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Effect of growth techniques on the structural and optical properties of TiO_2 nanostructures

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Abstract

Being a promising transition metal oxide having a phase dependent wide band gap, TiO_2 holds a significant place in semiconducting and flexible nanodevices. TiO_2 nanoparticles have been prepared by co-precipitation and hydrothermal methods. The effect of both the synthesis technique on the structural, morphological and optical properties of TiO_2 nanoparticles has been investigated. The as-prepared TiO_2 nanostructures were characterized by means of x-ray diffraction, field-emission scanning electron microscopy, Raman analysis, diffuse reflectance spectroscopy and photoluminescence studies. The studies reveal that co-precipitation method results in the formation of agglomerated nanoparticles with less defects and effective luminescent property compared to the hydrothermal counterpart.

Introduction

In the materializing domain of nanotechnology, the aim is to make innovative nanostructures displaying unique electrical, optical and chemical properties that extensively empower their importance in basic scientific research and potential technological applications. Metal-oxide nanostructures are functional materials exhibiting myriad novel phenomena and advanced applications because of their diverse properties at nanoscale dimensions. They have stimulated great interest by displaying as both interconnects and effective units in fabricating electronic, optoelectronic, electrochemical, magneto-optical and electromechanical devices with strong control on nano-dimensional scale. In technological applications, they have now been widely used in distinct areas, such as transparent electronics, piezoelectric devices, microelectronic circuits, fuel cells, ceramics, catalysis, sensors, electro-optical and electro-chromic devices [1]. Certainly, a detailed investigation and understanding of the fundamental and functional properties of metal oxide nanosystems is indispensable in research and advancement towards potential applications.

Titanium dioxide (TiO_2) is one among the most attracted metal oxides having distinct and novel properties from fundamental and practical point of view belonging to the family of transition metal oxides. TiO_2 is a remarkably attractive semiconducting material having excellent optical transparency and wide band gaps which crystallizes mainly into four main polymorphs such as rutile (tetragonal), anatase (tetragonal), brookite (orthorhombic) and TiO_2 (B) (monoclinic). Apart from these TiO_2 (II) exhibiting a PbO_2 structure and TiO_2 (H) having a hollandite structure are also represented as the polymorphs of TiO_2, high pressure forms of rutile phase [2]. Among the different crystallographic phases, TiO_2 endure mostly in rutile with an optical energy band gap of 3.0 eV and anatase with an optical energy band gap of 3.2 eV, in which rutile is the thermodynamically more stable phase [3]. But for nanosystems less than 14 nm anatase is more stable than rutile [4, 5]. High electron mobility and low dielectric constant of anatase phase allows for its advantage over other polymorphs. In addition, TiO_2 is highly corrosion resistive, chemically and thermally stable, non-toxic, biocompatible, high photocatalytic activity and have high refractive index ($n = 2.54$ for anatase and $n = 2.79$ for rutile) [4]. TiO_2 crystals are ionic compounds that are made up of positive titanium and negative oxygen ions. The electrostatic interactions between the titanium and oxygen ions result in strong ionic bonds. The presence of unfilled d-orbitals accord for array of novel and unique properties such as wide and tunable band gaps, high dielectric