28p-G9-5

Mass-detection Based In-plane Resonant Nano-electro-mechanical Sensors

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Compatibility with "In-IC" integration, low power consumption and high sensitivity are the benefits of nano-electro-mechanical (NEM) sensors [1]. The electro-mechanical biosensors are developed based on mass-detection principles [2]. One of the recent commercial mass-detection biosensors is a quartz crystal microbalance (QCM) biosensor which achieves a mass sensitivity of a few tens pico g/Hz [2]. In order to improve the mass sensitivity of the sensor much further, this paper presents the newly developed in-plane resonant NEM (IP-RNEM) sensor [3]. This sensor consists of a clamped-clamped (CC) suspended beam and two side electrodes (inset (a) to Fig. 1) that is later monolithically integrated with an metal-on-insulator filed-effect-transistor (MOSFET) on the same heavily doped silicon on insulator (SOI) layer, named as in-plane resonant suspended FET (IP-RSGFET) sensor (inset (a) to Fig. 1). The presented NEM sensor achieves the mass sensitivity, *S*, of 0.05 zepto g/Hz as shown in Fig. 1 that was numerically calculated by modelling the functionalization and detection processes of the suspended beam in different configurations (inset to Fig. 1) using three-dimensional finite-element-method [4]. The calculated sensitivity is approximately eleven orders of magnitude smaller than that of the reported value for present QCM sensors. Hybrid NEM-MOS circuit simulation (Fig. 2(a)) is also applied to investigate the impact of different functionalization processes, dimensions such as gap (Fig. 2(b)) and biasing voltages on the high frequency characteristics of the IP-RSGFET sensor. We show that the introduction of free-free (FF) suspended beam for the sensor as shown in Fig. 3(a), improves the quality factor about five orders of magnitude for the vacuum- and low temperature-working environments. The fabricated sensors are shown in Fig. 3. The DC characterizations of the sensors are conducted for the future radio-frequency characterization of the sensor.

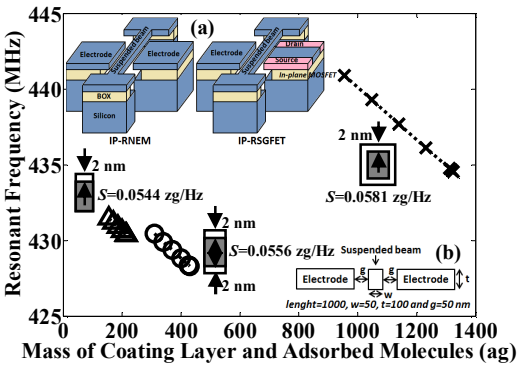

Figure 1: Resonant frequency versus the mass of coating layer, inset (a) schematic views of the IP-RNEM and IP-RSGFET sensors, inset (b) dimensions of the suspended beam.

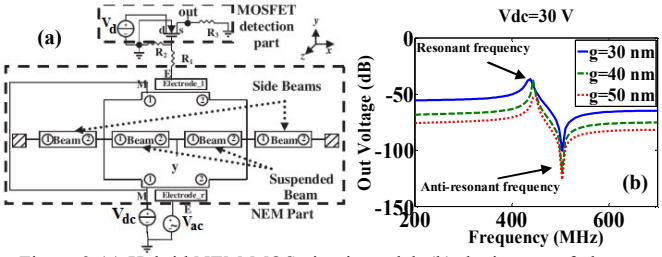

Figure 2 (a) Hybrid NEM-MOS circuit model, (b) the impact of changes of gap on the resonant frequency of the IP-RSGFET sensor

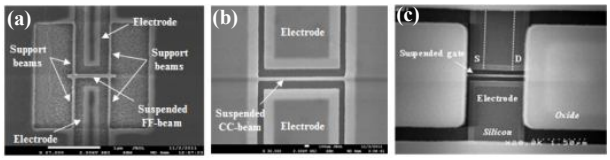

Figure 3 (a) FF IP-RNEM sensor, (b) IP-RNEM sensor, (c) IP-RSGFET sensor

Acknowledgment: This work is financially supported by EUFP7 project NEMSIC (Hybrid Nano-Electro-Mechanical/Integrated Circuit Systems for Sensing and Power Management Applications).

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