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a-ITZO based thin film transistor for ammonia gas sensing: a simulation study

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Abstract

This work is an optimization study by numerical simulation of the performance of amorphous indium tin zinc oxide thin film transistor (a-ITZO TFT) based gas sensor using SILVACO-ATLAS software. The optimization process is focused on the catalytic source/drain electrode, dielectric material and work-function difference. Based on simulation results, when the electrode material is switched from cobalt to molybdenum, the value of drain current was found to be increased from 39 μA to 231 μA. For molybdenum, ruthenium and cobalt with a work function difference of 200 meV, the OFF state current sensitivity (S_{IOFF}) and ON State current sensitivity (S_{ION}) values were found to be 607.27 and 213.2, 102.81 and 0.35 and 0.015 and 0.90 respectively. An increase in the sensitivity of simulated structure was observed with the value of work function difference that indicates an increase in the concentration of gas. The impact of the dielectric material also reveals that high-*k* dielectric materials boost the sensitivity of the proposed device. The simulation results confirm the a-ITZO TFTs potential in gas sensing applications.

1. Introduction

The 18th century saw the beginning of a new age of development brought on by the industrial revolution, and the years that followed saw a quickening of both industrialization and urbanization. As a result, in the 21st century, the air quality has deteriorated to hazardous levels, contaminating the environment and endangering biodiversity (Global Warming) [1, 2]. To safeguard flora and fauna, it is essential to monitor pollutant gas concentration levels. For this purpose, sensors can be very helpful. Gas sensor can detect minute amount of gas or any other particular form of gaseous emission in a specified area. It can be employed in industrial applications, medical applications, firefighting and environmental monitoring to detect combustible, flammable, toxic, and nontoxic gases. Various gases like ammonia (NH_3), Volatile Organic Compounds (VOCs), Carbon monoxide (CO), Carbon dioxide (CO_2), aerosol, NOx etc can be detected using gas sensors [3–5]. Among these, ammonia is utilized for specialized applications such as air conditioning, refrigeration, and water filtration. However, it is also one of the most dangerous toxic gas and can cause severe burns, lung/throat infections, and lifelong blindness [6, 7]. The production of ammonia on a global scale has increased linearly with 150 million metric tons in 2021, according to Statista's 2022 reports [8]. Also, Occupational Safety and Health Administration has set a 35 ppm for 15-minute acceptable exposure limit for ammonia. Furthermore, according to the American Conference of Government Industrial Hygienists, an individuals threshold limit value for ammonia is 25 ppm for an 8-hour weighted time average [9]. Therefore, a rapid and real-time sensor is required to detect ammonia in atmosphere at room temperature. Ammonia can be detected using a variety of gas sensing mechanisms including catalytic, electrochemical, optical, acoustic, and thermal conductivity. Prior research