Nano-heater implementation in gas sensing devices by Electron Beam Lithography

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In the last years we assisted to the increasing interest in air quality monitoring and the spread of activities for a sustainable development. For this reason, semiconductor gas sensors are extensively employed thanks to their chemical stability, good sensitivity and low-cost fabrication. However, some drawbacks such as high-power consumption and hard integration still strongly limit the application of this type of sensor [1].

In this study, we focused on the significant reduction in power consumption of the sensing device by downscaling the device with Electron Beam Lithography (EBL) [2]. Fig.1a shows the cross-section structure of the full nano-heater device (NHD) for the semiconductor-based gas sensor. The layout of the NHD includes micro-size electrodes and a nano-size heater, both platinum (Fig.1b). The sensing material (Fig. 2b) is deposited in between electrodes. The variation in temperature of the heater is obtained by changing the input voltage applied to heater pads. By exposing the sensing material to a target gas, the resistance value change defines the response of the sensor.

To fabricate the NHD, two solutions were explored: 1) single step procedure by a high current of 1 nA and 2) double-step procedure by combining high and low current (500 pA and 150 pA, respectively). The former approach is a fast way to produce an array of devices. However, as shown in figure 2c, it leads to joined features caused by the proximity effect. The latter strategy requires a “fast” exposure at high current for micro-sized elements (electrodes and markers) followed by development, and then a precisely aligned lithography at low currents for the nano-sized (heater part). This double-step process gives rise to isolated well-defined elements, as shown in figure 2d.

The measurement of resistance R for the NHDs produced by the second approach shows an average value of 173 Ω at room temperature. The temperature of the nano-heater rises to 300°C by applying an input voltage of 4.2 V with a power consumption of 0.082 W.

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[1] A. Gaiardo, D. Novel, E. Scattolo, M. Crivellari, A. Picciotto, F. Ficorella, E. Iacob, A. Bucciarelli, L. Petti, P. Lugli, A. Bagolini, Sensors 21 (2021).
[2] I. Simon, N. Barsan, M. Bauer, U. Weimar, Sensors and Actuators B 73 (2001).

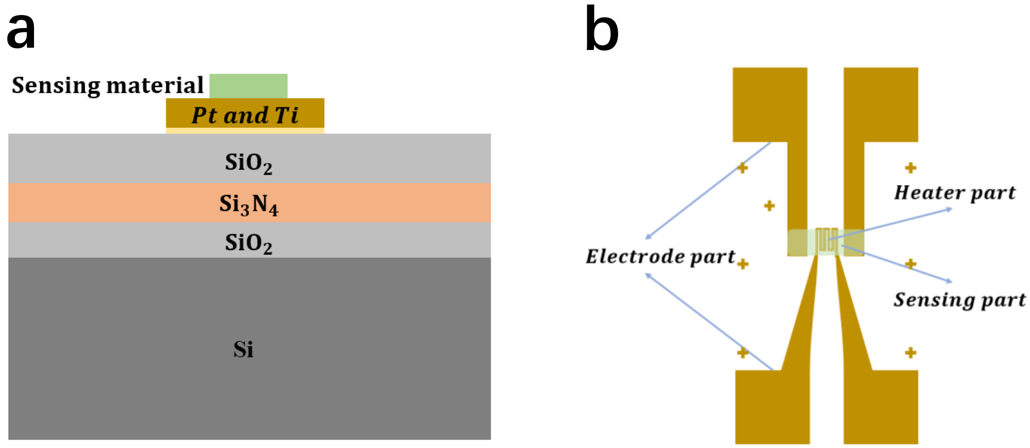

Figure 1. a) Cross-section structure of the Nano-heater device; b) Nano-heater device pattern with micro-size electrode part and nano-size heater part.

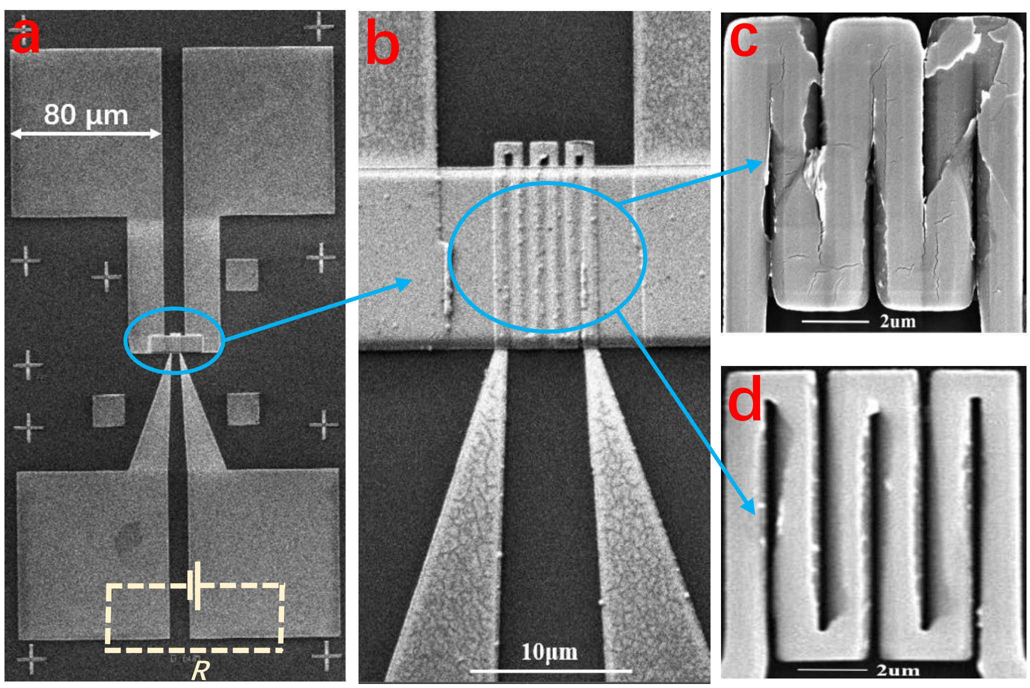

Figure 2. a) SEM of Nano-heater device for gas sensing; b) nano-size heater part fabricated by single step approach 1; c) nano-size heater part fabricated by double -step approach; d) Morphology of the layer of SnO_2 used as sensing material.