SOI sensing platforms optimized for water vapour and light detection

Keywords : Environmental sensors; CMOS circuits; Simulation; Measurements.

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Abstract – Miniature systems are highly required for in-situ monitoring of the environment, industrial processes... In this context, we develop two low-power sensors in SOI CMOS technology, with large temperature working range.

We report here the performances of two sensors based on the same micro-machined silicon-on-insulator (SOI) suspended platform [1]. Our motivation is to develop a low-cost, low-power and reliable sensor microsystem with integrated electronics interface for applications from ambient to high temperature (200 °C) [2]. Figure 1 presents the three functions embedded on the platform: (1) gas sensing with top electrodes, (2) heating with tungsten resistor for layer activation, drying, cleaning, temperature dependence cancellation and (3) diode for temperature and light measurements.

A water vapour sensor is based on coated electrodes embedded with its own temperature sensor. It exploits an atomic layer deposited 25nm-thick Al_2O_3 coating, in opposite to conventional polymer-based humidity sensors. The %RH variations are capacitively sensed, then converted to oscillating voltage period variations with a 200μW low power consumption. Figure 2 shows the sensor output under temperature and humidity variations from 25 to 85 °C and 35 to 95%RH. At 25 °C, the sensitivity to humidity is equal to ~2.5%/%RH [3]. The frequency output shows ±2% %RH level accuracy. This sensing micro-system was successfully tested up to 150 °C.

The SOI lateral PIN diode in Figure 1 can be used as an efficient photodetector. Photo-generated carriers in the intrinsic (I) region can be quickly separated by the lateral electric field and collected efficiently. As the ~5 μm thick membrane is transparent to light wavelengths above 450 nm, optical reflection from the gold finish layer of the device package, acting as a bottom mirror, occurs and creates cavity resonance in the multilayer stack improving light absorption in the on-membrane SOI PIN diode for specific wavelengths.

Experimental responsivities of the on-membrane photodiodes at room temperature (RT) are 0.02-0.06 A/W within the visible and near IR light range in Figure 3, under -2.0 V reverse bias. Up to 2.5 × responsivity improvement has been achieved with regards to the diodes on the substrate [4]. Furthermore the responsivities of both on-membrane and on-substrate diodes increase with intrinsic length (L_i = 5, 10, 20 μm), as the percentage of device photo-sensitive area increases with L_i.

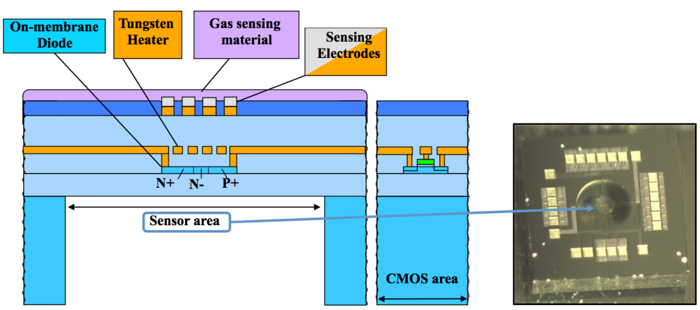

Figure 1: Cross-section and top view of the SOI sensing platform with embedded electrodes, heater and diode.

When temperature increases, the photodiodes can work stably from RT up to 200 °C, with a slight ~5-15 % decrease of responsivity at 200 °C which specifically depends on the device (on membrane or substrate) and intrinsic length L_i (5, 10, 20 μm).

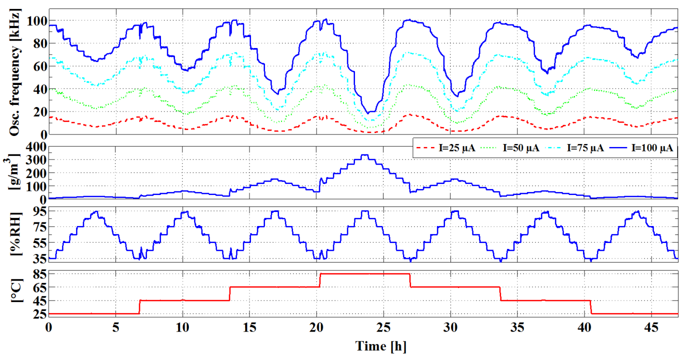

Figure 2: Oscillation frequency variations under different temperature and humidity levels and 4 different input currents.

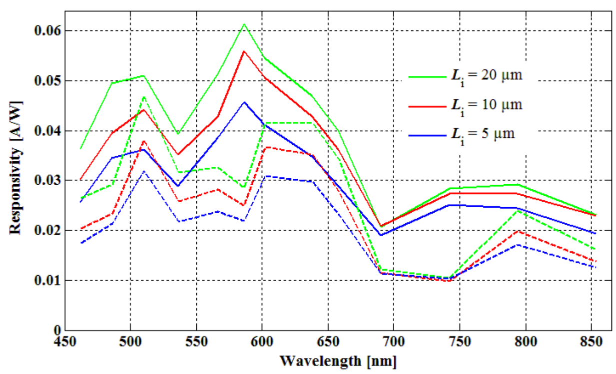

Figure 3: Measured typical responsivities versus light wavelength for the on-membrane (solid curves) and on-substrate (dashed curves) photodiodes (L_i = 5/10/20 μm), under -2.0 V reverse bias.

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