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Volatile Organic Compound Detection Using Nanostructured Copolymers

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ABSTRACT

Regioregular polythiophene-based conductive copolymers with highly crystalline nanostructures are shown to hold considerable promise as the active layer in volatile organic compound (VOC) chemresistor sensors. While the regioregular polythiophene polymer chain provides a charge conduction path, its chemical sensing selectivity and sensitivity can be altered either by incorporating a second polymer to form a block copolymer or by making a random copolymer of polythiophene with different alkyl side chains. The copolymers were exposed to a variety of VOC vapors, and the electrical conductivity of these copolymers increased or decreased depending upon the polymer composition and the specific analytes. Measurements were made at room temperature, and the responses were found to be fast and appeared to be completely reversible. Using various copolymers of polythiophene in a sensor array can provide much better discrimination to various analytes than existing solid state sensors. Our data strongly indicate that several sensing mechanisms are at play simultaneously, and we briefly discuss some of them.

The demand for low-cost, low-power, and portable volatile organic compound (VOC) detection is increasing dramatically due to the need for environment monitoring, space exploration, homeland security, agriculture, and medical applications.[1−3] Sensing devices are needed for stand-alone operation as well as building blocks for sensor network systems. One of the most difficult challenges is to find specific materials that have both high sensitivity and good selectivity to the substances to be detected. An array of chemical sensors, where each array element is a different chemically selective material, can potentially provide a combinatorial response that can be used to not only detect but also identify specific analytes. While there has been a lot of success in sensor development for greenhouse gases (CO_2, CH_4, N_2O, NO, and CO), technology for detection of VOCs remains a weak point. Existing VOC-sensing materials includes semiconducting metal oxides,[3−6] conductive polymers (CPs),[7−12] and carbon black−polymer composites.[13,14] Metal oxide materials such as SnO_2 and ZnO, have been widely used in commercial chemical vapor sensors. A big drawback of these materials is limited selectivity to various VOCs and the required high operating temperature (200−500 °C).[3] Carbon black−polymer composites have also attracted a lot of research interest as a promising sensing material system. The different gas−solid partition coefficients of different polymers to various analytes are believed to generate swelling-induced conductivity changes between carbon black particles via a percolation concept.[13] Therefore, these materials generally show similar responses (increased resistance) to all tested analytes. Conductive polymers with alternating single and double carbon−carbon bonds have recently attracted extensive research interest for sensor applications.[15,16] Of the conductive polymers, regioregular poly(3-alkylthiophene)s are very promising due to their high electrical conductivity and their large number of possible chemical variants. Indeed, extended chemical selectivity may be achieved by molecular structure modification. Furthermore, their solution solubility enables the possibility of using ink-like printing as a batch process for electronic device fabrication.[17−19]

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