

SURFACE SCIENCE APPROACH TO INDIVIDUAL QUASI-1D NANOSTRUCTURES: SPEM, X-PEEM, LEEM AND LEED ON SnO_2 NANOSTRUCTURES

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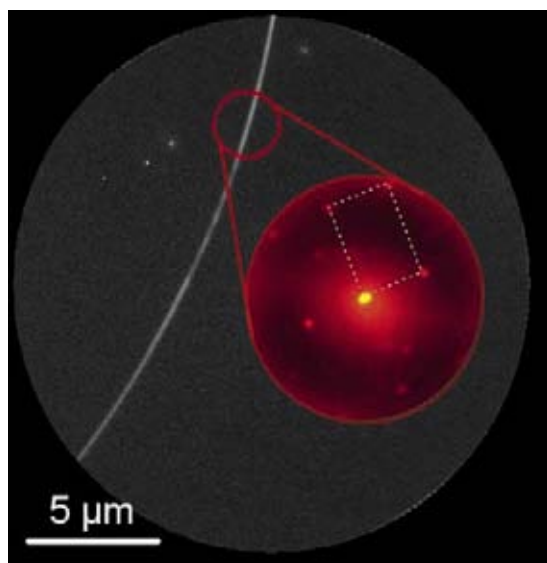
Figure 1.

(a) LEEM image (FOV 20 μm) and the micro-LEED pattern, corresponding to the (010) facet of the nanostructure
(b) XANES spectrum (violet) taken from individual SnO_2 nanowire, which contains features characteristic for the SnO (yellow) and SnO_2 (blue) compounds. The energy scale is offset with respect to the first maximum of $\text{Sn } 3d_{5/2}$.

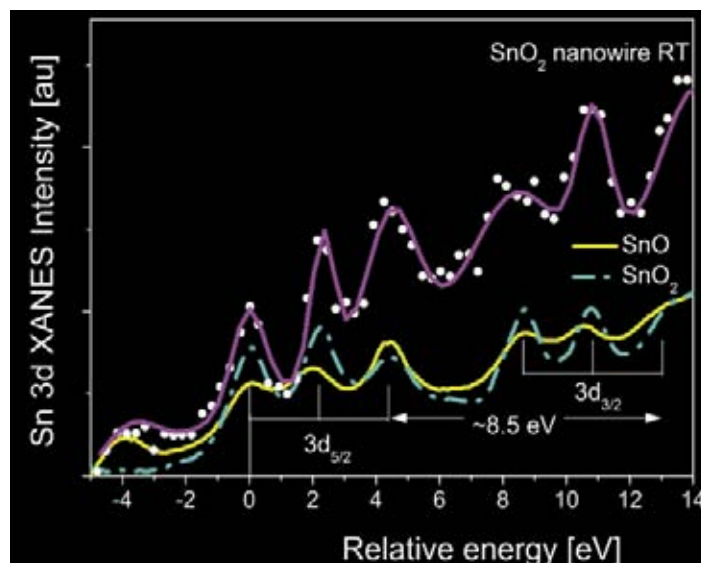
Metal oxide quasi one-dimensional nanostructures such as wires, belts rods and tubes are in the focus of intense research due to their unique potential for applications in the nano-(opto)electronics, chemical sensing and catalysis [1,2]. Due to the high surface-to-bulk aspect ratio of these materials, the surface structural and electronic properties play a dominant role, which has motivated the current rapidly growing communities exploring the modification of these properties by varying the size, defects density, doping level etc. In this respect surface sensitive electron spectroscopies are among the most appropriate methods, but they needed to step into microscopic world in order to probe *individual* nanostructures. Thanks to the ultra-bright and tunable photon beams provided by the synchrotron facilities the Scanning PhotoElectron Microscopy (SPEM) and X-ray Photoelectron Emission Microscopy (XPEEM) have become

amenable with the size domain of the nanostructures (10-100 nm) [3,4].

Using the SPEM and XPEEM instruments at Elettra in combination with structural sensitive Low Energy Electron Microscopy (LEEM) we explored the surface structure and chemical states of individual SnO_2 nanowires and nanobelts [4]. Figure 1a shows the LEEM image of a SnO_2 nanobelt and the micro-LEED pattern, which manifests the (010) structure of side facets comparable to the ones observed for SnO_2 rutile crystals. Figure 1b shows the XANES spectrum (violet) of the SnO_2 nanobelt, which contains overlapping features of SnO_2 and SnO phases, indicative for certain degree of oxygen deficiency. This was confirmed by Sn 3d and O 1s spectra measured on individual nanobelts with SPEM [4]. We also demonstrated the possibility to use SPEM for probing electron transport properties by imaging in-situ the

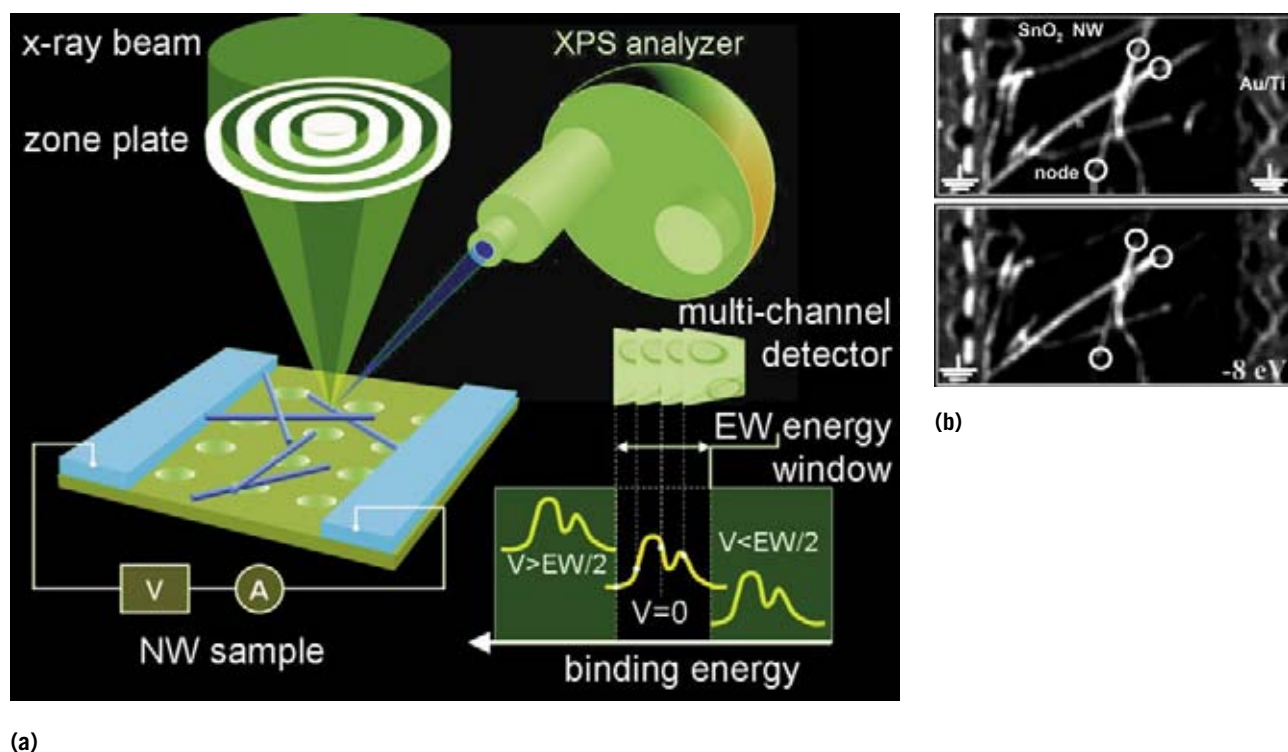


(a)



(b)

Figure 2. (a) Sketch of the device and the SPEM set-up for imaging the Sn 4d emission from the SnO₂ nanowire mats under variable bias conditions. (b) Sn 4d maps of the chemiresistor of percolating nanowires taken with grounded electrodes (top) and with right electrode biased at -8 V (bottom). The differences in the Sn 4d images are due to the presence of highly resistive nodes (marked with white circles), which impede even potential distribution along the nanowires. The caused rigid electron energy shift is beyond the energy window of the analyzer, tuned to the Sn 4d emission with grounded electrodes, which results in strong attenuation of the signal from certain nanowires.



nanostructures wired as active element of the chemiresistor device. Figure 2a shows a sketch of the fabricated chemiresistor gas sensing device: the SnO₂ nanowire network contacted by two electrodes. The support is a Si₃N₄ membrane with periodic holes, allowing the nanowires placed over the holes to be locally probed. The potential of SPEM for analyzing the charge distribution and transport properties is based on the correlation between the applied potential and kinetic energy of the emitted photoelectrons. The Sn 4d images in Figure 2b demonstrate that we can monitor the percolating character of the conductivity: the strong attenuation of the signal from certain wires when biasing one of the electrodes indicates their higher resistivity.

These pioneering results are opening new avenues to explore the effect of size and environment (e.g. gases and temperature) on the surface activity, electronic properties and functionality of nano-materials.

References

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