Phys. Status Solidi RRL **9**, No. 3, 171–174 (2015) / **DOI** 10.1002/pssr.201409562

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Integration of individual TiO_2 nanotube on the chip: Nanodevice for hydrogen sensing

Mihail Enachi[*,1], Oleg Lupan[*,,2], Tudor Braniste[1], Andrei Sarua[3], Lee Chow[4], Yogendra K. Mishra[2], Dawit Gedamu[2], Rainer Adelung[2], and Ion Tiginyanu[1,5]**

[1] National Center for Materials Study and Testing, Technical University of Moldova, 2004 Chisinau, Republic of Moldova
[2] Functional Nanomaterials, Institute for Materials Science, Christian Albrechts University of Kiel, 24143 Kiel, Germany
[3] H.H. Wills Physics Laboratory, University of Bristol, BS8 1TL Bristol, UK
[4] Department of Physics, University of Central Florida, Orlando, FL 32816-2385, USA
[5] Institute of Electronic Engineering and Nanotechnologies, Academy of Sciences of Moldova, 2028 Chisinau, Republic of Moldova

Received 28 December 2014, revised 19 February 2015, accepted 19 February 2015
Published online 25 February 2015

Keywords TiO_2, nanotubes, hydrogen, gas sensors, anatase, rutile

[*] Corresponding authors: e-mail enachimihai@mail.utm.md, Phone: +373 22 509 920, Fax: +373 22 509 920; e-mail ollu@tf.uni-kiel.de
[**] On leave from Department of Microelectronics and Biomedical Engineering, Technical University of Moldova, 168 Stefan cel Mare Blvd., 2004 Chisinau, Republic of Moldova.

Titania (TiO_2) exists in several phases possessing different physical properties. In view of this fact, we report on three types of hydrogen sensors based on individual TiO_2 nanotubes (NTs) with three different structures consisting of amorphous, anatase or anatase/rutile mixed phases. Different phases of the NTs were produced by controlling the temperature of post-anodization thermal treatment. Integration of individual TiO_2 nanotubes on the chip was performed by employing metal deposition function in the focused ion beam (FIB/SEM) instrument. Gas response was studied for devices made from an as-grown individual nanotube with an amorphous structure, as well as from thermally annealed individual nanotubes exhibiting anatase crystalline phase or anatase/rutile heterogeneous structure. Based on electrical measurements using two Pt complex contacts deposited on a single TiO_2 nanotube, we show that an individual NT with an anatase/rutile crystal structure annealed at 650 °C has a higher gas response to hydrogen at room temperature than samples annealed at 450 °C and as-grown. The obtained results demonstrate that the structural properties of the TiO_2 NTs make them a viable new gas sensing nanomaterial at room temperature.

1 Introduction The high interest in titanium dioxide or titania has been stimulated for decades by a myriad of applications of this versatile material such as heterogeneous catalysis, photocatalysis, solar cells, chemical sensors, corrosion-protective coatings, biomedicine etc. [1–4]. Over the last few years, increased attention has been paid to the study of nanostructured TiO_2 layers and membranes fabricated by anodic oxidation of pure titanium foils [5]. Recently we observed, for example, that anodic oxidation of Ti foils at temperatures below 0 °C leads to the formation of closely packed TiO_2 nanotubes distributed in a two-dimensional quasi-ordered fashion [6]. These findings open up new perspectives to the applications of TiO_2 nanotubular structures in the design and fabrication of novel photonic elements [7]. Among other applications, increasing interest has also been devoted to gas sensing properties of titania. TiO_2 based gas sensors were made by various processes such as thermal evaporation of TiO_2 powder [8], electrochemical deposition [9], anodization of Ti sheets in water based solutions containing fluoride ions [10], or organic electrolytes [11], etc. Sensing properties of TiO_2 have been investigated in film sensors [9], dots or TiO_2 nanotubular arrays [10]. Hydrogen gas sensors on undoped TiO_2 [12] and doped TiO_2 nanostructures with different dopants such as Nb [13], Eu, Yb, Pt [14], C or mixture of TiO_2 and other nanocompounds such as SnO_2 were previously reported by different groups. Vertically aligned and ordered TiO_2 NT arrays have been investigated as hydrogen sensors due to their change of electrical resistance in the presence of hydrogen gas [10]. It is well known that the