Individual single-walled carbon nanotubes for gas sensors: synthesis, localization, characterization and monitoring the device fabrication process

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This talk will address some challenges and their solutions related to fabrication of carbon nanotube-based gas sensors utilizing either substrate-bound or suspended individual single-walled carbon nanotubes (SWCNTs) as sensing elements.

SWCNTs were synthesized on SiO_2/Si chips or oxidized SOI MEMS structures from ferritin-based Fe catalyst nanoparticles by CH_4/H_2-CVD at 850°C [1]. Substrate-bound nanotubes were localized by AFM with respect to predefined markers. Positions of suspended CNTs were detected by optical microscopy utilizing deposition of volatile nanoparticles onto CNTs. In both cases nanotubes were characterized by Raman spectroscopy. For the optical microscopic visualization of nanotubes a para-nitrobenzoic acid (pNBA) based approach was used [2]. The visualization and characterization methods allows to select pre-characterized nanotubes with required specifications for further device fabrication.
Devices based on individual SWCNTs were fabricated either by standard photo- or electron-beam lithography, or by ultra-clean mechanical transfer from dedicated growth substrates onto the final device structures [3].
To identify the dominant impact of the fabrication process, selected SWCNTs were characterized by Raman spectroscopy after individual processing steps. By this approach, for example, the minimum thickness of sacrificial alumina layer required to protect SWCNTs from the impact of plasma ashing, used for removing lithography resist residuals [4], was determined. In the case of substrate-bound nanotubes, an application of the Raman monitoring of the CNFET fabrication lead to an optimized process flow producing devices with 8 times reduction of the variation of their electrical resistance and prolonging of the device life time, exceeding 90 days even for non-passivated contacts [5].

Finally, sensing ability of NO_2 at room temperature utilizing individual suspended SWCNT as transistor channel will be shown [6] as well as its cross sensitivity to humidity. The sensor recovery by channel self-heating consuming only about 3 μW that is enabled by the suspended device architecture will also be presented.

References:

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