A High Temperature SOI CMOS NO_2 Sensor

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Abstract. For more than 20 years researchers have been interested in developing micro-gas sensors based on silicon technology. Most of the reported devices are based on micro-hotplates, however they use materials that are not CMOS compatible, and therefore are not suitable for large volume manufacturing. Furthermore, they do not allow the circuitry to be integrated on to the chip. CMOS compatible devices have been previously reported. However, these use polysilicon as the heater material, which has long term stability problems at high temperatures. Here we present low power, low cost SOI CMOS NO_2 sensors, based on high stability single crystal silicon P+ micro-heaters platforms, capable of measuring gas concentrations down to 0.1ppm. We have integrated a thin tungsten molybdenum oxide layer as a sensing material with a foundry-standard SOI CMOS micro-hotplate and tested this to NO_2. We believe these devices have the potential for use as robust, very low power consumption, low cost gas sensors.

Keywords: SOI, CMOS, Gas Sensor.
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METHODS AND RESULTS

SOI-CMOS micro-hotplates employing single crystal silicon P+ heaters were designed and then fabricated at a commercial SOI foundry, followed by back etching by Deep Reactive Ion Etching (DRIE) at a commercial MEMS foundry to fabricate the membrane (Figures 1 & 2).

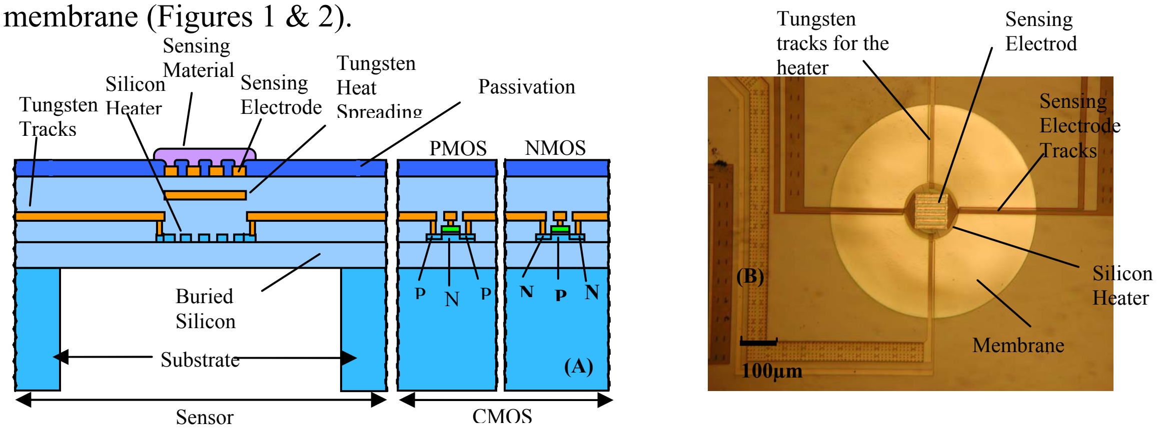

FIGURE 1. (a) Cross-section of the gas sensor structure (b) Photograph of a fabricated micro-hotplate

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The silicon P+ heater was made from a thin (0.25μm) monocrystalline silicon layer above the buried oxide. The process used tungsten metallization as a high temperature metal and was used to connect to the heater on the membrane. Devices based on silicon N+ and polysilicon were also fabricated, but the single crystal P+ heater has been found to be significantly more stable at high temperatures than the other two. The membranes had interdigitated electrodes at the top for the measuring sensing layer resistance. These were formed during the SOI CMOS process using the top metal layer and exposed to the surface by etching the passivation above them using the process step used for forming the bond pads. Extensive thermal characterization was performed on the devices; showing a DC power consumption of only 30 mW at 500°C (before material deposition), and a thermal t_{90} rise time of 10 ms. To make good contact with the sensing material, the gas sensing electrodes were plated with gold using a commercial bump-bonding process. To deposit the sensing material, the micro-hotplate chip was first plasma cleaned to prepare the chip surface. The sensing material, tungsten molybdenum oxide, was mixed in terpineol to form a slurry and then deposited on the micro-hotplate by micropipette deposition. The deposited slurry was then heated using the micro-hotplate at over 200°C for several hours to dry and sinter the sensing material. Figure 2a shows the material deposited on three micro-hotplates on a chip. Figure 2b shows the measurement results of the sensor when exposed to NO_2 gas. Initially the device is in air and the sensing material is at room temperature with very high resistance – so high in fact that it saturates the interface circuitry. The micro-hotplate was heated up to 450°C, which reduces the resistance of the material. NO_2 gas was then passed at concentrations of 1 ppm, 0.1 ppm, and 0.02 ppm, which caused a steep rise in the resistance of the sensing material.

We believe these results are encouraging for the aim of developing low-power low-cost CMOS sensor arrays for gas and odour sensing applications.

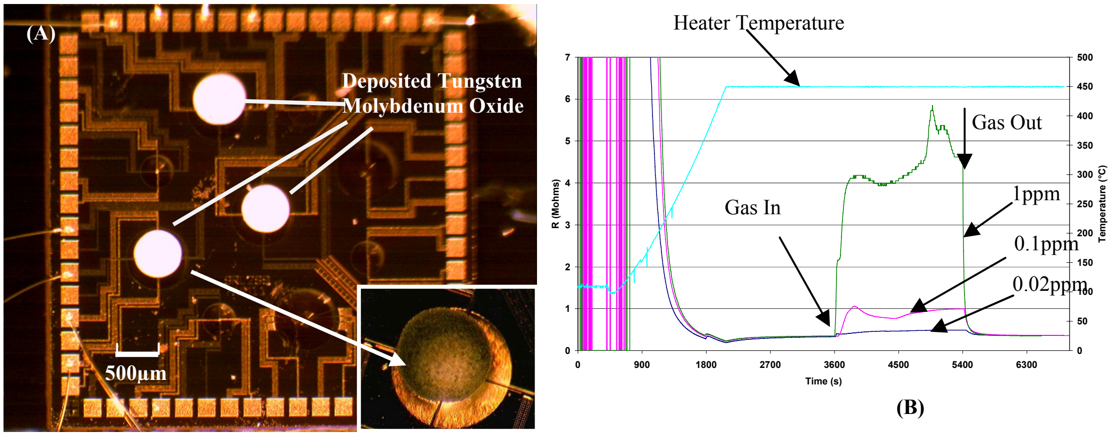

FIGURE 2. (a) Chip with deposited sensing material, (b) Gas sensing response to NO_2

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