A study on fully inkjet-printed chemiresistive gas sensor matrix

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論　文　内　容　の　要　旨

This research is mainly about the development of functional inks and the fabrication of fully printed gas sensor matrices using these functional inks.

In chapter 1, I introduce the application scenarios of gas sensors, existing gas sensing technologies, thin film fabrication methods and some common flexible substrates. The main object of this study is to realize the fabrication of large-scale sensor matrices on flexible substrates and further make the sensor matrices selective for VOCs.

Chapter 2 describes the dispersion effect of carbon black in different solvents with different dispersants. The preparation method of polymer carbon black ink that can be used for home inkjet printing is introduced in detail. Through a home printer, full inkjet printing of a sensor array containing 8 sensors was achieved. In addition, through experiments, it was found that some polymers and salts mixed with carbon black can be used to make gas sensing layers. This provides sufficient material for developing more sensors with different characteristics in the future.

In Chapter 3, I report a novel full printing process for fabricating chemiresistor gas sensor matrixes on photographic paper with an inkjet printer. Sensor matrices, which can increase the number of sensors significantly compared with a serial sensor array, were printed on one piece of A4 photographic paper. Each sensor matrix contains 36 interdigital electrodes in an area of less than 11 mm2, which greatly improves the density of the sensor. The basic architecture of the sensor matrix is electrodes that row and column intersecting. In order to insulate the row and column electrodes from meeting each other, an insulating layer needs to be fabricated at the point of intersection between the row and column electrodes. The insulation layer was produced by adjusting the number of printing passes and shape of the printing pattern of color pigment ink. Carbon black was used to form conductive composites by changing its resistivity with a specific polymer for the preparation of sensing material. In order to make the sensing material can be printed, it is necessary to disperse carbon black first. Carbon black was dispersed in aqueous solution with sodium dodecyl sulfate added as a surfactant to lower the surface tension, which enabled printing of carbon black using an inkjet printer. Some polymers have certain adsorption characteristics for gases. According to the different gas properties, the adsorption characteristics are also different. By adding polyethylene glycol polymer to the carbon black layer, the response to four gases with different properties is improved. Compared with the drop coating, the full-printing sensors not only reduces the production time

significantly, but also improves the gas response magnitude to ethanol by about 3 times. The results demonstrate that the developed sensor can be used as a low cost, disposable, and easily printable chemical sensor.

In chapter 4, a method was used to fabricate a fully inkjet-printed gas sensor matrix on photographic paper. An electrode matrix comprising 36 interdigital electrodes in a high-density layout that is easy to integrate has been fabricated using a combination of insulating ink and commercial silver ink. Molecular imprinted polymer (MIP) inks were then made using a simple solution mixing method, and these inks were printed together with carbon black ink on the electrode matrix to complete production of the sensor. Finally, experimental dynamic sensing of volatile organic compounds verifies that for detection of gases corresponding to the MIP template molecules, the MIP layer offers improvements in both sensitivity and selectivity when compared with non-imprinted polymer layers. The matrix can produce a response of more than 20% to 3 ppm propanoic acid gas through adjustment of the printing times for the carbon black layer and the MIP layer.

In the last chapter, the research is summarized, and the possible research prospect is proposed.