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# Chromium Doped TiO<sub>2</sub> Sputtered Thin Films

Synthesis, Physical Investigations  
and Applications

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# Introduction

Due to its interesting intrinsic properties, Titanium oxide which belongs to the metal transition oxide family was the most studied during the last two decades and demanded material in many fields of applications such as transparent electrodes, gas sensors, heterojunction solar cells, photocatalytic process, etc. To improve the performance of this oxide, doping  $\text{TiO}_2$  with suitable dopants offers an effective method to adjust some of its physical properties. Generally, the doping of semiconductors with appropriate metals is one of the most effective ways in research for developing sensitivity applications. However, the interaction between the doping metals and the semiconductor is complicated because the interaction relates to the carrier concentration, defect level, and surface states of the semiconductor, electronic, optical properties, and so on. Therefore, good understanding of the interaction will facilitate the fundamental and technical application of such oxides doped with some metallic elements.

It is indeed reported that this oxide based on transition metal and doped with an appropriate metallic element (Al, Nb, Sn, Ge, Fe, Cr) has a significant role in sensitivity applications such as photovoltaic solar cells, photocatalysis, and pollution sensors.

To achieve high efficiency in photovoltaic solar conversion, for example, solar cells-based  $\text{TiO}_2$  as transparent conductor oxide (TCO) must absorb a maximum amount of light energy.

On the other hand, in the field of gas sensors, the characteristic response of a polycrystalline semiconductor device (for example the  $\text{TiO}_2$ ) can be modified and controlled by several factors as: the size of particles, pore structure, density of grain. Knowledge of the influence of these parameters on the final component is essential for its operating.

Previous studies show that the variation of the microstructure is always accompanied by a more or less important variation of the electrical properties of the studied material. Metal additions are also an important factor; these additions can change dramatically the nature of the response of the material. However, it is important to distinguish the effect of these additions to the effect of other factors

(microstructure, humidity...). In fact, to perform a reliable study of the effect of metal additions, it is important to set the microstructural parameters, and to have a series of samples prepared under the same conditions.

The first chapter deals with some basic principles on the operation and the performance of the components used in gas sensors, photocatalysis, and photovoltaic cells. We will focus on the effect of the microstructure and the incorporation of the metallic aggregates on the optoelectronic and sensing properties of Cr-doped TiO<sub>2</sub> films.

In the second chapter we give a brief introduction to the deposition technique of TiO<sub>2</sub> thin films by sputtering (used at the INRS-EMT labs, Canada). We will study the optoelectronic properties of Cr-doped TiO<sub>2</sub> thin films obtained by sputtering for use in the field of pollution and photovoltaic sensors.

In the third chapter, different analytical and microstructural characterizations of TiO<sub>2</sub> thin films prepared by sputtering method have been provided. We study those prepared in ambient temperature and also those annealed under oxygen at different temperatures.

In the first part of the fourth chapter, the electrical properties of the Cr-doped TiO<sub>2</sub> thin films have been studied. The measurement of the electrical conductance under ethanol vapors were carried out in terms of Cr content, in low and high concentration doping. In the second part, we studied the microstructural and optoelectronic properties of TiO<sub>2</sub> thin films deposited on the monocrystalline and multicrystalline porous silicon.

# Abstract

Titanium oxide  $\text{TiO}_2$  thin films have attracted tremendous research zeal in recent years. Sensitivity devices using this oxide depend on the structural, optical as well as electrical properties of such films. First, some of the physical properties, fabrication processes as well as the physical applications of  $\text{TiO}_2$  material have been presented wherever necessary from previous works reported in the literature. Second, the synthesis protocol based on sputtering process has been detailed. A noticeable change from anatase to rutile phases of this oxide has been verified by means of some physical investigations such as: XRD, XPS, FTIR, reflectivity, ellipsometry, LBIC. It is also shown that the increase of doping content (from 0 % to 17 %) decreases the band gap energy value from 3.31 eV to 1.89 eV. Cr content controls the electrical conduction sensitivity of  $\text{TiO}_2$  films under ethanol test. A change of type (N type to P type) is indeed observed for the two Cr concentrations 13 % and 17 % atomic. This behavior may be of interest for various sensitivity applications. Finally, concluding remarks are provided to bring out some clues regarding the possible use of such materials in some optoelectronic devices (photocatalytic, gas sensors, passivation of solar cells.).

**Keywords** Cr-doped  $\text{TiO}_2$  • Thin films • Crystallographic structure • Microstructure • Band gap energy • Light Beam Induced Current (LBIC) measurements • Reflectivity • Photoluminescence • Photo-conversion • Gas sensors • Photocatalysis