Metal oxide nanostructured gas sensors for security applications

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Abstract

This work reports metal oxide nanostructures with thin film and nanowire morphology and their exploitation as gas sensor in the frame of selected security applications, namely, detection of chemical warfare agents and detection of hidden people.

Metal oxides such as ZnO or SnO_2 have been widely adopted in gas sensing, especially in a chemiresistor configuration due to the high sensitivity, low production cost, reduced weight and size of such devices. The working mechanism is based on the modulation of the metal oxide macroscopic resistivity due to red-ox reactions occurring at the metal oxide surface with adsorbing gaseous molecules [1].

Different metal oxide nanostructures will be presented in this work, based either on thin films and nanowire bundles, detailing the synthesis process [2], protocols to integrate such nanostructures into functional gas sensors devices [3] and functional performance with respect to compounds of interest in security field such as dimethyl methylphosphonate (a simulant for Sarin nerve agent), ammonia and acetone (these compounds may be produced, among other ways, by urine or breath, and may be exploited as marker of human presence).

Results obtained by the work group of SENSOR laboratory and collaborators will be reviewed in terms of sensitivity, selectivity and stability in the framework of security applications.

As for selectivity, sensor performance will be further shown with respect to the integration of the proposed nanostructure in an artificial olfactory system (AOS), namely an array of sensors based on different materials (each one showing its own response spectrum), with a pattern recognition software handling the collective response of the array [4]. Differently from analytical analyzer, AOS can be successfully used both to track the concentration of a given compound in a complex atmosphere or to identify odors, i.e. complex gas blends, without analyzing in detail their composition, but simply recognizing the presence of a particular odor (or gas) in a given atmosphere through the identification of the proper odor fingerprint (response of the sensor array to such a smell). Such a sensing system provides a large flexibility and can be tuned to identify different targets. For example, AOS based on a mixed array of metal oxide nanowires and thin films revealed suitable to distinguish chemical warfare agents from compounds typical of everyday life, such as ethanol or CO, or to identify the presence of human-related odors, [5].

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References

[1] N. Barsan, U. Weimar, J. Electroceram., **7** (2001) 143–167

[2] A. Ponzoni, E. Comini, I. Concina, M. Ferroni, M. Falasconi, E. Gobbi, V. Sberveglieri, G. Sberveglieri; Sensors **12** (2012) 17023-17045

[3] A. Vomiero, A. Ponzoni, E. Comini, M. Ferroni G. Faglia and G. Sberveglieri; Nanotechnology **21** (2010) 145502

[4] F. Rock, N. Barsan, U. Weimar, Chem. Rev. **108** (2008) 705−725

[5] A. Ponzoni, C. Baratto, S. Bianchi, E. Comini, M. Ferroni, M. Pardo, M. Vezzoli, A. Vomiero, G. Faglia, G. Sberveglieri; IEEE Sens. J. **8** (2008) 735-742

Figures

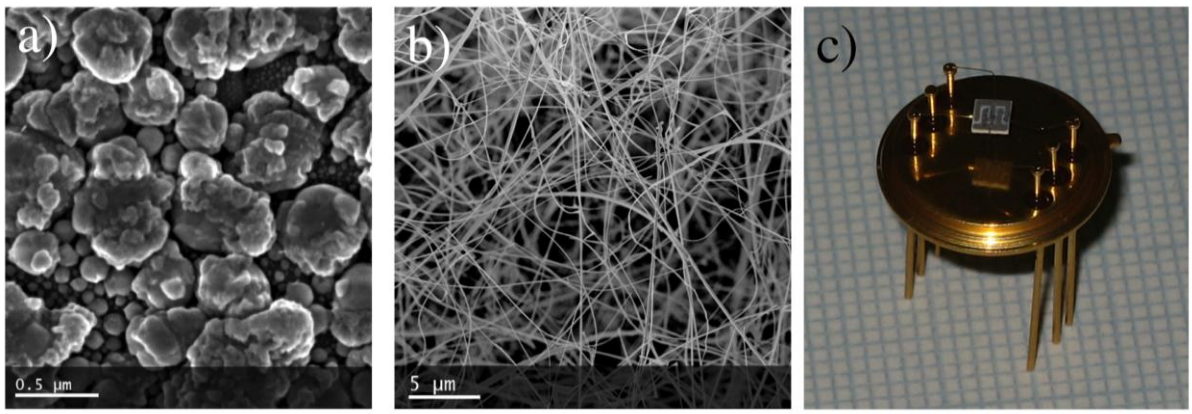

Figure 1: metal oxide based gas sensors. SnO_2 thin film prepared through RGTO technique, [2] (a); SnO_2 nanowire bundle prepared through evaporation and condensation method, [2] (b); chemiresistor device (c).

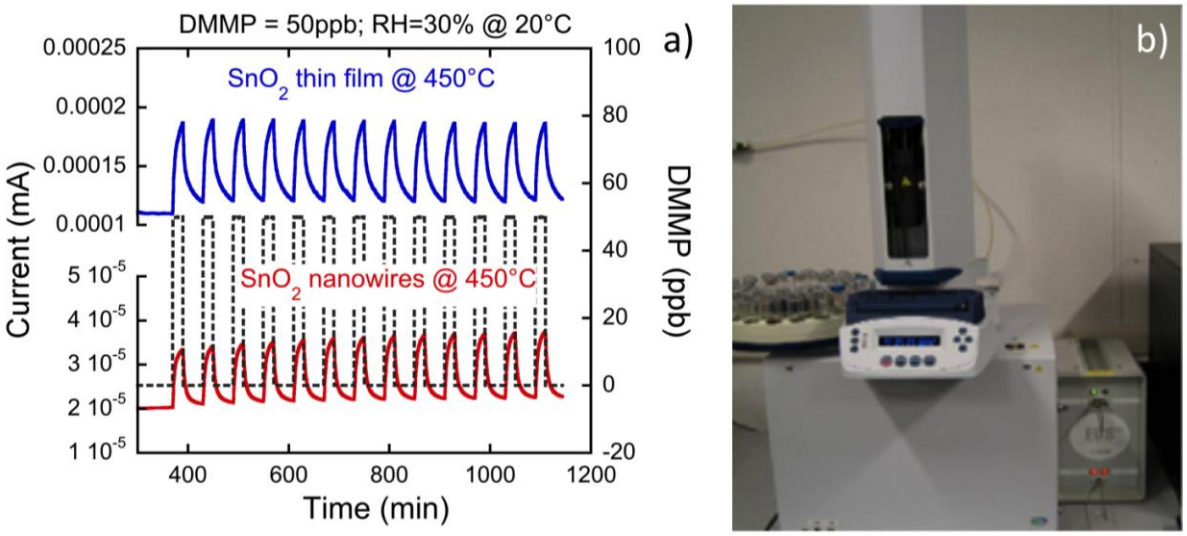

Figure 2: response of SnO2 sensors prepared through nanowire and thin film technologies to repeated DMMP (dimethyl methylphosphonate – a Sarin nerve agent simulant) injections, a). Artificial Olfactory System (AOS) equipped with metal oxife chemiresistors and coupled with an autosampler for static head space generation, b).