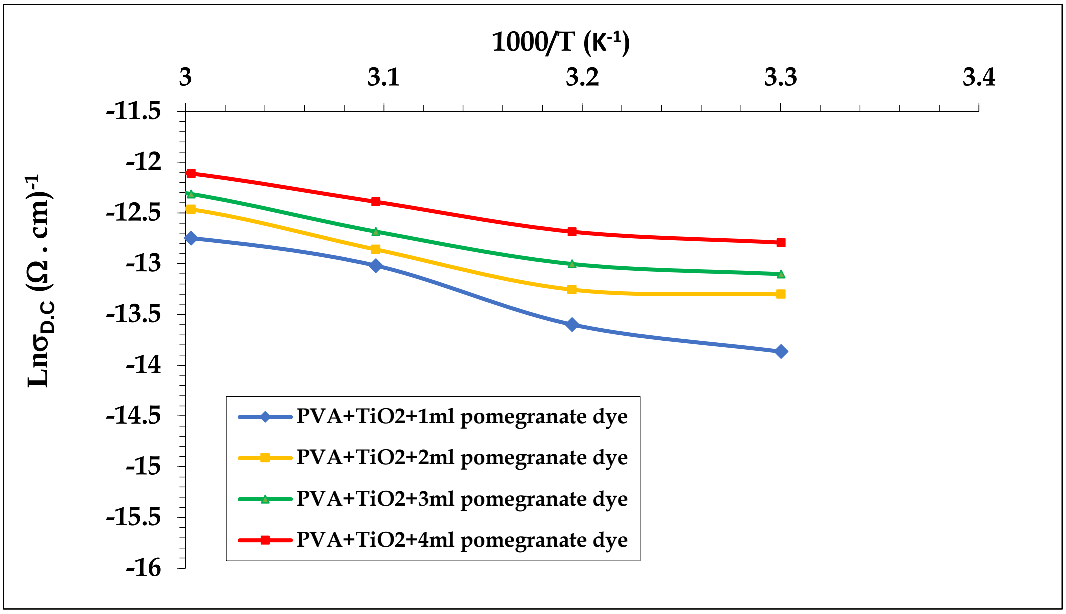

Figure 10: Variation of LnσD.C with T for (Pomegranate/PVA-TiO2) NCs.

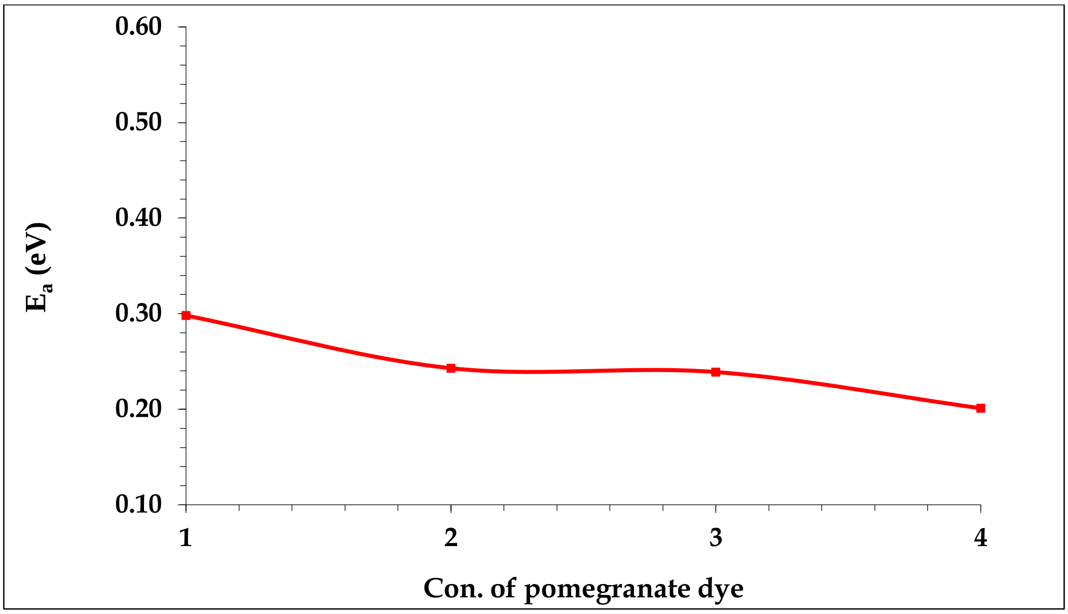

Figure 11: Variation Eact. for D.C electrical conductivity with concentration of pomegranate dye for (Pomegranate/PVA-TiO2) NCs.

The SnO2/p-Si HJ I-V characterisation is present at forwarding bias voltage within this range (-2 to 2 Volts). Charts (12) and (13), which show how current behaves in relation to forward and reverse bias voltage, respectively. The efficiency (η) was observed to rise from (4.3-4.75) after being coated with (Pomegranate/PVA-TiO_2) nanocomposites, as shown in table (2) below. The higher electro-catalytic activity is the cause of the improved performance. The series resistance of the cell decreases as Isc and Voc rise [24] But it was evident that the dye served as a photosensitive[25]. As shown in Table 2, the natural dyes IV dye molecules inject more electrons into the SnO2 conduction band when exposed to light, enhancing the cell's photovoltaic properties such as Isc and.[26] Therefore, it has been established that these thin films can function as solar cell coatings. Graphene, amongst others, has been used in gas sensors [27]. The improvement in electro-catalytic activity is what is responsible

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for the performance improvement. As a result, the cell's series resistance decreases as Isc grows and increase Voc. As a result, it has been proven that these films can be used as coverings for solar cells[26].

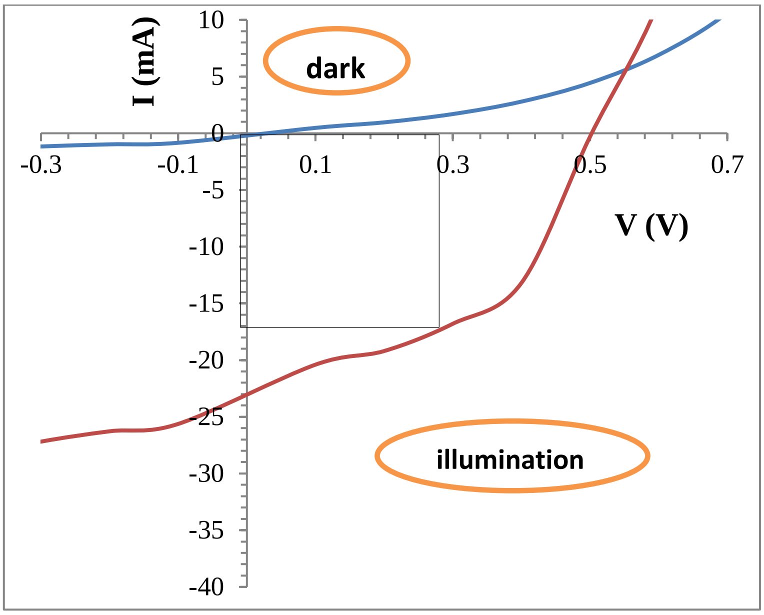

Figure 12: I-V characteristic for SnO2/Si solar cell under P=115 mW/cm2

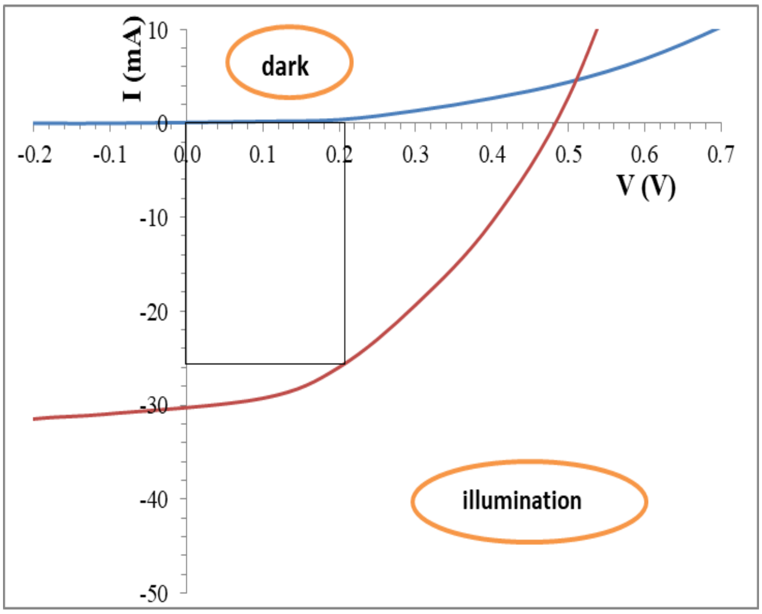

Figure 13: I-V characteristic for SnO2/Si solar cell under P=115 mW/cm2 after coating (PVA/TiO2/4ml pomegranate dye).

Conclusion

TiO2 with grains) The particle concept includes the segregation of solid, liquid and gaseous particles, the particles that make up the granules). between 47 and 55 nm was seen in various aggregations or chucks on the FE-SEM images. At a concentration of 1 ml (76%), the largest transmittance peaks were recorded. Pomegranate dye concentration with (PVA/TiO2) causes an

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increase in electrical conductivity. The electrical conductivity was (6.4×10-6) (W.cm)-1 at a concentration of 4 ml. With an increase in pomegranate dye concentration, there was a corresponding decrease in activation energy. Efficiency was raised from (4.3-4.75) by coatings made of (pomegranate/PVA-TiO2) nanocomposites.

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