Miniaturized 3D gas sensors based on silicon nanowires for ppb range detection

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The atmosphere is a complex natural gaseous system that is essential to support life. Stratospheric ozone depletion due to air pollution has been recognized as a threat to human health as well as to the ecosystems. Some of the most prominent gaseous air pollutants are SO_x, NO_x, CO, NH_3 and VOCs, all mainly produced by human activity. Moreover the ability to monitoring the air quality is essential to prevent health effects. Regarding the NO_2, which reacts with the intern mucus membrane of lungs, and produces nitric acid, the recommended long period exposure is below the olfactory level (300ppb). Most commercial sensors, using metal oxide as sensitive layer, have two drawbacks: sensitivity in the ppm range and global power consumption. One-dimensional nanostructures, such as nanowires[1], hold a great potential for the new generation of high sensitive sensors, nevertheless very few demonstrations showed sub-50 ppb sensitivity[2,3].

Here, we report 3D devices (Fig1.a) based on silicon nanowires (SiNW) for chemical gas sensing, working at room temperature. This sensor combines for the first time high sensibility, selectivity, reversibility, low-power consumption, reliability and low-cost large scale fabrication. Under controlled atmosphere, the sensor demonstrates high sensitivity and selectivity, by discriminating NO_2 and NH_3 without being interfered with CO and C_3H_8 (Fig1.b). A very high response (30%) is obtained at 50 ppb of NO_2. Compare to the state of the art, 25% reached for 200 ppb[3], this significant response indicates that the lowest detectable NO_2 concentration by our device is greatly below 20 ppb. In addition, the recovery of the sensor is achieved naturally at room temperature, without flushing[3] or specific illumination[2] for the NO_2 molecules desorption, with reliability over 6 months.

The SiNW are developed through a top down approach: combination of photolithography to control the number, spacing and position of each nanowire and so achieve a high reproducibility and sacrificial oxidation to master the diameter. The device is composed by two symmetrical aluminium contacts (low access resistance) at each extremity of the NWs, including a top contact done by air bridge approach (Fig 1.c). In addition, this CMOS approach is top-down and bottom-up compatible, leaving a choice for the selection of appropriate materials in function of the target species.

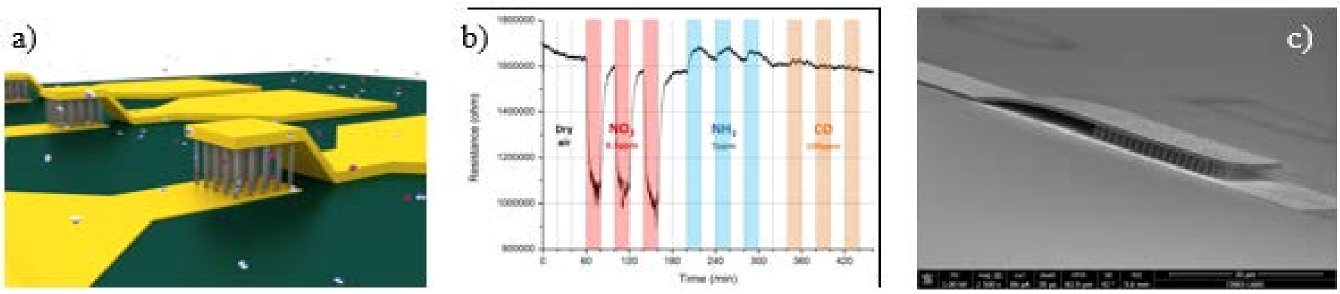

Figure 1: a) 3D model; b) Response of the device to NO_2, NH_3 and CO; c) SEM picture of the sensor.

References:

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