PRINTED RESISTIVE GAS SENSOR ARRAY FOR WEARABLE DEVICE

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In this research, to meet the growing need of wearable electronic devices, a low cost and low energy consumption gas sensor array chip combined with printed electrodes and flexible substrate is developed. Eight different layouts are designed and the relation between sensitivity and electrode gap is discovered through the testing responses to different concentrations of ethanol and methane.

The flexible gas sensor integrated to wearable device can monitor those harmful volatile organic compounds and explosive gases real-time in our daily life and be part of the Internet of Things (IoT) [1]. To achieve the ideal using condition and lower the price, resistive gas sensor array using polymer and carbon black mixture as sensing material may be the best choice due to the advantages of low cost, easy coating and room temperature operation.

The principle of sensing mechanism is shown in Fig. 1. After drop coating a thin layer of polymer and carbon black mixture on the electrodes, when exposing in vapor, the expansion of polymer enlarges the distance among carbon blacks which will change the overall resistance. The ability of measuring gas can be derived by analyzing the resistance change stemmed from the adsorption of the gas molecules by the polymer, which is a reversible physical reaction [2].

The sensor array containing seven sensors is shown in Fig. 2. It can be coated with different polymers so that every polymer will response to gas differently. The goal of identifying gases can be reached by calculating the resistance change with statistical analysis. Eight different combinations of electrode's width/gap are designed indicated in Fig. 2 (20μm/20μm、20μm/30μm、30μm/30μm、30μm/45μm、40μm/40μm、40μm/60μm、50μm /50μm、50μm/75μm). The chip shown in Fig. 3 is fabricated by gravure printing on the flexible substrate polyethylene terephthalate (PET). The gas measuring system setup is shown in Fig. 4. Ethanol vapor is produced by the gas generator and methane is came from the gas cylinder.

One of the developed sensing materials polyvinylpyrrolidone (PNVP) is coated on the seven-sensor array to do the preliminary check on uniformity of each individual sensor. The resistance of the sensors increases upon exposing in ethanol shown in Fig. 5(a) but decreases in methane oppositely shown in Fig. 5(b). By this obviously different characteristic, it's fairly easy to identify these two kinds of gases. The standard deviation of the responses for the seven sensors is below 5%. Furthermore, to find out the optimized layout design and do the following experiment, eight different layout design chips are used to test different concentrations of ethanol shown in Fig. 6. The results show that the smaller the gap, the higher the sensitivity. Sensors with electrode width/gap: 20μm/20μm have the highest sensitivity and the limit of detection (LOD) is about 50ppm, which is low enough to apply in drunk driving test. For the methane test shown in Fig. 7, electrode width/gap: 20μm/20μm sensors have the highest sensitivity as well and the LOD is about 36ppm.

Word Count: 493

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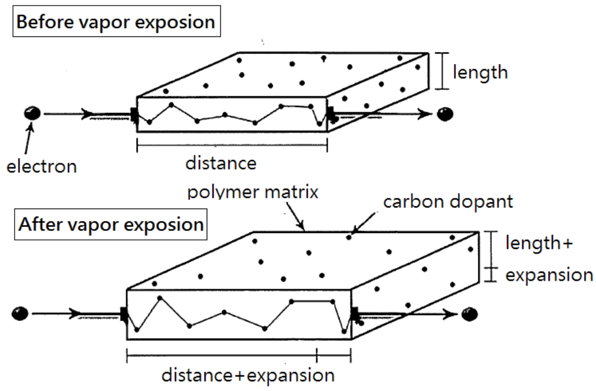

Fig. 1 The mechanism of resistive gas sensor using polymer and carbon black mixture as sensing material.

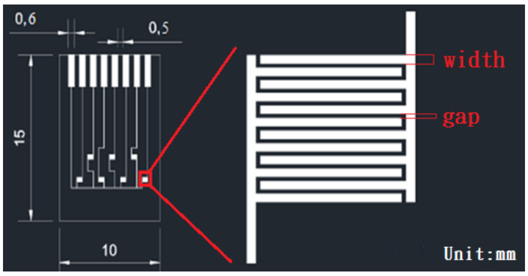

Fig. 2 Sensor chip layout and the magnified interdigitated electrode with line width and electrode gap illustrated.

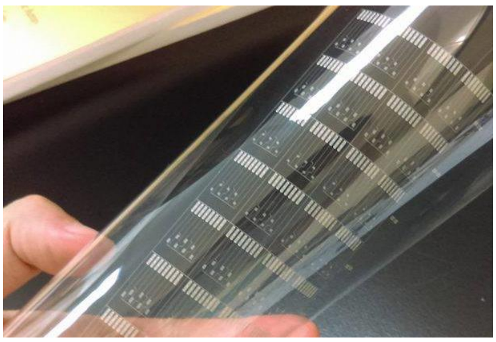

Fig. 3 The gas sensor array printed on PET.

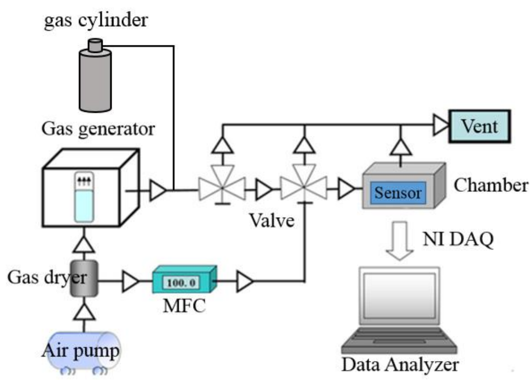

Fig. 4 Gas measuring system setup.

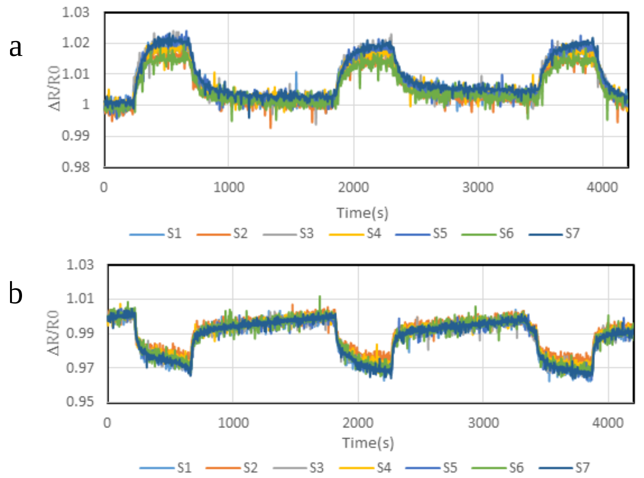

Fig. 5 When the sensor is coating with PNVP, (a) resistance increases upon exposing in ethanol and (b) decreases in methane on the contrary.

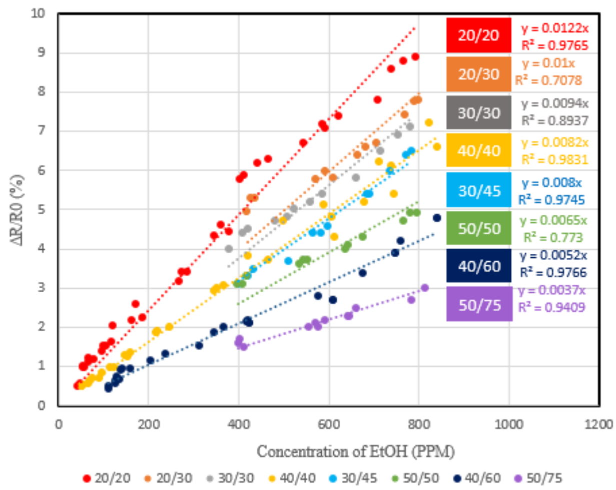

Fig. 6 The sensitivity of different layout sensors with response to ethanol concentration. The numbers indicate line width/electrode gap (μm).

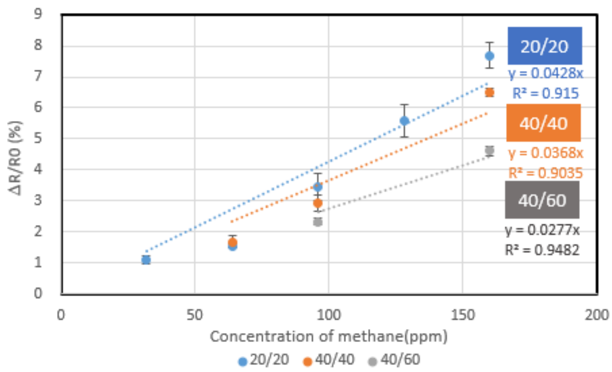

Fig. 7 The sensitivity of different layout sensors with response to methane concentration. The numbers indicate line width/electrode gap (μm).