Gas Sensors Based on Coated and Doped Carbon Nanotubes

Large specific surface areas of nanotubes could enable attainment of high sensitivities.

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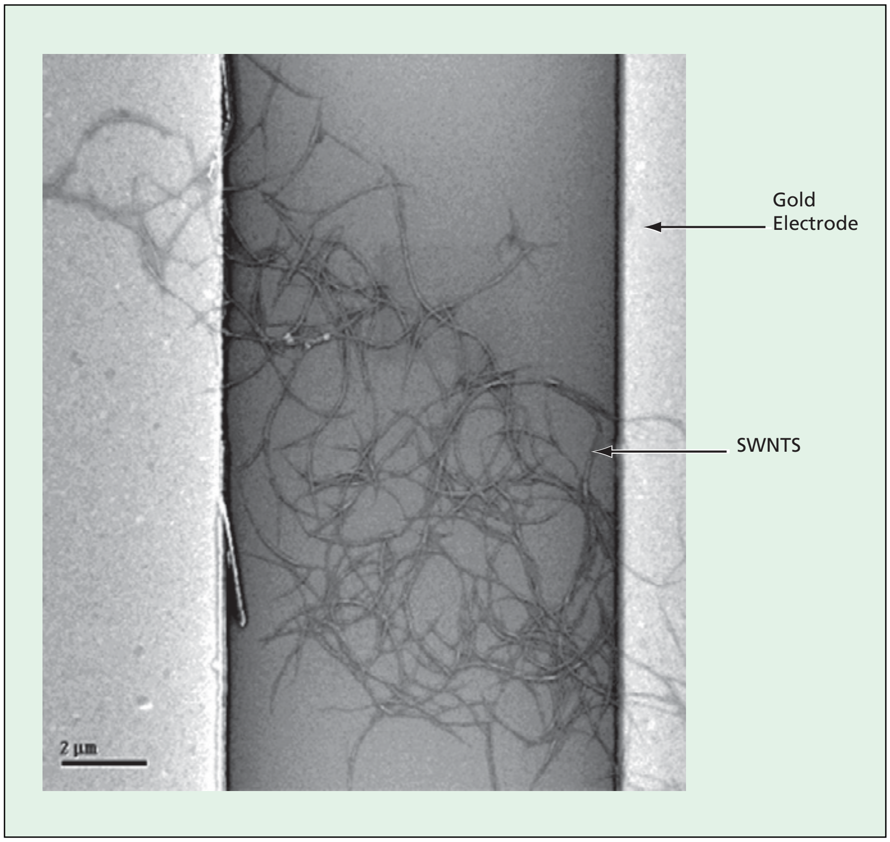
Efforts are underway to develop inexpensive, low-power electronic sensors, based on single-walled carbon nanotubes (SWCNTs), for measuring part-per-million and part-per-billion of selected gases (small molecules) at room temperature. Chemically unmodified SWCNTs are mostly unresponsive to typical gases that one might wish to detect. However, the electrical resistances of SWCNTs can be made to vary with concentrations of gases of interest by coating or doping the SWCNTs with suitable materials. Accordingly, the basic idea of the present development efforts is to incorporate thus-treated SWCNTs into electronic devices that measure their electrical resistances.

A typical sensor device based on this concept includes a set of interdigitated metal microelectrodes fabricated by photolithography on an electrically insulating substrate. In preparation for fabricating the SWCNT portion of such a sensor, a batch of treated (coated or doped) SWCNTs is dispersed in a solvent. The resulting suspension of SWCNTs is drop-deposited or injected onto the area containing the interdigitated electrodes. As the solvent evaporates, the SWCNTs form an irregular mesh that connects the electrodes. The density of the SWCNTs in the mesh can be varied by varying the concentration of SWCNTs in the suspension and/or the amount of suspension dropped on the electrode area. To enable acquisition of measurements for comparison and to aid in calibration, undoped SWCNTs can be similarly formed on another, identical set of interdigitated electrodes.



A **Mesh of SWCNTs** bridges the gap between two gold electrodes in an experimental sensor device.

Examples of coating materials that have been tested thus far include chlorosulfonated polyethylene (which imparts sensitivity to chlorine) and hydroxypropyl cellulose (which imparts sensitivity to hydrogen chloride). Examples of dopants that have been tested are Pd nanoparticle doped SWCNTs (which imparts sensitivity to methane) and other dopants include clusters of nanoparticles of catalytic metals — for example, Pt and Au for sensing hydrogen and hydrocarbons or Cu and Rh for sensing nitric compounds.

Although the response of a sensor of this type is a generally monotonic function of the concentration of a gas species of interest, it is not always a linear function, sometimes it is a linear function to the logarithmic concentration. Moreover, a given sensor can be sensitive to more than one gas, and the sensitivities to different gases can be expected to differ. In a typical contemplated application, a device would incorporate multiple sensors, each tailored to maximize its response to a specific gas or family of gases, and the sensor would be operated in an environment containing a mixture of gases. The readings of the sensors would be digitized and processed by algorithms for differentiating the gases and estimating their concentrations or at least limits on the concentration of a gas species of interest in the face of the nonlinear responses to the various gases that may be present.

This sensor technology has been developed to readily scale up for mass production with high yield and good reproducibility. The sensing device can be used for *in-situ* air monitoring, wireless network sensing, and in-line chemical detection.

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This invention is owned by NASA, and a patent application has been filed. Inquiries concerning rights for the commercial use of this invention should be addressed to the Ames Technology Partnerships Division at (650) 604-2954. Refer to ARC-15566-1.