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Novel multi pixel-based gas sensor fabricated by local Inkjet printing of metal-oxides structures

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Summary:
This paper highlights the development of a novel multi pixel-based gas sensor fabricated by local Inkjet printing of metal-oxides structures. Multiple metal-oxide particles have been printed on a four-pixel micro-hotplate platform (from Sciosense) already available on the market for low power applications. With this approach we hope to drastically improve the lack of selectivity of standard chemiresistive detectors using a fabrication process applicable at the industrial level.

Keywords: Inkjet printing, metal oxides, multi pixels, gas sensing.

Introduction

Chemiresistive gas sensors based on the metal-oxides technology are widely used for gas detection due to their high sensitivity and fast response time. These sensors function by altering the electrical resistance of metal-oxides when exposed to a gas. The change in resistance is directly related to the concentration of the gas, allowing for precise monitoring [1]. They are cost-effective, robust, and capable of detecting low concentrations of gases, making them ideal for multiple applications like environmental monitoring and industrial safety. The limitation of metal-oxide based gas sensors lies in a relatively low gas selectivity, as they can respond to multiple gases simultaneously, making the identification of a specific one very complicated or even impossible [2].

An alternative to circumvent the selectivity restrictions of metal-oxides gas sensors is the designing of multi-pixel ones, with different materials on each pixel. The concept of multi-pixel gas sensors has been widely studied at the laboratory scale [3], but their commercialisation suffers from several challenges, particularly the lack of industrial method for depositing efficiently several metal-oxides materials on a single chip. Currently, commercial products based on the multi-pixel approach do not show selectivity improvement as compared to single sensors because they are produced with a single identical material on each different pixel.

In this work, we propose an innovative approach to manufacture multi-pixel gas sensors, fabricated with four different metal-oxide materials for four pixels, by using a localized Inkjet printing technic. To reach this goal, four metal-oxides materials known for their gas sensing properties (CuO, SnO_2, Co_3O_4 and In_2O_3) have been synthesized in liquid phase and processed into four stable printable inks. The local printing of the formulated inks has been performed with a high droplet resolution compatible with interdigitated electrodes of less than 100 μm x100 μm.

Materials and methods

All metal-oxides materials have been synthesized in liquid phase, using Cobalt nitrate, Copper chloride, Tin chloride and Indium nitrate as metal source. A cobalt oxalate complex has been prepared in a water/dimethylacetamide solvent mix before to be annealed into Co_3O_4, while CuO, In_2O_3 and SnO_2 have been prepared using water as solvent. For the ink formulation, the protocol described in the work of J.S. Gebauer *et al.* [4] has been followed. The Inkjet printing of inks has been performed using a Ceraprint X-serie printer from the Ceradrop company. Morphological characterizations have been realized with an optical microscope MX-61 from the Olympus company and a SEM Helios Nanolab 650 from the FEI company.

Discussion

Spherical SnO_2 and anisotropic Co_3O_4, In_2O_3 and CuO have been synthesized for their

chemiresistive sensing properties. The morphology of cobalt oxide particles and the printability of its ink are presented herein as an example. The typical morphology obtained for Co_3O_4 is presented on the SEM images on the Figure 1, where one can observe homogeneous anisotropic nanorods of widths below 50 nm and an aspect ratio around six. Those nanorods been suspended in a slightly acidified H_2O/Ethylene glycol solvent mix at 0.4_{wt}% to form a printable ink.

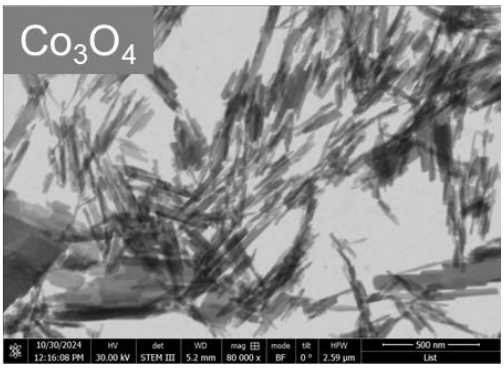

Fig. 1. SEM images of cobalt oxide nanorods.

The jetting properties of the formulated ink are presented on the Figure 2. On this image, recorded with a high framerate CCD camera, we can see that droplets ejected from the cartridge form single drops with no tails, which is evidencing an appropriate printability behavior. At 200 μs after jetting, most of the droplets are beyond 400 μm, except for the nozzle 6. It indicates that the jetting of this ink is a little bit to fast, as the targeted value is usually $2m.s^{-1}$. Also, it points out some instability of the jetting that must be further improved.

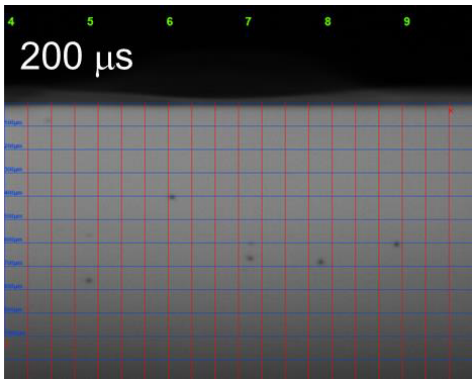

Fig. 2. Optical image of droplets formed at 200μs after jetting for five ejection nozzles.

Drawing from the results obtained for the Co_3O_4 ink, the three other metal-oxide materials have been formulated into processable inks and tested alongside with the Co_3O_4 one for the local printing on the Sciosense commercial micro-hotplate platform. Printing results are presented on the Figure 3where three out of the four inks that have been printed on each pixel can be observed. For each case, 15 drops have been performed on top of the interdigitated electrodes. It is clear from this picture that the local printing of each material is successful, even if the particles density must drastically be improved to form a homogeneous layer on top of the metallic fingers.

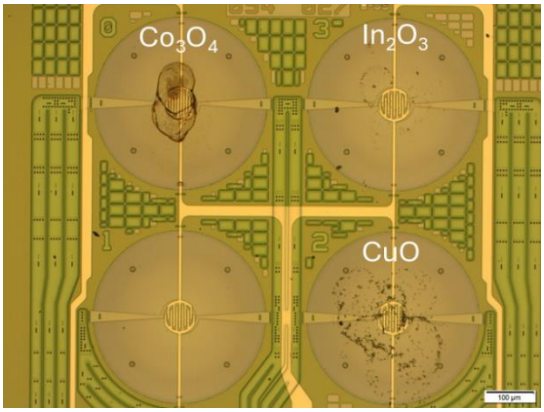

Fig. 3. Optical microscope image of a multi pixel sensor. Three materials out of four have been printed by the Inkjet technic.

This last aspect is already under consideration. We envisage to increase the concentration of materials in the ink, or we foresee multiple pass with the printing head.

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