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Structural and optoelectronic properties of nanostructured TiO_2 thin films with annealing

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ABSTRACT

About 480 nm thick titanium oxide (TiO_2) thin films have been deposited by electron beam evaporation followed by annealing in air at 300–600 °C with a step of 100 °C for a period of 2 h. Optical, electrical and structural properties are studied as a function of annealing temperature. All the films are crystalline (having tetragonal anatase structure) with small amount of amorphous phase. Crystallinity of the films improves with annealing at elevated temperatures. XRD and FESEM results suggest that the films are composed of nanoparticles of 25–35 nm. Raman analysis and optical measurements suggest quantum confinement effects since Raman peaks of the as-deposited films are blue-shifted as compared to those for bulk TiO_2 Optical band gap energy of the as-deposited TiO_2 film is 3.24 eV, which decreases to about 3.09 eV after annealing at 600 °C. Refractive index of the as-deposited TiO_2 film is 2.26, which increases to about 2.32 after annealing at 600 °C. However the films annealed at 500 °C present peculiar behavior as their band gap increases to the highest value of 3.27 eV whereas refractive index, RMS roughness and dc-resistance illustrate a drop as compared to all other films. Illumination to sunlight decreases the dc-resistance of the as-deposited and annealed films as compared to dark measurements possibly due to charge carrier enhancement by photon absorption.

1. Introduction

Among the transition-metal oxides, TiO_2 is one of the most extensively studied materials. The rising interest in its applications and research in the last few years is due to its unique and outstanding structural, optical and electronic properties [1–4]. TiO_2 is known to exist in three polymorphic forms: anatase, rutile and brookite. The most widely used crystallographic structures (tetragonal) are anatase and rutile. Depending on the structure, the properties of TiO_2 vary greatly, which make them useful for many applications. The rutile phase has a direct band gap at 3.06 eV and indirect band gap at 3.10 eV [5] with high refractive index and dielectric constant (~80) [6,7], better

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