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Abstract Details

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Abstract

TITLE: 3D silicon nanowires sensors for NO₂ detection down to ppb levels

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ABSTRACT BODY:

Abstract Body: Nitrogen dioxide, one of the most prominent gaseous air pollutants, is a reddish-brown toxic gas, mainly coming from internal combustion engines and thermal power stations. The NO₂ reacts with the intern mucus membrane of lungs, and is at the origin of large increase of respiratory diseases. Various international agencies recommend level of long period exposures well below the olfactory detection level (300ppb).

Most commercial sensors, using metal oxide as sensitive layer, exhibit sensitivity in the ppm range. Moreover to be efficient, these layers operate at elevated temperatures, which drastically increase the global power consumption of the device. One-dimensional nanostructures, such as nanowires [1] or nanotubes [2], hold a great potential for the new generation of high sensitive sensors due to the high surface-to-volume ratio operating at a room temperature (low consumption). However, very few demonstrations showed sub-50 ppb sensitivity. Two nanowire based-sensors exhibit 20ppb sensitivity in air with In₂O₃ [3] and Si [4] nanowires but with some remaining critical drawbacks to address in term of recovery of the sensing mechanism or device repeatability.

Here, we report new miniaturized chemical gas sensors, working at room temperature, based on 3D silicon nanowires (SiNW) device, which is developed through a large scale approach. The vertical SiNW networks are patterned by top-down approach, which combines photolithography and sacrificial oxidation to precisely control the dimension, number, spacing and position of each nanowire in order to achieve high reproducibility. The device is composed by two symmetrical Al contacts (low access resistance) at each extremity of the NWs, including a top contact done by air bridge approach. Under controlled atmosphere, the sensor demonstrates gas selectivity, by discriminating NO₂ and NH₃, without being interfered with CO and C₃H₈. Due to the enhanced adsorption surface conferring by the 3D configuration, extremely low sensibility level has been reached. A very high response (30%) is obtained at 50ppb of NO₂, the dilution limit of our test bench, in comparison of the 25% reached for 200ppb in [4], indicating that lowest detectable NO₂ concentration by our device is greatly below 20ppb. Furthermore, the recovery of the sensor is achieved naturally at room temperature, without flushing [3] or specific illumination for the molecules desorption [4] with a reliability over 6 months.

In summary, we demonstrated detection of NO₂ down to ppb level, using resistor gas sensors based on 3D SiNW networks. This device combines for the first time high sensibility, selectivity, reversibility, low-power consumption, reliability and low-cost large scale and CMOS compatible fabrication.

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[3] D. Zhang *et al*, Nano Lett., vol. 4, 1919–1924, 2004

[4] M.C. McAlpine *et al*, Nat. Mater., vol. 6, 379–384, 2007