Carbon Nanotube Based Chemical Sensors for Gas and Vapor Detection

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Purified single wall carbon nanotubes (SWCNTs) have been used as a sensing material in an interdigitated electrode platform for gas and vapor sensing. Due to extremely high surface-to-volume ratio, efficient gas adsorption occurs on the surface of the carbon nanotubes. The one-dimensional quantum wire nature[1] makes its electronic properties very sensitive to the gas molecules adsorption[2]. SWCNT based chemiresistors have demonstrated high sensitivity to gases and vapors such as nitrogen dioxide, benzene, nitrotoluene, ammonia and other chemical species.

Experimental:

a. Purification and characterization of SWCNTs[3]

SWCNTs produced by high pressure CO disproportionation (HiPco)[4] were purified with acid to remove the residuals of metallic catalyst and air oxidation at high temperature to remove the graphitic carbons. The final purified SWCNT has purity over 99.6%.

b. Fabrication of interdigitated electrodes

A wafer of interdigitaed electrodes with 8μm gap between fingers was fabricated using lithographic and metal evaporation method. The electrode was made from 20nm Ti and 40nm Au on a layer of SiO_2 thermally oxidized on top of a silicon wafer. See figure 1 for the details.

c. Sensor assembly

The purified SWCNTs were dispersed in DMF for a good suspension solution. 0.1μl of 3mg/L SWCNT-DMF solution was drop deposited onto the interdigitated area of the electrodes. After the DMF evaporated, a network type of carbon nanotube lays on the electrodes to bridge the fingers for conductivity measurement. See figure 2 for details.

d. Sensor testing and evaluation

The above assembled sensors were exposed to NO_2 at different concentrations and as well as nitrotoluene.

Results:

CNT chemiresistors have been exposed to NO_2 and nitrotoluene respectively at different concentrations. The results show that the CNT sensor gives larger response to NO_2 due to the higher bonding energy and larger partial electron transfer of CNT to NO_2. For the same reason, the recovery time is also slow because it takes high energy to pull the NO_2 molecules off the CNTs. In contrast, the sensor response to nitrotoluene shows faster and more reversible response. However, the response is smaller than for NO_2 due to weak bonds and less partial electron transfer between CNTs and nitrotoluene molecules. Figure 3 shows a CNT chemiresistor response to NO_2. From the experiment results, the detection limits are estimated in ppb for NO_2 and sub ppm for nitrotoluene. By vary the operating temperature, the higher sensitivity and faster response are expected. The sensor response and response time will be correlated to the operating temperature and the operating voltage.

Reference:

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[3] Marty Cinke, Jing Li, Bin Chen, Alan Cassell, Jie Han, and M. Meyyappan, Chem. Phys. Lett. 366 (2002) 69-74.
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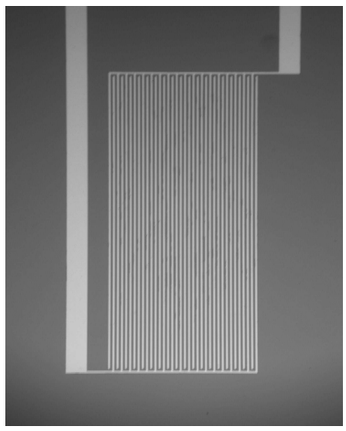

Figure 1 Interdigitated Electrodes

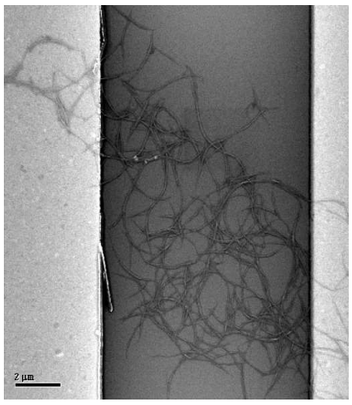

Figure 2. SWCNT across two electrodes

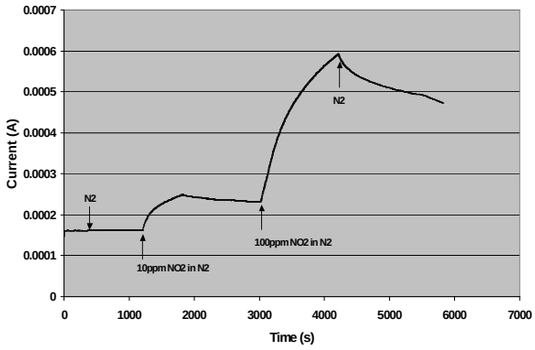

Figure 3. Sensor response to different concentrations of NO_2 at room temperature with flow rate of 500 ml/min.

[1] Eloret Corporation under NASA Contract: NAS2-99092