Creation of one-dimensional nanostructures based on zinc oxide

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•Abstract

One-dimensional nanostructured metal oxides present great potential for both research and practical applications. Due to their catalytic properties, high chemical and thermal stability, pronounced surface chemistry and biocompatibility, such nanostructures have attracted increasing research interest. Much attention is currently devoted to the development of reliable methods for producing such nanomaterials, which require specific growth conditions, including those based on alternative processes that exploit novel physical effects. Nanostructures based on zinc oxide are currently used in sensing applications and present interest as functional electrical contact materials. Pulsed-periodic laser irradiation is promising for the creation of zinc oxide-based nanomaterials.

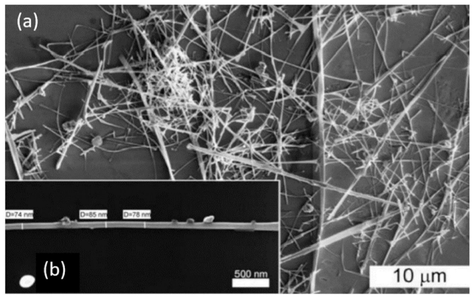

Figure 1. Synthesized SnO_2 nanowires using the gas transport method (a), and a single SnO_2 nanowire (b) [1].

Figure 5. Experimental setup for investigation: 1 – 1kW Rofin DC CO_2-laser; 2 – three-dimensional vibrometer Polytec® PSV-400-3D; 3 – optical system; 4 – Polytec PDV 100 measuring instrument; 5 – thermometer Kelvin LCM-1300; 6 – brass sample [5].

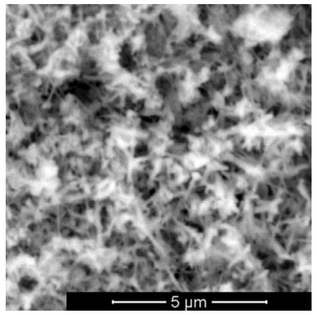

Figure 6. Image of ZnO nanowires formed on the Cu–Zn alloy surface after laser irradiation on the pre-etched material recorded on a scanning electron microscope [6].

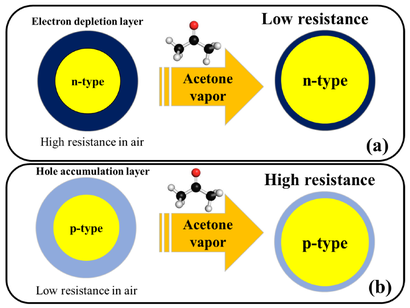

Figure 2. Schematic representation of the mechanism of acetone sensing in n-type (a) and p-type metal oxides (b) [2].

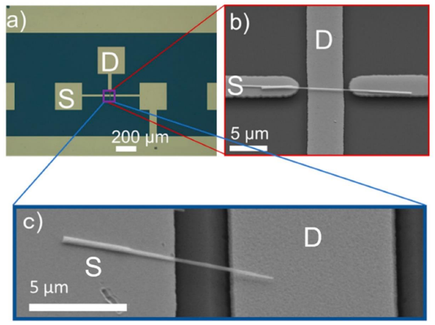

Figure 3. Optical microscope image of a device connected to a micropatterned gold electrode line that joins it with other devices (a); SEM image of a double-clamped single nanoelectromechanical switch device in an array of 2 µm wide electrodes (b); SEM image of a single-clamped nanowire in an electrically identical setup with wide (20 µm) DEP electrodes (c) [3].

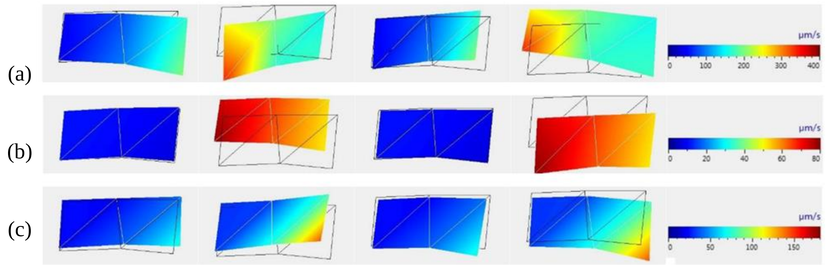

Figure 7. Images of samples and graphical displays of the magnitude of the vibration rate at each point of the sample at time intervals of a quarter of the oscillation cycle, obtained using PSV Presentation software that correspond to the frequencies of the sound range: 100 Hz (a), 200 Hz (b) and 300 Hz (c) [7].

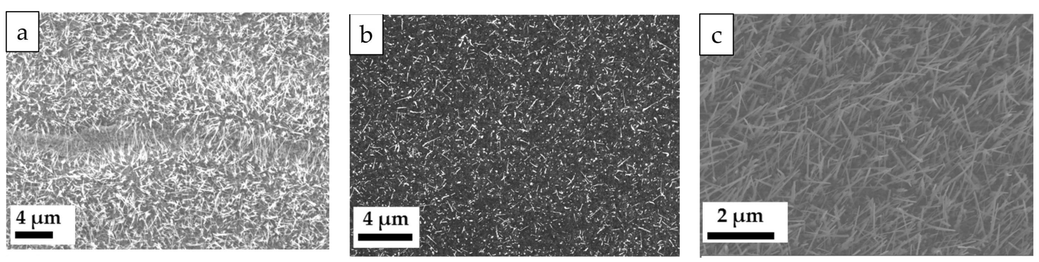

Figure 4. Scanning electron microscopy images of the copper foil (a), vapour deposited copper (b), and sputtered copper after the heat treatment (c) [4].

•Conclusion

Metal oxides and nanostructures based on them exhibit a wide range of exceptional functional properties. There are two main approaches for the production of arrays of one-dimensional oxide nanostructures on metal substrates. Gas-phase chemical synthesis, electrochemical deposition, vapour or liquid phase crystallisation and template synthesis methods are mainly used for the creation of thin films. The main disadvantage that limits the broad practical application of such methods, which are based on the enlargement of initial elements into one-dimensional nanostructures under the action of physical and chemical forces, is the difficulty of transferring and bonding the fabricated structure onto planar substrates. Nanolithography methods are characterized by a low productivity and high equipment costs, which also limit the area of their application.

Nanostructures based on zinc oxide are used in sensing applications and currently represent interest as functional electrical contact materials. For the synthesis of zinc oxide nanowires on conductive substrates of metallic materials, the use of pulsed-periodic laser irradiation is promising.

A nanomaterial based on ZnO nanowires was synthesized by means of periodic pulsed laser irradiation. A significant increase of the diffusion coefficient in the metallic material was identified. This can be explained by the synergy of thermal effects and laser-induced vibrations, mainly in the sound frequency range, resulting from pulsed-periodic laser irradiation. It can be assumed that this approach will be successful for the formation of metal oxides with a lower reactivity (iron), including those with a positive electrochemical potential (copper).

•References

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