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Optical Characterization of TiO_2-PVA Thin Films

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Abstract
Titanium dioxide (TiO_2) thin films and nanoparticles are synthesized by the sol-gel method using titanium tetraisopropoxide (TTIP) as the precursor material. Poly (vinyl alcohol) (PVA) films are prepared by the solution casting method. PVA films are doped with TiO_2 nanoparticles. The optical properties of TiO_2 films are studied using UV/VIS spectrophotometer. The optical transmittance is found to be very high in the visible region and high absorption in the UV region. The refractive index decreased with wavelength. An FTIR spectrum is used to analyze the stretching and bending vibrational modes in TiO_2 films and PVA doped with TiO_2 nanoparticles.

Keywords: *TiO_2, nanoparticles, PVA, Optical properties, FTIR.*

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I. INTRODUCTION

TiO_2 thin films have been prepared by various methods, such as thermal evaporation, electron beam evaporation, rf sputtering, dc sputtering, chemical vapor deposition (CVD), sol-gel method and spray pyrolysis etc., [1] in which the sol-gel method finds many advantages including cost effectiveness, easy process, large area deposition at room temperature (RT) etc [2]. TiO_2 films can be used for various applications including photocatalysis, antireflection coatings, and anti-bacterial agent [3]. TiO_2 is a large band gap metal oxide semiconducting material with a wide band gap of 3.3 eV. The optical band gap energy of nanomaterials can be tuned by varying several parameters such as the concentration of the solution, annealing temperataure, addition of dopants, and change of surface morphology, etc.[4]. Perovskite solar cells are the advanced energy storage devices which are fabricated using organic and inorganic materials with electron and hole transport layers of nanomaterials. TiO_2 film is used for perovskite solar cell applications as an electron transport layer. TiO_2 is also used for self cleaning surfaces, environmental purification, hydrogen production and sterilization etc., due to its photo-catalytic activity [5-7]. TiO_2film is also used as a dielectric film in CMOS device applications [8]. In this article, the investigation on optical properties of pure TiO_2 and TiO_2 mixed PVA films is reported.

II. EXPERIMENTAL PROCEDURE

TiO_2 thin films and nanoparticles are synthesized by the sol-gel spin coating method using TTIP as precursor material, absolute ethanol as a solvent and concentrated HCl as a catalyst. TiO_2 sol is obtained by mixing of optimized quantities of precursor material, solvent and catalyst and stirring for 20 minutes. The sol prepared is stirred further using a magnetic stirrer with a hot plate maintained at 70^oC for 1 hr to get the precipitate and TiO_2 nanoparticles are obtained after filtration by Whatman filter paper and dried in an oven maintained at 100^oC for 1 hr. The glass substrates are used for the preparation of TiO_2 thin films. TiO_2 films are obtained on glass substrates by spinning a few drops of the sol for 30 seconds at 3000rpm by using spin coating unit. Prior to film deposition, the glass substrates are first washed with soap solution and then subjected to ultrasonic cleaning in a water bath. Then the substrates are cleaned in acetone solution and dried in air. The flow chart for the preparation of TiO_2 thin films and nanoparticles is shown in Fig.1. The PVA films are synthesized using PVA of 1g (M.W. =1,15,000) crystals dissolved in 5 g of de-ionized water. The detailed procedure of preparation is published in previous article [9]. TiO_2 nanoparticles (5, 10 and 15 mg) are mixed in PVA films and studied the optical properties of the thin films using UV/VIS/NIR spectrophotometer (Ocean Optics, USA) and FTIR spectrophotometer.

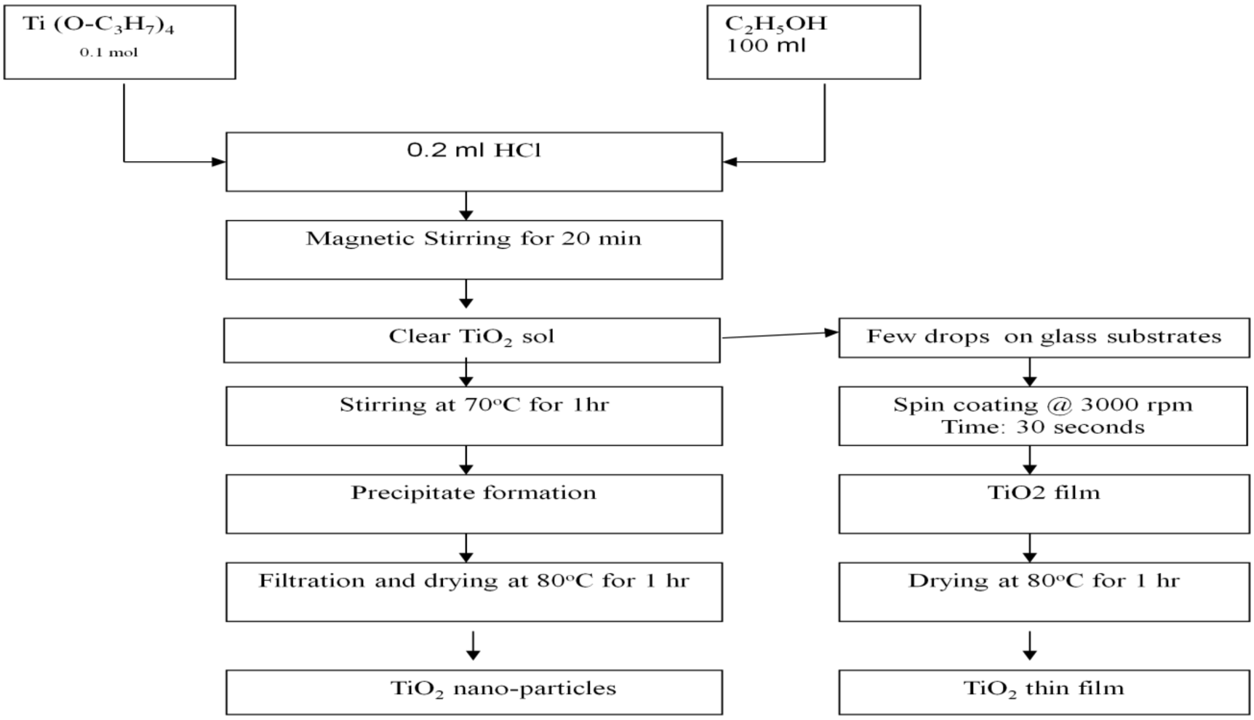

Figure 1: Flow chart for the preparation of TiO_2 film and nanoparticles

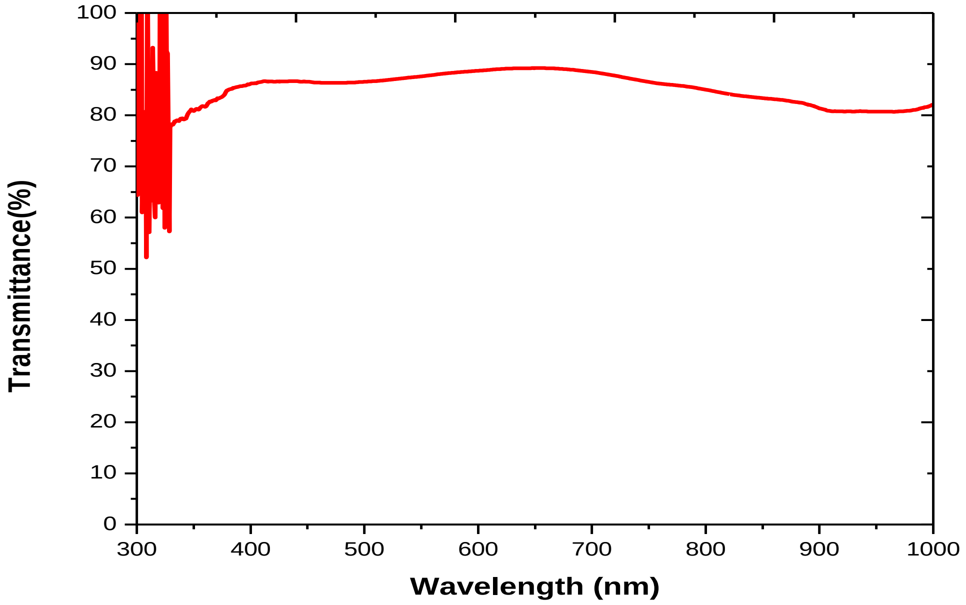

Figure 2: Optical transmittance spectra of TiO_2 film on glass substrates.

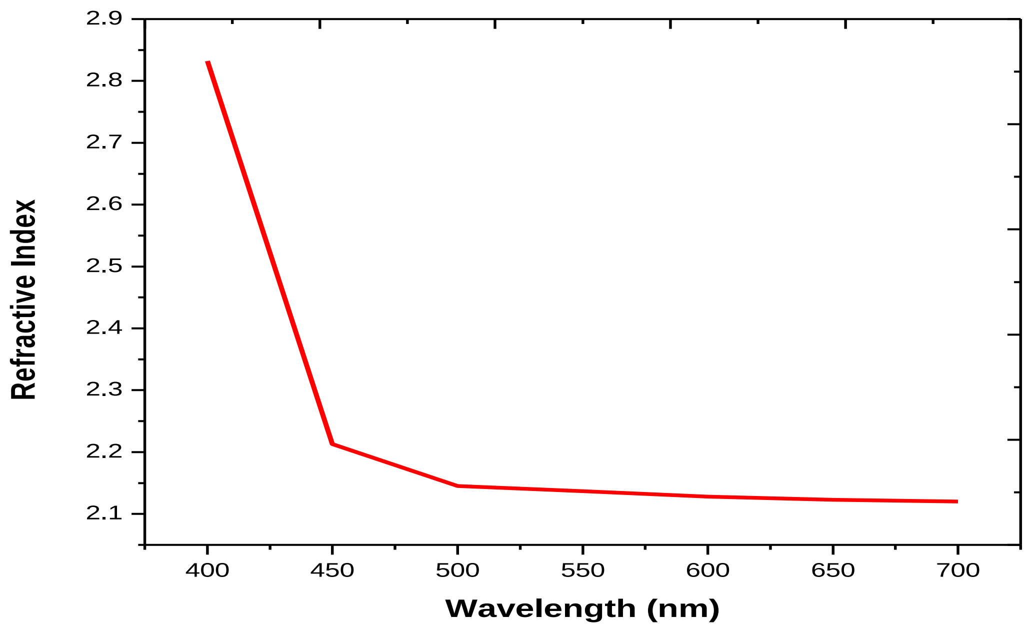

Figure 3: Variation of refractive index of TiO_2 film with wavelength.

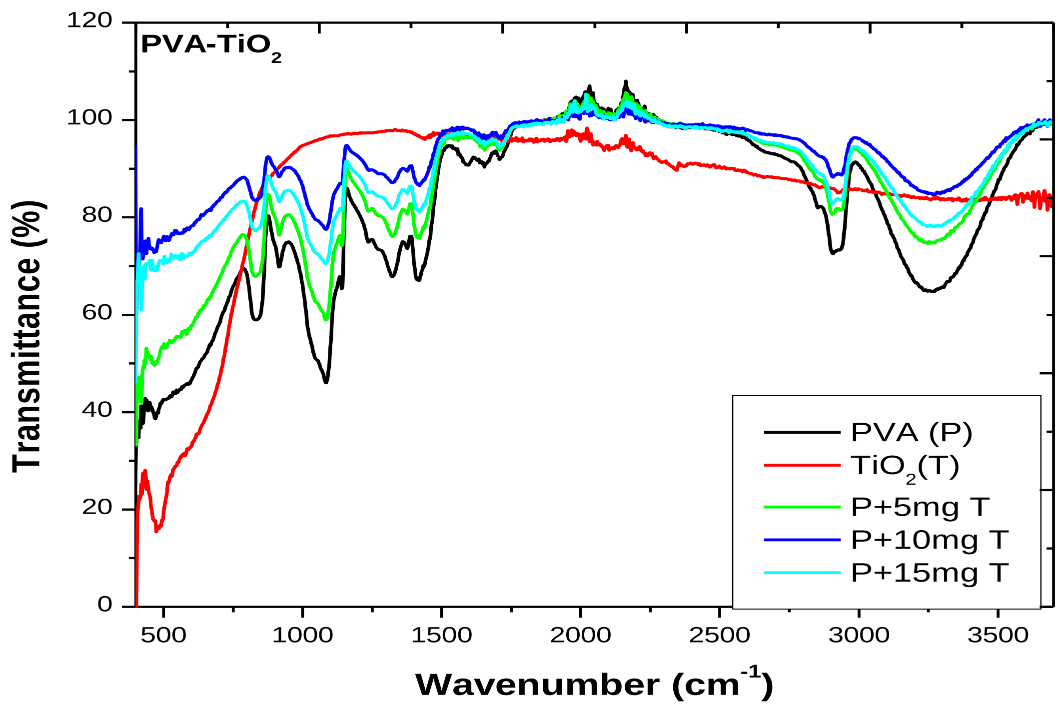

Figure 4: FTIR spectra of Pure TiO_2 and TiO_2 doped PVA films.

III. RESULTS AND DISCUSSIONS

Fig.2 shows the optical transmittance spectra of TiO_2 film as prepared at room temperature in ambient air. It is clear from the figure that, the optical transmittance is greater than 85% in the visible region exhibiting very good transparency of the film. The film thickness and refractive index of the film are measured by the envelope technique [10]. The film thickness is 145 nm and refractive index of the film is ~ 2.132 at 550nm (visible region). The refractive index of the film decreased with increasing the wavelength and become almost constant after 550 nm as shown in Fig.3.

The FTIR spectra of pure TiO_2 film and TiO_2 doped PVA films recorded in the range of 3600 cm^{-1}–400 cm^{-1} are shown Fig.4. A broad band is observed between 3150 cm^{-1} and 3450 cm^{-1}, representing the presence of free hydroxyl groups and bonded O-H stretching vibrations of PVA. The peaks at 2925 cm^{-1} and 1085 cm^{-1} indicates the presence of C-H stretching and C-O stretching vibrations corresponding to inplane and outplane bending vibrations of PVA–TiO_2 nano composite film. The peak at 2950 cm^{-1} is due to the stretching vibration of CH_2 and CH_3. The several peaks in the region 450–1500 cm^{-1} may be due to TiO_2 crystallites embedded in the matrix of PVA. PVA–TiO_2 film showed peaks at 1407 cm^{-1}, 1322 cm^{-1}, indicating the symmetric bending mode (CH_2), wagging vibration of CH_2 and CH respectively [11].

IV. CONCLUSIONS

TiO_2 thin films and nanoparticles were successfully prepared by the sol-gel method. TiO_2-PVA films were prepared by solution casting method. The optical properties such as optical transmittance and refractive index were studied from transmittance spectra. The stretching and bending vibrations of TiO_2 and PVA films were analysed from infrared spectrum.

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