WO₃ NANOPARTICLE-FUNCTIONALIZED NANOWIRES FOR NO₂ SENSING

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Abstract

WO₃ has been proved to be a great material for NO₂ sensing [1,2]. This n-type semiconductor needs high temperatures, around 250 °C to operate in order to provide a fast response to the gas adsorption [2]. The sensing mechanism lies in the change of film resistance resulting from physisorption, chemisorption and reactions of NO₂ with the intergran boundaries of the WO₃ aggregates. The NO₂ adsorbed, even at low temperatures, on the semiconductor surface are thought to be ONO⁻ (nitrito type adsorbates) and dissociate into nitrosyl type adsorbates (NO⁺, NO⁻) [3]. These adsorbates act on the potential barrier of the grain boundaries improving the conductance of a thin film made of WO₃.

WO₃ nanoparticles (NPs), around 100-nm diameter (see figure 1, left image), have a great surface-to-volume ratio, so its sensitivity is thought to be higher than a thin film. The WO₃-based commercial devices present instabilities that need to be corrected by zeroing the sensor over time. These instabilities are a direct consequence of the charge and discharge of the capacitors associated to the grain boundaries. Therefore, the device design should be refined to minimize this effect. The use of a two adsorption-conduction separated region device may help to prevent these issues.

In our work, the crystal structure of the nanostructures was characterized. The NPs show an amorphous structure since no evidence of diffraction rays were found in the x-ray diffraction (XRD) scans. Energy-dispersive x-ray spectroscopy (EDX) studies show 1:3 stoichiometric compositions (see figure 1, right image). To fabricate the first sensors, the NPs are randomly dispersed on interdigitated electrodes. However, a better approach is also studied. Metal oxide nanowires can be functionalized with WO₃ nanoparticles through electrostatic or covalent bonds. The metal oxide nanowires (NWs) act as conductive channels whereas the WO₃ NPs perform as the signal transducers. The charge transfer from the WO₃ NP surface to the NW makes that the electrical current flows through the NW avoiding the grain boundaries. For the proof of concept of the device design, dielectrophoresis was used to align the functionalized NWs between electrodes, previously made by photolithography (see figure 2) [4]. Gas sensing tests are planned to evaluate the performance of this architecture as a potential sensor device.

References

Figures

Fig. 1: Scanning electron microscope of $\text{WO}_3$ NPs on a silicon wafer (left); EDX result showing the NP composition.

Fig. 2: Schematic view of the proposed sensor. The NW, dielectrophoretically aligned, is covered with $\text{WO}_3$ NPs (green circles), and acting as a conductive channel.