Spatial, Temporal, and Chemical Aspects of Vapor Detection Using Conductive Composite Chemically Sensitive Resistors

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Abstract

We have investigated the vapor response properties of chemically sensitive thin film resistors prepared from conductor-insulator composites. A new sensor type was developed from alkylamine-capped gold nanocrystals, and films of this composite, which are composed of nanometer-scale gold cores separated by regions of insulating alkylamine chains, exhibit small reversible resistance increases upon exposure to vapors such as water, acetone, or toluene. However, these films exhibit large irreversible resistance decreases in exposure to vapors possessing the thiol (-SH) functionality. The resistance change is shown useful for determination of the mercaptan concentration, and readily permits the detection of methylmercaptan at concentrations as low as 4 ppb (parts per billion), and hydrogen sulfide at concentrations as low as 9 ppm (parts per million). We have also investigated the geometric, spatial, and temporal response properties of chemically sensitive resistors prepared from polymer-carbon black composites in exposure to common organic vapors. The reversible resistance responses of these detectors were evaluated with short rise-time pulses of vapor, and detectors formed from very thin (< 200 nm) films of polyethylene-co-vinyl acetate (PEVA)-carbon black composites produced steady-state responses within 17 ms for methanol exposures and within 90 ms for toluene, acetone, or n-hexane. In accord with Fickian diffusion, the response times of PEVA-carbon black detectors were proportional to the square of the film thickness, l, in the range $510 \leq l \leq 5700$ nm, and the response vs. time profiles were well fit by a simple finite difference model based on Fickian diffusion. The temporal response also provides useful information for the identification or discrimination of solvent vapors beyond that available solely in the steady-state response employed in previous studies of this sensor type. We also demonstrate that there is an optimum detector volume to produce the highest signal/noise ratio for a given composite when exposed to a fixed volume of analyte vapor, and we show that useful information and optimizations can be obtained from the spatiotemporal response profile of an analyte moving in a controlled path across an array of chemically identical, but spatially nonequivalent, detectors.

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