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Inkjet printed chemical sensor array based on polythiophene conductive polymers

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Abstract

Multiple regioregular polythiophene polymers with a variety of side chains, end groups and secondary polymer chains were used as active sensing layers in a single chip chemresistor sensor array device. A custom inkjet system was used to selectively deposit the polymers onto the array of transduction electrodes. The sensor demonstrated sensitivity and selectivity for detection and discrimination of volatile organic compounds (VOCs). The conductivity responses to VOC vapors are dependent on the chemical structure of the polymers. For certain VOCs, conductivity increased in some polymers, while it decreased in others. Principal component analysis (PCA) of sensor responses was used to discriminate between the tested VOCs. These results are correlated to the chemical structures of the different polymers, and qualitative hypothesis of chemical sensing mechanisms are proposed. This research demonstrates the potential for using such devices in VOC detection and discrimination sensing applications.

Keywords: Chemresistor; Gas sensing; Inkjet printing; Polythiophene; Volatile organic compounds

1. Introduction

The development of a low cost, low power and portable device for detection and identification of volatile organic compounds (VOCs) is needed for applications such as homeland security and monitoring of agriculture, medical, and manufacturing environments [1–9]. One of the most difficult challenges is to find sensing materials that have good sensitivity and robust selectivity to the substances to be detected. While there has been some success in sensor development for greenhouse gases (CO_2, CH_4, N_2O, NO and CO), the technology for the detection of VOCs remains challenging due to the similarities in chemical composition and structure between the small VOC molecules. For one example, semiconducting metal oxide sensors, which are based on chemical oxidizing and reducing reactions between the oxygen ion and analytes at elevated temperatures (300–500 °C) [1,10], are limited because VOCs generally have similar reducing reaction energies. For another example, carbon black composite materials operate based on swelling of the polymers by the absorbed analytes, which increases the space between carbon particles, leading to a decrease in conductivity upon exposure to VOCs [7,11]. This percolation-based sensing mechanism has been a limiting factor for these materials because it is restricted to a single sensing modality that has similar responses to many VOCs.

Conductive conjugated polymers are a relatively new class of VOC sensing materials that show considerable promise to overcome these limitations. First, their chemical composition is similar to VOCs, which may induce physical interactions between sensing materials and analytes, leading to new sensing mechanisms [2]. Second, their chemical structures are readily modified, which enables custom material designs with specific selectivity to target analytes. And third, unlike the semiconducting metal oxide sensors, the sensing operation occurs

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