Chapter 9
Synthesis, Properties, and Applications of Special Substrates Coated by Titanium Dioxide Nanostructured Thin Films via Sol–Gel Process

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ABSTRACT

In this chapter, the sol-gel made titanium dioxide nanostructured thin films deposited on special substrates such as glasses, mica, steels, textiles, fibers, and other organic/inorganic substrates were reviewed. Through this review, several distinctive properties such as optical, electrical, photocatalytic, morphological, and mechanical properties of TiO_2 nanostructured thin films were described. Also, a wide range of practical application of TiO_2 nanostructured thin films such as dye-sensitised solar cells, optical coatings, humidity and gas sensors, selfcleaning, dielectric, and antibacterial surfaces were discussed in details. Dip and spin coating techniques were demonstrated as suitable methods for deposition of thin films. It has been shown that properties of such films can be affected by type of coating technique, stabilizer, precursor material, solvents, pH and viscosity of precursor solution, aging, and etc. Finally, Successive Interference Fringes Method (SIFM) was presented as a simple method for the determination of optical constants and thickness of TiO_2 thin films from single transmission measurements.

DOI: 10.4018/978-1-4666-5125-8.ch009

INTRODUCTION

"Nanostructures" or "nanomaterials" as wide groups of nanoscale materials with unrivaled properties, are the most well-known substances used in solid state physics as well as other basic sciences. Currently, a lot of nanomaterials such as nanoparticles, -powders, -tubes, and -wires have been discovered. Among these nanomaterials, 'nanoparticles' have been received a growing interest in the most of scientific projects especially those based on solid state physics (Ramsden, 2005).

Nanoparticles can be classified into three categories: conductors, semiconductors, and insulators. From the standpoints of practical applications, metal oxide based semiconductor nanoparticles are recently finding increasing attention particularly in solid state physics. For instance, smooth or rough surfaces like glasses and textiles, respectively, can be coated using these nanoparticles by several methods to attain novel properties with effective specifications (Battiston, Gerbasi, Porchia, & Marigo, 1994; Brinker & Harrington, 1981; Leinen, Fernández, Espinós, Belderrain, & González-Elipe, 1994; Löbl, Huppertz, & Mergel, 1994; Martin, Rousselot, Savall, & Palmino, 1996). Among huge variety of nanosized metal oxide semiconductor particles such as ZrO_2, ZnSe, CdS, SnO_2, Al_2O_3, MgO, ZnO, and TiO_2, titanium dioxide (TiO_2) nanoparticles with high refractive index, high dielectric constant, excellent physical and chemical stability, and wide band gap are the best inorganic metal oxides capable to provide inconceivable properties. Basically, four crystalline spatial configurations have been suggested for nanosized TiO_2 particles: anatase, rutile, brookite, and srilankite. However, rutile phase with refractive index about 2.7 at a wavelength of 500 nm is thermodynamically stable in high temperatures than the other crystalline phases. The main properties of these structures are summarized in Table 1 (Ye, Liu, Tang, & Zhai, 2007). Studies show that tetragonal rutile and anatase structures are highly ordered in comparison with orthorhombic structure of brookite and srilankite. Figure 1 shows spatial configurations suggested for rutile and anatase structures of the nanosized TiO_2 particles (Bally, 1999).

Optical behavior (Ghodsi, Tepehan, & Tepehan, 2008b), dye-sensitivity (Sung & Kim, 2007), dielectric activity (W. Yang & Wolden, 2006), selfcleaning and photocatalytic effects (Euvana-

Table 1. Physical, optical, and electrical properties of four different spatial configurations of TiO_2 (Bally, 1999)

Properties	Anatase	Rutile	Brookite	Srilankite
Configuration	Tetragonal	Tetragonal	Orthorhombic	Orthorhombic
Density (g/cm^3)	3.89	4.25	4.12	4.37
Refraction Index*, **	n_{per}(to *c* axis)=2.55 n_{par}(to *c* axis)=2.48	n_{per}(to *c* axis)=2.60 n_{par}(to *c* axis)=2.89	n_{par}(to *a* or *b* axis)=2.57 n_{par}(to *c* axis)=2.69	--- ---
Dielectric Constant*	k_{per}(to *c* axis)=31 k_{par}(to *c* axis)=48	k_{per}(to *c* axis)=89 k_{par}(to *c* axis)=173	78 78	--- ---
Band Gap (eV)	$E_{g(per)}$(to *c* axis, direct)=3.42 $E_{g(par)}$(to *c* axis, indirect)=3.46	$E_{g(per)}$(to *c* axis, direct)=3.04 $E_{g(par)}$(to *c* axis, indirect)=3.05	3.14 3.14	--- ---
Electron Mobility (10^{-4} m^2/Vs)	As a Crystal=15-550 As a Thin Film=0.1-4	As a Crystal=0.1-10 As a Thin Film=0.1	--- ---	--- ---

* 'per' = 'perpendicular' and 'par' = 'parallel'

** Measured at λ = 600 nm.

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