Semiconductor Metal Oxide Based Gas Sensors Towards Monitoring of Environment and Human Health

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ABSTRACT:

Semiconductor metal oxide (SMO)-based chemiresistive gas sensors have gained significant interest due to their ability to selectively detect hazardous gases and volatile organic compounds (VOCs) amidst interfering gases. These sensors are particularly promising for non-invasive breath analysis for early disease detection and for monitoring indoor and outdoor air quality. The major components of exhaled breath are N_2 (~ 79%), O_2 (~ 14-16%), and CO_2 (~ 4-6%). Although it also has about 1000 additional gases and volatile organic compounds (VOCs) in it, the majority of which are present in trace amounts (in ppm, ppb, ppt levels). Certain gases and volatile organic compounds (VOCs) have been recognized as indicators for various diseases and irregular physiological states such as diabetes, kidney disorders, and diverse types of cancer. SMO-based sensors offer high sensitivity and selectivity at room temperature, addressing this issue. My doctoral research focuses on developing diverse chemiresistive gas sensors using pure, doped, and heterojunction metal oxides and studying how dopants and heterojunctions enhance gas sensing performance in these materials. The whole thesis consists of eight different chapters which includes general introduction, literature review, five original research works, comprehensive collusion and future research scopes. In first research work, aluminium (Al) and yttrium (Y) were used as strategic dopant in ZnO crystal. The Al and Y- codoped ZnO based sensor exhibited enhanced sensitivity towards trace ethanol. Role of defect states, elevated surface area, particle size in enhancing the sensitivity of the codoped ZnO system were discussed in detailed. In second work, Li doped ZnO based ammonia sensor was fabricated. Herein this work ammonia sensing mechanism was explained from theoretical point of view through Density Functional Theory (DFT) calculations. For later work in thesis ferrite materials were explored. The third and fourth research work focuses on the synthesis of perovskite yttrium ferrite in various different crystal phase. In third part, formalin sensor was prepared for indoor air quality monitoring using hexagonal Yttrium ferrite. Subsequently in fourth work highly sensitive and selective acetone sensor was fabricated from orthorhombic $YFeO_3$. The improved acetone sensing capabilities of orthorhombic Yttrium Ferrite (YFO) are elucidated through quantitative phase analysis, and the bivalency of iron. Experimental results also verified through DFT. In the fifth research work heterostructure between metal oxide and ferrite (ZnO-$ZnFe_2O_4$) was synthesized for fabricating CO sensor. Advantages of heterojunction composite over the pristine metal oxides in gas sensing activity is discussed in detailed here in this part from both the experimental and theoretical point of view.

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