Integrated Optical Gas Sensors on Silicon-on-Insulator Platform

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ABSTRACT

A wide range of applications such as environmental pollution monitoring, industrial process & explosion control, and forensic breath analysis heavily rely on gas sensors.

Optical gas sensors are becoming attractive compared to other competitive technologies, such as electrical gas sensors, for various reasons. Robustness, multiplexing of sensor arrays, safety, remote sensing and low power consumption are among those interesting features about the optical sensors.

Optical structures fabricated on the silicon on insulator (SOI) platform have recently been proving to be promising for various integrated optical application. These structures have been demonstrated with submicron scale features and can be realized on a very small area on a chip owing to the high index contrast between the waveguides and the surrounding claddings. Moreover, the compatibility of the SOI devices to CMOS fabrication tools and the promise of inexpensive mass fabrication make them highly attractive. Owing to these facts, the research on SOI optical structures is recently extending beyond the telecom to other applications such as optical bio-molecule and gas sensing.

Optical gas sensors can be realized with the aid of transducer chemical coatings on optical circuits. A proper choice of both the sensitive optical component and the chemical coating can lead to a significant enhancement in the sensor response. Chemical coatings made from metal oxides have been extensively studied for electrical gas sensing applications. However, not much work has been done with regard to their potential for optical gas sensing especially at integrated level. We demonstrate the promise of a reasonably sensitive, compact and inexpensive optical gas sensing route using metal oxide coatings on SOI micro-ring resonators (MRR). Two reasonably sensitive gas sensors, namely, a hydrogen sensor and an ethanol sensor based on SOI microring resonators are experimentally investigated in this work.

The hydrogen and ethanol vapor sensors are implemented using two different sensing principles. A catalytic Pt doped WO3 film is coated on silica clad micro ring resonator for hydrogen sensing. The heat generated from the combustion of hydrogen in air modifies the effective index of the guided mode in the underlying ring resonator through thermo-optic effect. MRR resonance shifts higher than 1nm are measured for hydrogen concentrations below the lower explosion limit (LEL).

The ethanol sensing relies on a rather different principle. In this case, a Porous ZnO film is coated on SOI ring resonator. The ZnO film refractive index changes on ethanol vapor adsorption at room temperature. The MRR resonance wavelength is, as a result, shifted to longer wavelengths via evanescent field interaction with the film. The detection of 100ppm Ethanol vapor concentration is experimentally demonstrated and a detection limit of 25ppm is predicted with such a sensing configuration.