Nano-crystalline metal oxide gas sensors and Electronic Olfactive Systems at SENSOR Lab , INFM – CNR & Brescia University.

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ABSTRACT

The research and development of solid state gas sensors with low cost and reduced size for the monitoring of the gaseous species is rapidly increasing in the last years [1].

Many technological approaches have been proposed regarding the different materials and the detecting principles. The currently available sensors use several transduction principles: thermal, mass, potentiometric, amperometric, conductometric, and optical [2]. The application range comprises the environmental monitoring, the automotive applications, the air conditioning in the aircrafts and spacecrafts, in the sensor networks and, more generally, in the industrial and domestic environments. Sensors based on metal oxide semiconductors seem to be the most promising devices among the chemical sensors due to the facility of measuring the chemical quantity to be transduced, the reduced size, the long term stability, the low cost and power dissipation, the on-line operation and the full compatibility with the standard microelectronic techniques of machining.

Nano-structured materials exhibit unique properties for many application fields; there are remarkable improvements or at least deviations from the properties of the coarser grained material. The explanation for these particularities is attributed to the significant increase in grain boundary area due to the smaller grain sizes. In the gas-sensing field the applications of nanostructured materials are manifold, it has been proved experimentally and theoretically that decreasing of grain size leads to an enhancement of the sensing performances. The main problem is that the annealing process necessary for the stabilization of the sensing layer causes grain coalescence. There is a great effort in reducing the grain dimension and increasing the surface area exposed to the interaction with gaseous species. One of the strategies used is the addition of a second element, which can inhibit the grain growth.

Another approach is the use of metal oxide semiconductors quasi one dimensional structures such as nanowire, nanobelts or nanorods of SnO_2, ZnO, In_2O_3, TiO_2 and WO_3, these materials, due to their peculiar

characteristics and size effects, often show novel physical properties compared to those of the bulk. The potential of these innovative structures is exploited in gas-sensing, by reducing the metal oxide wires diameter, it is possible to confine the electrons wave functions, leading to quantized energy levels and to a huge modification of the transport properties of the material. The hugely enhanced surface/volume ratio augments the role of surface states a crucial feature for gas sensor response and their high degree of crystallinity assures a high stability. SENSOR lab was the first to verify the gas sensor characteristics of these 1 D Structure [3,4]. Different ENs were built at SENSOR Lab either based on MOX gas sensor or specific SW both developed in the same lab (5,6)

Electronic Noses (EN) also called Electronic Olfactive System (EOS), in the broadest meaning, are instruments that analyze gaseous mixtures for discriminating between different (but similar) mixtures and, in the case of simple mixtures, quantify the concentration of the constituents. ENs consist of a sampling system (for a reproducible collection of the mixture), an array of chemical sensors, electronic circuitry and data analysis software.

In this contribution, we briefly illustrate the Pico EN, which, after being first designed at the Sensor Lab in Brescia has been developed and is now commercialized by the SACMI Company as *Electronic Olfactory System EOS*^{835} for industrial applications. We then illustrate two paradigmatic applications, to coffee analysis and to the monitoring of landfill sites. For the coffee analysis, we discriminate between single varieties of coffee of different origin and quality, which are then blended together in the commercial product. For the malodors, we distinguished between four odor intensities originating from different locations inside and near to the landfill site. For both applications, the EN data could be correlated with panels of trained judges. For the coffee, a global index (called Hedonic Index, HI) characterizing the sensorial appeal could be predicted with the EN, while for the landfill site the malodour intensity could be quantified.

We finally shortly review a couple of recent advancements at the border between artificial olfaction and robotics performed in other labs.

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