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Single layer gold hotplate, printed on polyimide, with heater used as sensing current drain for metal-oxide gas sensor

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Abstract

We report a simple transducer architecture based on two interdigitated inkjet-printed gold electrodes deposited on polymer substrate. The particularity of this transducer is the double functionality of the heater, since it works as heater and sensor electrode simultaneously. This way, a metal-oxide gas sensor can be realized easily using a two-step fabrication process, the printing of the two electrodes and their coating with the sensing film. The transducer was validated by coating it with tungsten oxide nanoneedles (NNs) functionalized with Pt nanoparticles (NPs) via aerosol assisted CVD method (AACVD) and then tested under different concentrations of H₂ gas. The proposed flexible printed transducer allows the simple and cost-effective realization of metal oxide gas sensors.

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1. Introduction

Flexible polymers, easily integrable in wearable devices, are inexpensive and present many advantages as sensor substrates compared to conventional ceramic or silicon materials. AACVD is an inexpensive high-yield technique for growing metal oxide nanostructures with remarkable gas sensing properties [1]. As shown by our prior results [2]

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this method has demonstrated its ability to directly grow metal oxide nanostructures onto conventional flexible polymeric substrates.

Reported devices, mostly, rely on a well proven architecture where two interdigitated electrodes lay on top of a heater, electrically isolated by a dielectric layer. That is a costly three step process. We propose a new architecture where heater and electrodes are built in the same layer in a quick and inexpensive one-step process.

2. New architecture proposal

Previous transducers, as the above-mentioned, were obtained through a three-step process: sputtering and lift off for the heater, spin coating of a thin dielectric PI film as isolator, sputtering and lift off for the electrodes [2,3].

The novelty of this design is the simultaneous double functionality of the heater (H+/gnd in Fig. 1(a)) since, at the same time, it drains the sensing current to ground. Whereas, the other electrode (E+ in Fig. 1(a)) is used to read current variations due to changes in the sensing surface resistivity.

3. Proof of concept fabricated device

In this work, we report a single-step fabrication process of a simple flexible hotplate transducer based on two inkjet-printed electrodes, much less costly and more power efficient than the usual three-steps one. Furthermore, we show that the coating of this device with NNs results in performing metal-oxide gas sensors, which represents a clear improvement in comparison to previous works reported in the literature [1].

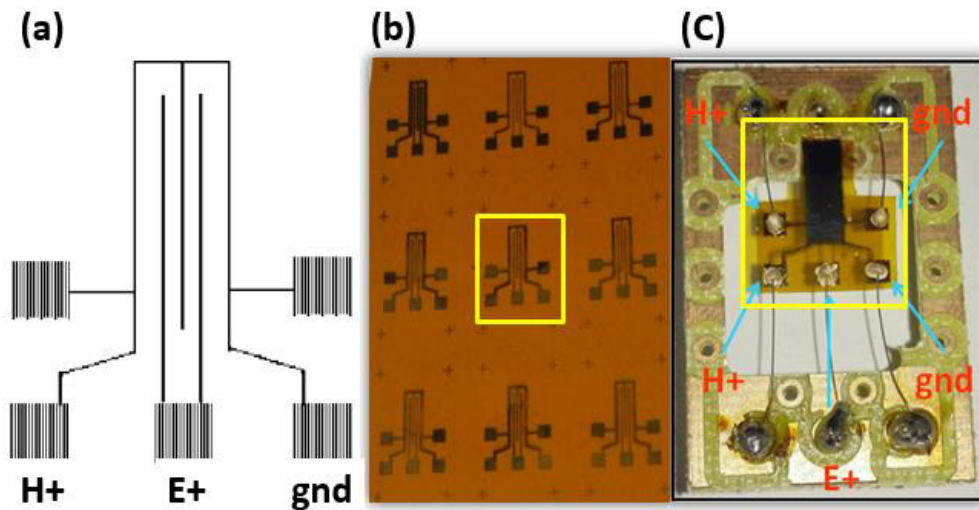


Fig. 1. (a) Electrodes layout, (b) Various printed electrodes over Kapton film and (c) One sample device after AACVD deposition.

The new flexible transducer consists of two interdigitated inkjet-printed gold electrodes over a Kapton 200EN 50 μm thick polyimide film (Fig.1 and Fig. 2). For the sensing material, WO_3 NNs decorated with Pt NPs were directly grown onto the 7530 μm x 2830 μm electrode area, by using AACVD technique at 380 $^\circ\text{C}$ (Fig.1c-3).

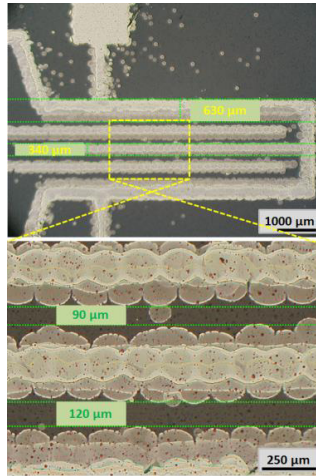


Figure 2: Optical images of the obtained inkjet-printed electrodes.

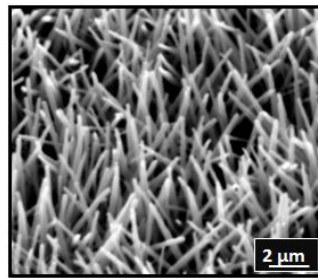


Figure 3: SEM image of the WO₃ NNs decorated with Pt NPs.

4. Experimental results

We have tested our sensor toward various concentrations of H₂ at heater power consumption of 14.87 mW/mm² (Fig.4 and Fig. 5). The sensor exhibited an *n*-type semiconductor behaviour (Fig.4), with a stable and fast response to the target gas.

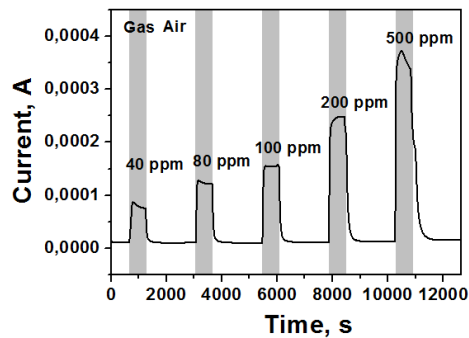


Figure 4: Current change of Pt-WO₃ based flexible sensor exposed to different concentrations of H₂ gas at heater power consumption of 14.87 mW/mm².

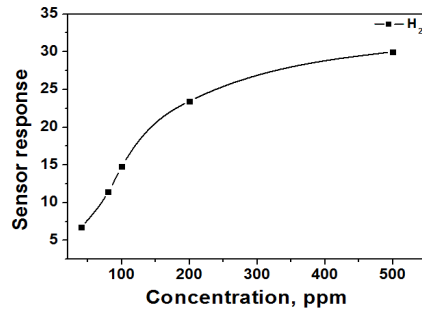


Figure 5: Sensor response (I/I_0) as a function of H_2 concentrations at heater power consumption of 14.87 mW/mm^2 .

5. Conclusions

All these findings have demonstrated the successful processing and implementation of this new electrode architecture for metal oxide gas sensors. We have been able to sense H_2 concentration changes by means of reading current injected through a sensing electrode that is drained through the, “hot” continuous working, heater electrode.

Acknowledgements

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