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Enhanced H_2S Sensing Properties at Room Temperature of Printed In_2O_3-Based Sensors for Food Quality Control Applications

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Extended Abstract

Hydrogen sulfide (H_2S) is one of gases that evolves as a degradation product from organo-sulfur rich foods [1]. Depending on the H_2S concentration level, it can be a potential bio-marker for food quality control applications [2]. Consequently, H_2S sensors can be valuable as odour sensing systems (or as called electronic nose) in the growing food industry. Such sensors are in development since decades [3]. However, challenges persist prior to their practical deployment in food packaging for various reasons. Briefly, promising sensors must possess excellent sensitivity and selectivity performances toward H_2S gas in ppb levels at ambient conditions, a good anti-humid property, a high chemical stability against harsh environments, and good mechanical properties to resist deformation.

In this area, we recently introduced a printed and flexible H_2S sensors that we prepared from an easily prepared nanocomposite mixtures of indium oxide (In_2O_3), graphite flakes (Gt) and polystyrene (PS) [4], [5]. We engineered our sensors by employing In_2O_3 as the sensing material, Gt flakes to enhance their electrical property, and PS binder to improve their mechanical flexibility. Namely as standard sensors, they showed an excellent sensitivity toward 100 ppb H_2S gas at room temperature while being resistant to humidity changes up to relative humidity (RH) $\approx$ 90%. We ascribed the superior sensing improvements to additional benefits for the Gt flakes and the PS binder. Both additives contributed equally to enhance the In_2O_3 NPs distribution in 3D structure with improvement on the surface-to-volume ratio. Besides, they improved the anti-humid property for the sensors owing to their hydrophobic nature. The sensing mechanism for these sensors depends mainly on the sulfuration and/or partial sulfuration of In_2O_3 owing to their reaction with H_2S gas to form indium sulfide (In_2S_3), which is conductive and responsible to decrease the sensor resistance (R_{gas}) compared to their resistance in air (R_{air}) before exposure to H_2S gas..

Although the promising achievements, we believe modifications on the sensing performance for sensors are still a necessity to reach the recommended requirements for food quality control applications. Therefore, we further enhanced the sensors sensing performance by adding a modifying additive of copper acetate (CuAc) powder. CuAc can convert to copper sulphide (CuS) owing to reaction with H_2S gas [6], [7]. Whereas standard sensors (without CuAc) showed a response of 2 after 25 minutes of exposure to 100 ppb H_2S gas (detection limit). The modified sensors (with CuAc) exhibited a significant sensing performance with a detection lower than 100 ppb (<100 ppb) of H_2S gas at room temperature. At 100 ppb, the modified sensors showed a response of $\approx$ 18 (9 folds higher than standard sensors) after 60 seconds of exposure to H_2S gas at room temperature. Furthermore, the modified sensors showed superior selectivity toward H_2S gas than the standard sensors when evaluating against various hazardous vapors. Here, we believe the key change on the sensing mechanism for the modified sensors is related to the formation an ohmic contact between CuS (after exposure to H_2S) and In_2O_3, which leads to enhance the conductivity of nanocomposite layer. Therefore, a remarkable reduction on R_{gas} can be recorded.

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