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Abstract

Gas Sensing Capabilities of $CuInS_2$/ZnO Core–Shell Quantum Dot †

Antonio Orlando [1,2,*], Guglielmo Trentini [1,2], Pietro Tosato [2], Soufiane Krik [1], Matteo Valt [2], Andrea Gaiardo [2] and Luisa Petti [1]

1 Sensing Technologies Lab, Faculty of Engineering, Free University of Bolzano-Bozen, Piazza Università 5, 39100 Bolzano, Italy; guglielmo.trentini@student.unibz.it (G.T.); soufiane.krik@unibz.it (S.K.); luisa.petti@unibz.it (L.P.)

2 Sensors and Devices Center, Bruno Kessler Foundation, Via Sommarive 18, 38123 Trento, Italy; ptosato@fbk.eu (P.T.); mvalt@fbk.eu (M.V.); gaiardo@fbk.eu (A.G.)

* Correspondence: antonio.orlando@natec.unibz.it; Tel.: +39-0461-31415033

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Abstract: Chemoresistive gas sensors are surely one of the easiest and most commonly used methods to monitor the presence of different polluting gases. Nevertheless, there are still several challenges to overcome in order for these sensors to be widely used. In particular, the selectivity and sensitivity of chemoresistive gas sensors towards a wide range of analytes need to be improved. This is why new sensing materials capable of detecting different analytes in a sensitive and selective manner are being investigated. In this regard, this work is focused on the development and characterization of a new sensing material based on the quantum dot (QD) core–shell of $CuInS_2$/ZnO (CIS-ZO). Optimized films of the QD core–shell of CIS-ZO were integrated into a micro-electromechanical system (MEMS)-based gas sensor platform, showing excellent sensing performance versus different gases and especially towards ethanol (C_2H_5OH).

Keywords: chemoresistive gas sensor; quantum dots; micro-electromechanical system

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1. Introduction

In recent years, low dimensional materials (2D, 1D, 0D) have attracted researchers' attention thanks to their high-surface-to-volume ratio, low cost, and optimal electrical proprieties. In particular, in the field of gas sensing, they have represented a step forward thanks to the high active surface area, allowing a strong interaction with target molecules within rapid response times. Moreover, the possibility to tailor these materials with different properties could also enable the selective detection of specific target gases, allowing the realization of highly selective devices [1].

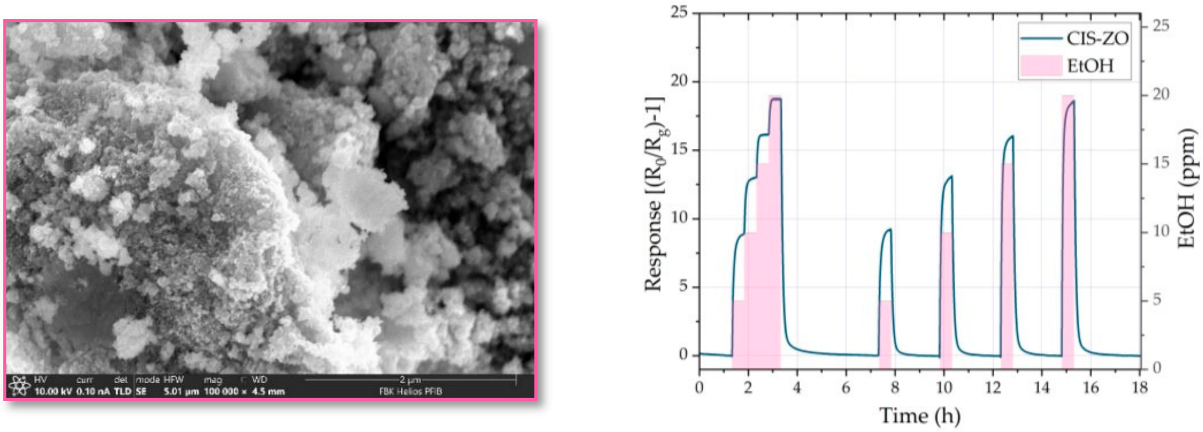
Starting from metal oxide-based semiconductors (especially tin oxide, zinc oxide, and tungsten oxide) that are commonly used as gas sensing materials, many recent studies have focused on the fabrication of gas sensors with metal oxide-based quantum dots (QDs) as a sensing material.

In this work, we developed a micro-electromechanical system (MEMS)-based gas sensor that uses the QD core–shell of $CuInS_2$/ZnO (CIS-ZO) as a sensing material for the detection of different gases. In particular, ethanol (C_2H_5OH) showed very high sensitivity and fast response/recovery.

2. Materials and Methods

In this study, the MEMS-based gas sensor platform presented in [2] was used for the investigation of the sensing proprieties of CIS-ZO.

CIS-ZO was obtained after the oxidation at 650 °C in air of QDs of $CuInS_2$/ZnS (ZCIS) synthesized with the procedure reported by W. Hu et al. [3]. The powder of the obtained CIS-ZO was characterized using scanning electron microscopy (SEM), as shown in Figure 1a.



(**a**) (**b**)

Figure 1. (**a**) SEM image on CIS-ZO powder. (**b**) Response of CIS-ZO–based gas sensors calculated as $Response = \left(\frac{R_0}{R_g}\right) - 1$ with different concentrations of ethanol (5, 10, 15, and 20 ppm) at 0 RH% and 400 °C.

In order to perform an optimal deposition of the CIS-ZO on the MEMS device, the CIS-ZO powder was mixed with an organic matrix in order to obtain a screen-printable paste. The paste was then deposited on the device by means of screen printing, using the Aurel 1520B.

The fabricated device was bounded on a gold support (TO-39) in order to integrate it into a customized chamber for the resistance measurements. The chamber was then connected to a dedicated gas mixing system capable of obtaining different concentrations of different gases.

3. Discussion

The SEM image of the CIS-ZO (Figure 1a) showed an average diameter of the nanoparticles of 5 nm. The sensing performances of CIS-ZO were tested using the MEMS-fabricated gas sensor platform. For the sensing measurements, the sensing material was heated up to 400 °C, and the relative humidity in the gas chamber was maintained at 0%. The devices were tested versus 5, 10, 15, and 20 ppm of ethanol (Figure 1b). The results showed excellent reproducibility and stability in the response. Moreover, they showed a high response (18.5 vs. 20 ppm of ethanol) and excellent recovery.

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