Efficient Ammonia Sensors Based on Single Walled Carbon Nanotubes

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Carbon nanotubes (CNTs) have emerged as a promising alternative for highly efficient gas sensing technologies due to their remarkable properties like high surface to volume ratios and the possibility of doping or functionalization according to a specific application [1]. Single-walled carbon nanotubes (SWCNTs) based chemiresistor sensors for the detection of ammonia gas have been proposed and studied in recent years showing a sub-ppm detection limit at ambient conditions (room temperature and fixed humidity) [2]. Still, there are some contradicting arguments on how sensitivity of SWCNT-based sensors towards ammonia can be increased by means of SWCNT doping.
In this work, the fabrication and response of chemiresistor-type gas sensing devices based on networks of pristine single-walled carbon nanotubes (p-SWCNTs), boron-doped nanotubes (B-SWCNTs), nitrogen-doped nanotubes (N-SWCNTs), and semiconducting nanotubes (sc-SWCNTs) to sub-ppm concentrations of ammonia at room temperature was investigated.
All nanotubes were dispersed without surfactants and the doping was performed via introduction of N or B atoms into the host carbon lattice of nanotubes, not via on-surface molecular dopants.
Electrical characterization and analysis of the structure of fabricated devices showed a close relation between amount and quality of the distribution of deposited nanotubes and their sensing properties.
In addition, sensors based on sc-SWCNTs exhibited the highest sensing response to all NH_3 concentrations compared to pristine and doped SWCNTs and a limit of detection of 100 ppb was achieved (Fig. 1). Furthermore, the power consumption of these sensors is approximately 5 orders or magnitude lower than existing commercial ammonia sensors based on metal oxides [3]. Such sensitivity and low power consumption are relevant for applications like permanent remote environmental monitoring or the diagnosis of certain diseases based on the analysis of exhaled breath samples.

References

[1] E. Llobet, Sensors and Actuators B: Chemical, 179 (2013) 32-45.
[2] F. Rigoni et al, Analyst, 138 (2013) 7392-7399.
[3] L.A. Panes-Ruiz et al, ACS Sensors, 3 (2018) 79-86.

Figures

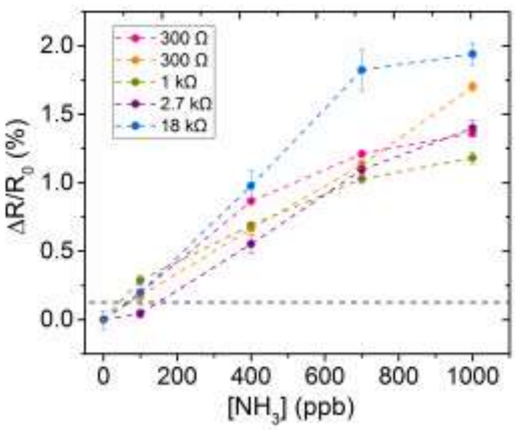

Figure 1: Sensing response $\Delta R/R_0$ of five devices based on sc-SWCNTs under exposure to different NH_3 concentrations of 100, 400, 700 and 1000 ppb [3].