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Effect of annealing and O_2 pressure on structural and optical properties of pulsed laser deposited TiO_2 thin films

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ABSTRACT

In this paper, effect of annealing and O_2 pressure on the structural and optical properties of pulsed laser deposited thin films of TiO_2 is reported. XRD, FTIR spectra and SEM images confirm that at high annealing temperatures, the rutile phase and crystalline quality of thin films increases. Higher pressure of O_2 during deposition improves the rutile phase and favors the rod like growth of TiO_2 thin film. The red shift in photoluminescence (PL) spectra of TiO_2 thin films with annealing temperature is reported. Contact angle measurement data for the thin films reveals the hydrophobic nature of the films. The very low reflectivity (∼10%) reported in this paper may be promising for anti-reflection coating applications of pulsed laser deposited TiO_2 thin films.

1. Introduction

TiO_2 is an important n-type wide band gap II–VI semiconductor with high refractive index and high dielectric constant. TiO_2 thin films have drawn a great deal of attention in recent years due to their wide application in solar cells, photo catalyst and self cleaning windows [1–3]. TiO_2 thin films have found applications in multilayer optical filter [4], anti-reflection coating [5] and metal–insulator–semiconductor (MIS) devices [6]. Room temperature grown TiO_2 thin films can have three structural forms anatase (tetragonal), rutile (tetragonal) and brookite (orthorhombic). Annealing at temperatures between 300 °C and 800 °C initiates a transition from primary anatase to the rutile phase [7,8].

Deposition of TiO_2 in anatase as well as rutile phase has been reported very well in the literature [5,7,9]. Among all the reported techniques, pulsed laser deposition (PLD) provides the precise manipulation of the properties of thin films of TiO_2 by controlling the deposition parameters [9–14]. Normally, TiO_2 thin films deposited at room temperature are amorphous with the anatase phase which gets converted to rutile phase after annealing [15] as former being thermodynamically unstable. Ambient oxygen pressure and post-deposition annealing are the most important parameters that affect the phase formation, morphology and microstructures and optical properties of pulsed laser deposited TiO_2 thin films. Xin et al. [16] discussed the effect of oxygen pressure on the structural properties of Co-doped TiO_2 films and Long et al. [17] have reported effect of substrate temperature and ambient pressure on the microstructure of TiO_2 films. However, the effect of ambient pressure and post-annealing is not well documented in the literature for room temperature deposited TiO_2 thin films using PLD.

In the present paper, we have reported pulsed laser deposition of high quality TiO_2 thin films at room temperature in oxygen ambient using high purity TiO_2 pellet. The effect of ambient pressure (O_2) and post-deposition annealing over structural, optical properties and the contact angle with water of pulsed laser deposited TiO_2 thin films is presented.

2. Experimental setup

The experimental setup used to deposit the TiO_2 thin films is shown in Fig. 1. The second harmonic of Q switched Nd:YAG laser (Model—Quanta systems-HYL101, 400 mJ/pulse in fundamental with 8 ns pulse duration and 10 Hz repetition rate) is focused on to the rutile TiO_2 of high purity (sintered at 1100 °C for 3 h and at 1200 °C for 18 h) target with a lens of focal length of 35 cm. The target was mounted inside the vacuum chamber through a motorized vacuum feed through and continuously moved in order to avoid piercing with the repeated shots of laser. The chamber was initially evacuated to a base pressure of 10^{-6} mbar and then filled with O_2 gas in the pressure range of 10^{-1} mbar to 10^{-3} mbar. When the high power laser was focused on to the TiO_2 target in the ambient of O_2 gas, plasma containing neutral

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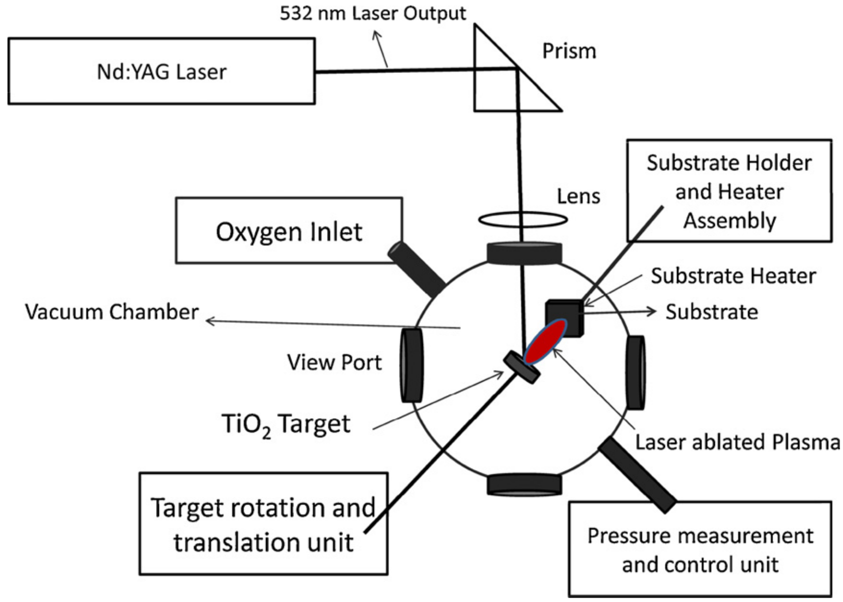

Fig. 1. Experimental setup.

and excited species of titanium and oxygen expanded and undergoes through the proper dynamics and finally thin films of TiO_2 were deposited on ultra sonically cleaned, polished glass substrates placed parallel to and 3 cm apart from the target at room temperature as shown in Fig. 1. Deposition time was kept fixed for 30 min for all the results reported in this paper. After deposition, TiO_2 thin films were annealed in high temperature furnace for 6 h at different temperatures in the range of 400–650 °C in air. These films of TiO_2 were scanned with SEM (LEO-1430vp) for surface morphology and XRD (SEIFERT 3003) for the crystal structure. Optical characterizations were performed with UV–vis spectrophotometer (Cary 100 Varian), photoluminescence (Thermo-spectronic Aminco Bowman Series 2) and FTIR (Horriba Jobin Yuvon). Contact angle measurement of TiO_2 films annealed at different temperature was performed by the pendant drop technique using Phoenix

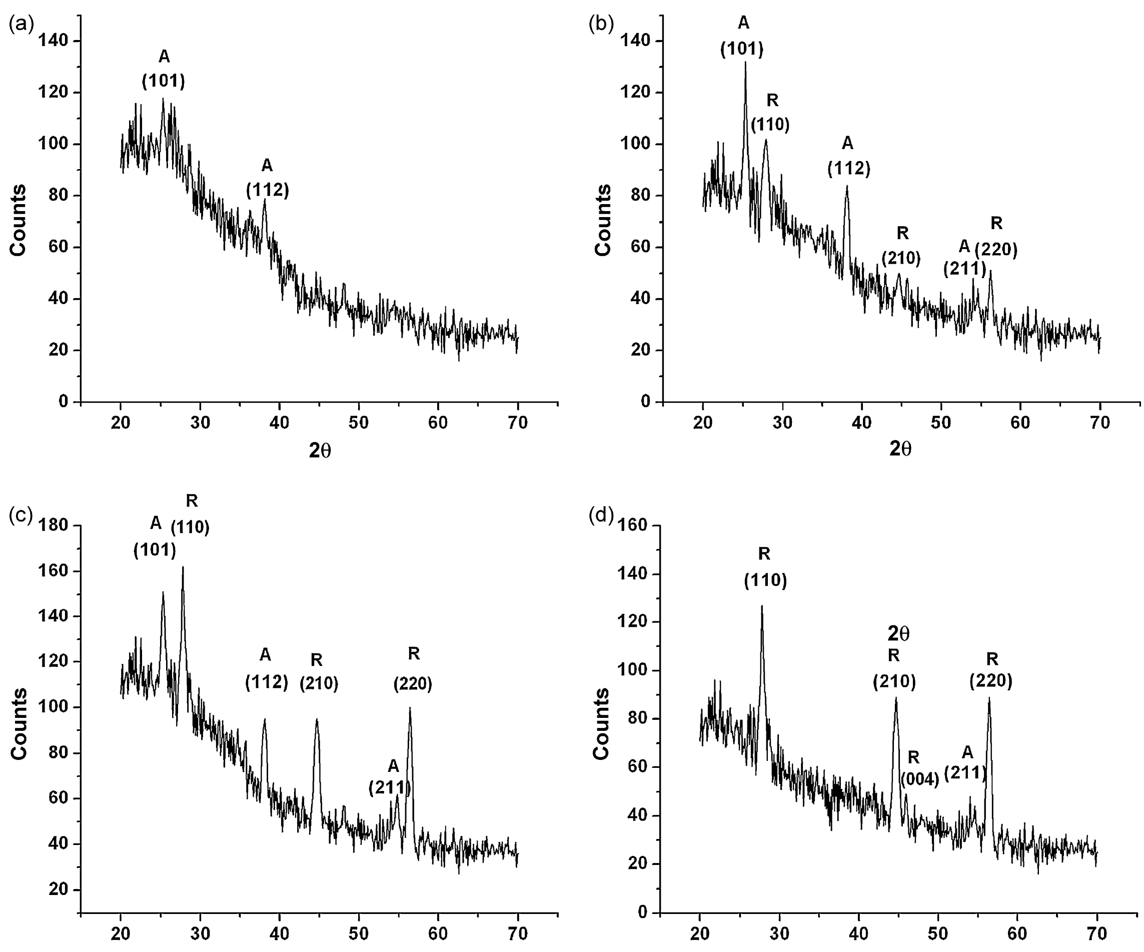

Fig. 2. XRD pattern for TiO_2 thin films deposited at 10^{-1} mbar O_2 pressure at room temperature; post-annealed at (a) as-deposited (b) 400 °C (c) 500 °C and (d) 650 °C.