Materials Science & Engineering Doctoral Defense

High Performance Semiconductor Gas Sensors

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Abstract

There are increasing demands for gas sensors in air quality and human health monitoring applications due to rising awareness regarding the impact of environmental pollution on health. The qualifying sensor technology must be highly sensitive towards parts-per-billion (ppb) level gases of interest, such as CO, H2S, and volatile organic compounds (VOCs). Moreover, the new applications require the sensors to be incorporated into wireless Internet of Thing (IoT) system or portable consumer electronics, hence the sensors must also be miniaturized in size, extremely energy efficient, and low cost. Among the commercially available sensor technologies, conductometric gas sensors with semiconductor metal oxides as sensing materials hold significant advantages in cost and device size. Moreover, because semiconductor gas sensors often respond to a broad range of gases, their sensor arrays generally possess good cross-compatibility, which is desirable when the identification of certain gas combinations is more critical than the absolute concentration. However, before the widespread adoption of semiconductor gas sensors in air quality and human health monitoring, there are major challenges including power consumption, sensitivity, humidity interference, and stability. In this thesis, the effect of bulk doping on the thermal stability of tin (IV) oxide sensor was first investigated. Secondly, a new type of room temperature, versatile deposition technique to fabricate sensing film consists of monolayers of ordered one-dimensional zinc (II) oxide nanowires, and two-dimensional copper (II) oxide nanosheets was developed to unlock the device's potential in energy efficiency and sensitivity. To complement the new deposition technique, a low power micromachined hotplate was designed and fabricated. Moreover, a sensing mechanism study on the humidity influence on H2S detection was performed to gain more fundamental understandings of the role of the hydroxyl group in the surface reaction. Lastly, a semiconductor sensor array was developed to analyze the composition of gas mixture dissolved in transformer oil.

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