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Synthesis and Characterization of Titanium (iv) Oxide Loaded with Silver Nano Particles Thin Films

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Abstract: This research investigates effect of annealing temperature on the optical properties of titanium dioxide loaded with silver nanoparticles (TiO_2: AgNPs) thin films deposited on glass substrate by spin–coating technique. Silver nanoparticles was prepared using *laguminosae-paplionodeae* extracts as a reducing agent for silver nitrate and commercially available titanium (iv) oxide was used. Deposition of TiO_2:AgNPs blend solution was done in different volume ratio. The blend solution volume ratio of (1:0.2) was deposited at 7 different thicknesses with different speed of revolution per minutes (rpm) for 30 seconds. Annealing of 16 samples deposited at 1000 rpm on the glass substrate was carried out at temperature range of 50°C to 425°C with 10°C interval in a tubular furnance. It is observed from the results that the peak absorption of photon energy occurred at 375°C in the visible range of the wavelength spectrum. Optimal thickness for peak absorbance of the TiO_2:AgNPs blend layer occurred at 115 nm in the visible spectrum and at the corresponding spin speed of 1000 rpm. Optimized fabrication process with blend layer thickness of 115 nm yielded the best absorbance at annealed temperature of 375°C in the visible spectrum. The volume ratio of (1:0.2) gave the peak absorption at 0.75 a u. The band gap energy of the blend thin film is 3.58 eV at 375°C in the visible range of wavelength spectrum. It is revealed from the result that the light absorption, broadened absorption spectral range and thermal stability of titanium (iv) oxide film could be enhanced using silver nanoparticles. The results can be therefore used as a guideline for improving the design and fabrication of organic solar cells.

Keywords: Organic Thin Film, Silver Nanoparticles, Titanium Dioxide, Annealing, Blend AgNPs:TiO_2, Optical Properties

1. Introduction

The demand for clean energy sources has increased, leading to a rapid growth in the field of research and development of solar energy. The creation of nanoscale materials for advanced structures has led to a growing research interest in the area of photovoltaic energy conversion using photovoltaics devices Today's solar cells are simply not efficient enough and are currently too expensive to manufacture for large-scale electricity generation. However, potential advancements in nanotechnology may open the door to the production of cheaper and slightly more efficient solar cells. Solar cells are devices which convert the light into electrical energy [1]. Solar cells can be fabricated using organic, inorganic or hybrid materials and are divided into three different generations [2]. The First generation consists of crystalline semiconductor wafers with a thickness of 200-300 μm. The Second-generation solar cells are based on thin film technology having thickness, usually in the range of 1-2 μm. The- Third generation solar cells are under research process, to increase the efficiency with the help of second generation solar cells. A new method has evolved in recent times for increasing the light absorption i.e., the use of nanoparticles with size ranging between 10-1000 nm [3-4]. Nanotechnology is a new branch of technology that studies different materials at a nanometric scale. It partakes in the design, production, and use of chemical structures with extremely small dimensions, which have been applied in areas such as materials science, engineering, and electronics. The nano structured metal oxides have received increasing consideration due to their unique physical and chemical properties and in particular, the functional metal oxides have emerged as strong candidates for variety of applications [5-11]. Silver nanoparticles have unique optical, electrical, and thermal properties and are being incorporated into products that range from photovoltaics to biological and chemical sensors [12-16]. Examples include conductive inks, pastes and fillers which utilize silver nanoparticles for their high electrical conductivity, stability, and low sintering temperatures. Nanomaterials are used in many different industrial fields such as microelectronics, micro-machineries, optics, molecular diagnostics, photonic devices, and composite materials [17-23]. This research investigates effect of annealing temperature on the optical properties of titanium dioxide loaded with silver nanoparticles (TiO_2:AgNPs) thin films deposited on glass substrate by spin–coating technique. It is revealed from the result that the light absorption, broadened absorption spectral range and thermal stability of titanium (iv) oxide film could be enhanced using silver nanoparticles. The results can be therefore used as a guideline for improving the design and fabrication of organic solar cells.

2. Materials and Methods

2.1. Materials

The materials used for the research are Titanium (IV) oxide Nano powder (<.35nm), 97%. supplied by Sigma – Aldrich. Silver nitrate was purchased locally.

2.2. Methods

The following experimental procedures were carried out.

2.2.1. Substrate Preparation

Clean rectangular glass slides of dimension 25.4 mm by 76.2mm were used as substrates. The glass substrates were washed with detergent solution for 10 to 15 minutes in ultrasonic sonicator and rinsed in distilled water for 15 minutes at 30°C. The substrate was cleaned with Isopropanol alcohol [IPA] in ultrasonic bath for 15 minutes at 30°C and dried in a stream of nitrogen gas (N_2).

2.2.2. Sample Solution Preparation

i Titanium Dioxide (TiO_2) Preparation

25ml Ethanol solvent was added into 3g of TiO_2 powder from Sigma Aldrich. The solution then underwent ageing process for 3 hours upon sonication at room temperature without heat to allow homogeneous mixture and TiO_2 powder to fully dilute into solvent. Ethanol was chosen as a solvent because it has no characteristic absorption and emission in the visible range.

ii Aqueous Silver Nitrate Solution Preparation

0.168g of Silver nitrate was dissolved in 100ml distilled water which gives colorless clear solution.

iii Silver Nanoparticles (AgNPs) Preparation

3 grams of *Agunmaniye* (Yoruba name), *laguminosae-paplionodeae (Botanical name), Glincidiasepium (English name).* The leaves were thoroughly washed, rinsed and cut into smaller piece. Thereafter, the smaller pieces of leaves were immersed in 300ml of boiling distilled water for 30 minutes and filtered. The obtained extract was dripped into 100ml of 0.01M of aqueous silver nitrate solution with constant gentle stirring for homogenous mixture. The yellowish brown appearance of the product indicated the formation of the silver nanoparticles. It was then stored in brown bottle and shield from the ray of light.

iv Blend Solution Preparation

The blend solution (TiO_2:AgNPs) was done by mixing TiO_2 solution with AgNPs solution at different volume ratio (1:1, 1:0.8, 1:0.6, 1:0.4, 1:0.2) ml and stirred using magnetic stirrer for homogeneous mixture.

2.2.3. Deposition

Deposition of TiO_2:AgNPs blend solution on the cleaned glass substrate was done at 5 different volume ratio (1:1, 1: 0.8, 1: 0.6, 1: 0.4, 1: 0.2) ml using spin –coater (laurel WS-650Hz-23NPP). The blend solution with volume ratio of (1:0.2) ml with optimized absorption was used to deposit (7) film of layer thicknesses of 30nm, < 35nm, 35nm, 87 nm, 98 nm, 115 nm, and 146 nm corresponding to spin coating speeds of 4000 rpm, 3000 rpm, 2000 rpm, 1500 rpm, 1250 rpm, 1000 rpm, and 750 rpm, respectively for 30 seconds. Depending on the concentration and the speed of the spin coater, the desirable thickness of the sample was obtained. At 1000 rpm with corresponding thickness of 115nm, has best absorption value. The optimum absorbance at 1000 rpm was used for the preparation of the 17 samples film fabrication process. 17 samples deposited at 1000 rpm served as annealed films (16) and control.

2.2.4. Annealing

Annealing of the samples deposited was carried out at temperature ranges of 50°C to 425°C with 10°C interval in a carbolite tubular furnance model Srw 21-501042 Type-CT17 for 30 minutes. One sample was used as a reference.

2.2.5. Characterization

Characterization studies were carried out on the annealed samples. Absorption spectra were measured using a UV-Vis spectrophotometer (Avantes, Avalight-DH-5-BAL). The absorbance of the samples was determined from transmittance and reflectance values obtained from the spectrophotometer. Observation showed that the peak absorption of photon energy occurred at 375°C in the visible spectrum of the wavelength.

(i) Plots of absorption vs. photon energy in electron volts (eV).

The values of the photon energy were determined from the inverse relationship between energy (in electron volts) and wavelength of the UV-visible spectrum in equation 1.

$$E= hc/q\lambda \quad (1)$$

Where h is the planck's constant (6.626×10^{-34} J.s), C is the speed of light (2.998×10^{8}), λ is the wavelength in nanometres, q is the electronic charge (1.6×10^{-19} C), and E is the energy in electron volt. 1 electron volt is the energy gained by an electron moving through a potential difference of 1 volt (i.e., 1 eV = 1.6×10^{-19} J).

3. Results and Discussion

TiO_2 loaded with AgNPs prepared at different volume ratio as shown in figure 1 and optimized volume ratio deposited at different spin speeds of 4000rpm, 3000 rpm, 2000rpm, 1500 rpm, 1250 rpm, 1000 rpm, and 750 rpm in figure 2. Heat treatment was carried out on all the samples as shown in figures 3 and 4. Optimized film thickness for peak absorbance of the TiO_2:AgNPs blend layer occurred at 115nm in the visible spectrum and at the corresponding spin speed of 1000 rpm. Optimized fabrication process with blend layer thickness of 115 nm yielded the best absorbance at annealed temperature of 375°C in the visible spectrum as shown in figures 3 and 4, the result is in agreement as was reported by [24]. The graph of the plot of absorbance versus photon energy in eV of TiO_2:AgNPs is shown in figures 5 and 6. The band gap energy of the blend thin film is 3.58 eV at 375°C in the wavelength range of visible light similar to reported result by [25]. The result also revealed that heat treatment or thermal annealing is a tool that can be used to tune the optical properties of TiO_2:AgNPs blend thin film.

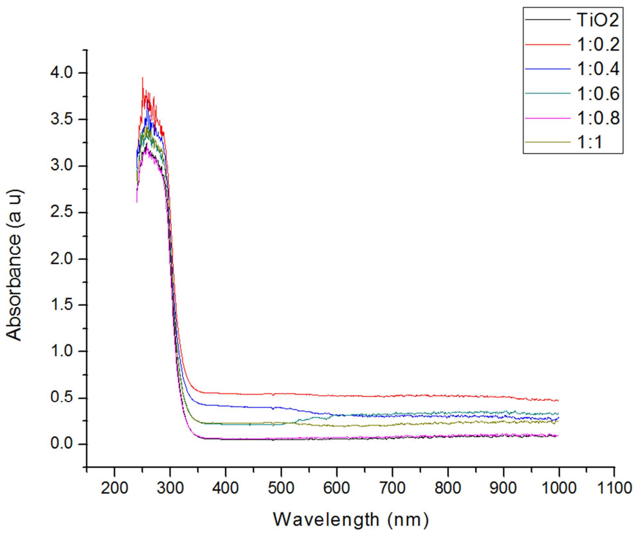

Figure 1. *Plot of absorbance of TiO_2:AgNPs vs wavelength blend at different volume ratio.*

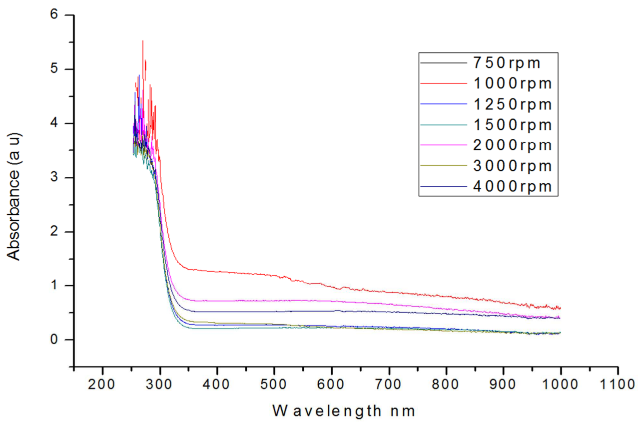

Figure 2. *Plot of TiO_2:AgNPs (1:0.2) absorbance vs wavelength at different layer thicknesses.*

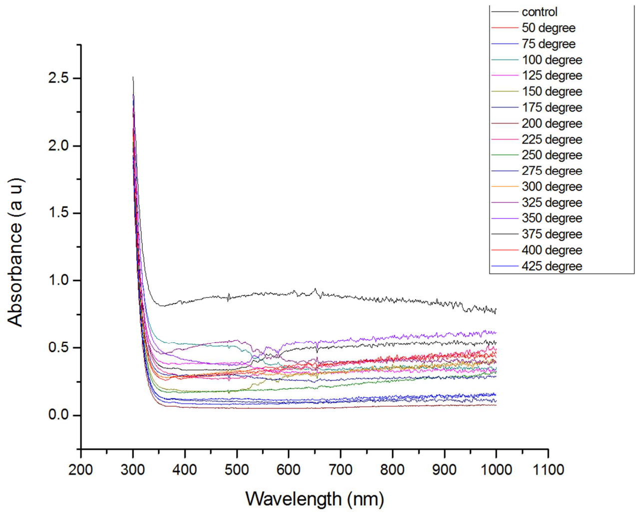

Figure 3. *Plot of TiO_2:AgNPs absorbance vs Wavelength at different annealing temperature.*

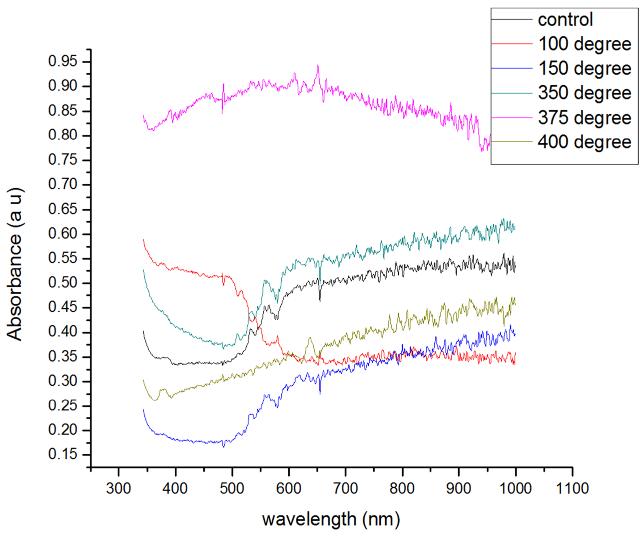

Figure 4. *Plot of TiO_2:AgNPs (1:0.2 volume ratio, at 1000rpm) absorbance vs Wavelength at selected annealing temperature.*

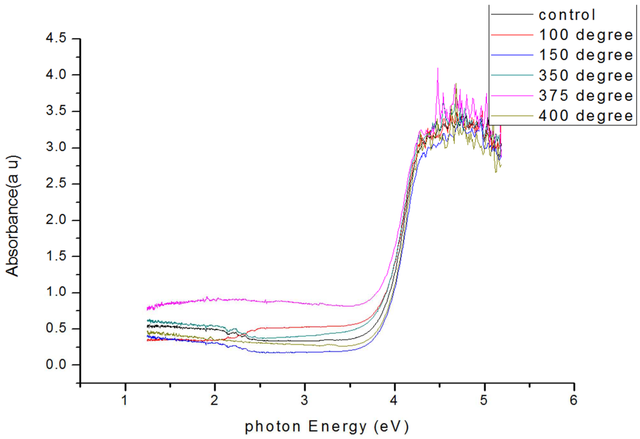

Figure 5. *Plot of absorption vs. photon energy in electron volts (eV).*

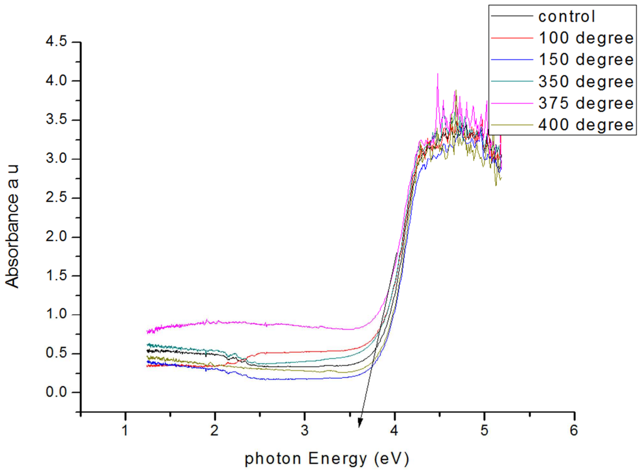

Figure 6. *Plot of absorption vs. photon energy in electron volts (eV) at 375°C.*

4. Conclusion

It has also been demonstrated in the work that gradual thermal annealing, in a controlled manner revealed a more stable and efficient control in tuning the TiO_2:AgNPs thin film. The results can be used to develop a guideline for improving the design and fabrication of organic solar cells. The result obtained could lead to improvement in performance and stability of solar cells. The research was chosen to study the effect of thermal annealing on the optical properties of TiO_2: AgNPs materials a precursor towards an improved dye synthesized solar cells (DSSC) and organic solar cells fabrication.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this article.

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