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TiO_2/Ni composite as antireflection coating for solar cell application

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ABSTRACT

Titanium dioxide (TiO_2) considered as one of the best material already used as a window in solar cells due to its antireflection capability. In this work, pure and Ni-doped (1, 3 and 5 wt%) TiO_2 thin films were deposited using pulsed laser deposition (PLD) method. The optical measurements obtained by UV–vis indicate that the highest optical band gap was found with (5%) doping level (E_g=3.82 eV), corresponding to a lower reflectance and higher transmittance. Empirical equations between energy band gap and concentration level, reflectance with energy band gap, refractive index and concentration have been determined; a perfect fit with the experimental data was obtained.

1. Introduction

Antireflective Coatings (ARCs) are usually composed of thin films of different materials; these films should exhibit desired optical properties such as high transparency, wide optical band gap and other crucial properties like homogeneity, good adhesion and ability to withstand various environmental conditions to become potential candidates for multilayered structure. The most often used for optical coating fabrication are TiO_2, SiO_2, Al_2O_3, Nb_2O_3 and MgF_2 [1,2].

Crystalline oxide films are important components in a wide range of electronic and optical devices. The study and characterization of such compounds in addition to devices manufacture involve major aspects of current science and technology. Nanocrystalline TiO_2 is a multifunctional material that has many important applications in particular antireflection coatings [3,4].

The wide optical energy band gap of TiO_2 makes it a very suitable material for important applications in optoelectronic devices [5], it is familiar to photovoltaic industry [6–8], and it has been used as a single-layer antireflection coating for silicon solar cells for many years [9].

Pulsed laser deposition (PLD) is considered as versatile, cost-effective, fast and scalable [10,11]. It has been widely used to deposit various nanostructures of metal oxides onto different substrates.

In the present work, nanostructured TiO_2 thin films were deposited using PLD onto heated glass substrates at 573 K and kept in vacuum pressure (2×10^{-5} mbar).The effect of Ni-doping concentration (1, 3 and 5 wt%) on the evaluation of optical properties (energy band gap, optical constants and refractive index) of TiO_2 film has been investigated.

2. Experimental part

Pure and Ni-doped TiO_2 thin films were deposited onto pre-cleaned glass substrates by using pulsed laser deposition (PLD) technique. The used PLD system is based on pulses of Q-switched Nd:YAG laser by using the following experimental parameters: pulse duration 10 ns, wavelength λ=532 nm, 12 cm focal length of converging lens, high purity Ti target (99.999%), angle of incidence 45°, doping concentrations 1, 3 and 5 wt% using Ni Metal with a purity of (99.999%). The targets rotated with frequency of 6 Hz. The pulse laser energy at the target surface was maintained at 573 K and 800 mJ.

The transmittance and reflectance of the films were recorded in the spectral range (300–1100) nm using UV–vis (SP8001) Shimadzu double beam spectrophotometer. The average thicknesses of the prepared films were measured using optical method (laser light interference) were found to be around 150 nm.

3. Results and discussion

3.1. Optical transmittance and estimation of energy band gap

The optical transmittance spectra (Fig. 1) of as-deposited pure and Ni-doped TiO_2 films reveal that the transmittance depends on doping concentration, it decreases with increasing Ni content reaching minimum transmittance at doping ratio 1% then

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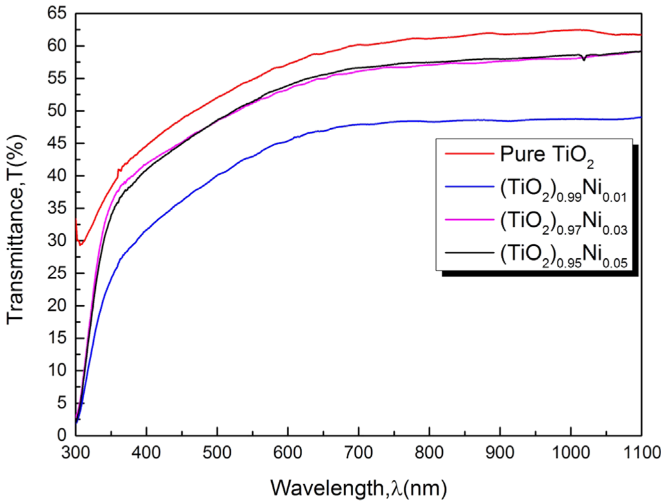

Fig. 1. Transmittance of pure and Ni-doped TiO_2 thin films (1, 3 and 5 wt%).

increased at higher ratios (3% and 5%) due to the increasing in energy gap which is in a good agreement with the work reported by Rajeh et al. [12]. It is also found that the average transmittance of TiO_2 film exceeds 60% in the near-infrared region, which indicates that TiO_2 films can be used as a window material in solar cells.

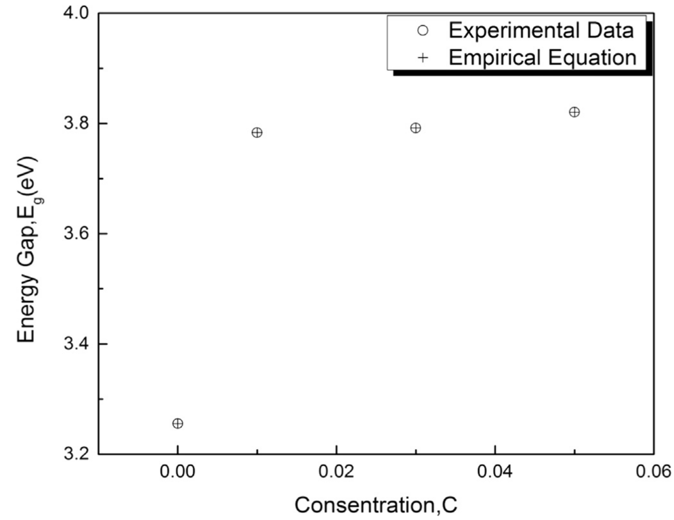

Fig. 3. The relationship between energy gap (E_g) and Ni concentration (C) as well as the complete fit with the empirical equation.

The optical band gap of the films was evaluated from Eq. (1) [13]:

$$(\alpha h\nu) = A\left(h\nu - E_g\right)^n \tag{1}$$

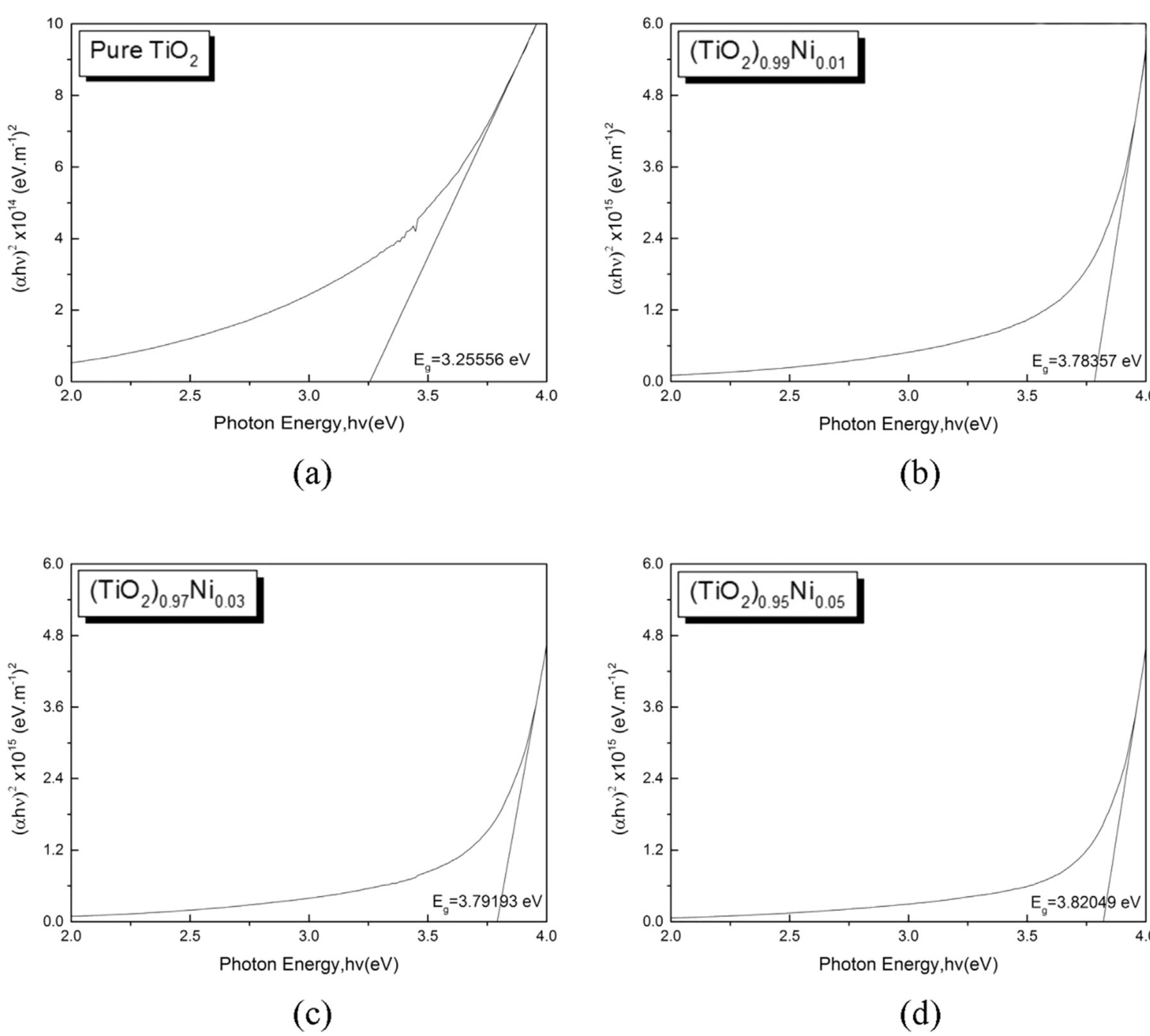

Fig. 2. Energy band gap of (a) pure TiO_2 (b) $(TiO_2)_{0.99}Ni_{0.01}$ (c) $(TiO_2)_{0.97}Ni_{0.03}$ (d) $(TiO_2)_{0.95}Ni_{0.05}$.