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Chromium Doped TiO_2 Sputtered Thin Films

Synthesis, Physical Investigations and Applications

Springer

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ISSN 2191-530X ISSN 2191-5318 (electronic)
SpringerBriefs in Applied Sciences and Technology
ISBN 978-3-319-13352-2 ISBN 978-3-319-13353-9 (eBook)
DOI 10.1007/978-3-319-13353-9

Library of Congress Control Number: 2014955615

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

Acknowledgments

This material is based upon work supported by the collaboration between two institutions: «Laboratoire de Photovoltaïque, Centre de Recherches et des Technologies de l'Energie, Technopole de Borj-Cédria, Hammam-Lif, Tunisia» and the Institut National de la Recherche Scientifique, INRS-Énergie, Matériaux et Télécommunications, Varennes, Canada.

The authors would like to thank all the people who kindly helped them, especially Dr. Samir Saidi for his help in the dissertation, Prof. Latifa Bousselmi for photocatalysis experiments, and Dr. Wissem Dimassi for his help during LBIC measurements.

Contents

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 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 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 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_2 films.

In the second chapter we give a brief introduction to the deposition technique of TiO_2 thin films by sputtering (used at the INRS-EMT labs, Canada). We will study the optoelectronic properties of Cr-doped TiO_2 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_2 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_2 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_2 thin films deposited on the monocrystalline and multicrystalline porous silicon.

Abstract

Titanium oxide 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 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 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 TiO_2 · Thin films · Crystallographic structure · Microstructure · Band gap energy · Light Beam Induced Current (LBIC) measurements · Reflectivity · Photoluminescence · Photo-conversion · Gas sensors · Photocatalysis