

# INTEGRATION OF GAS SENSORS IN FLEXIBLE CIRCUITS: TOWARDS A FLEXIBLE TAG MICROLAB FOR FOOD LOGISTICS

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**Abstract:** Enabling technologies for the realization of a flexible tag microlab featuring gas sensing capabilities will be presented. Development of micromachined ultra-low-power MOX sensor hotplates and flexible circuit technologies for the realization of multilayer polymeric circuits and device encapsulation is shown. These technologies will allow the realization of gas sensing RFID tags by integrating innovative sensors with off-the-shelf electronic components.

**Keywords:** Micromachining, Hotplates, Flexible Circuit Technology

## INTRODUCTION

In the framework of the “GoodFood” Integrated Project [1], a flexible tag gas sensing system with RFID communication capabilities for food logistics is being proposed (Fig. 1). This visionary application requires the development and optimization of several technologies such as Micro System Technologies (MST) for the realisation of ultra-low power consumption sensors and Flexible Circuits Technologies (FCT) [2] for the fabrication of multilayer polymeric substrates. Furthermore, specific integration issues have to be addressed.

## ULTRA-LOW-POWER MOX SENSORS

Several constraints on power consumption, mechanical stability and encapsulation issues have to be faced for metal oxide semiconductor (MOX) sensor integration in FCT. For this purpose, new ultra-low power consumption, front-side silicon bulk micromachined hotplates are being designed (Fig. 2).

Arrays of circular and rectangular suspended  $\text{Si}_3\text{N}_4/\text{SiO}_2$  hotplates (Fig. 3) smaller than  $100\ \mu\text{m}$  with geometrically optimized Pt heaters and electrodes will be realised. The heater and electrode metallizations will be either on two different layers separated by a  $\text{SiO}_2$  film, as usually done in conventional devices [3], or on a single level, resulting in a simplified process flow. In the latter case, the electrical insulation between the heater and the electrodes will be obtained through a self-shielding layout.

The small dimensions of the chip (as low as  $0.5 \times 1.0\ \text{mm}^2$  for a 4-sensor array) and the very low power consumption ( $< 5\ \text{mW}$  at  $400^\circ\text{C}$ ) will allow exploiting MOX sensor technology on flexible, thin-film-battery powered RFID tags.

The design of these micro-hotplates will be shown, including the results of thermo-electrical simulations and the characterization of first realized test structures and prototypes.

## FLEXIBLE CIRCUIT TECHNOLOGIES

FCT refers to a group of additive processes for the construction of multi-layers flexible circuits, commonly based on the use of a polyimide [4] as raw material. We will describe the procedure implemented for the fabrication of a multilayer high density integrated circuit, based on the following main steps:

- 1) Deposition of the dielectric interlayer
- 2) Patterning to open the vias
- 3) Deposition of the metallic layer by physical vapour deposition for thin conductive films ( $< 1\ \mu\text{m}$ ) or electrodeposition for thick conductive films ( $< 20\ \mu\text{m}$ )
- 4) Photolithographic patterning of the metallic layer (lift-off process or chemical etching)

These steps can be repeated until obtaining the desired number of layers, followed by the final curing and passivation (Fig. 4). A multi-purpose photosensitive polyimide was used, suitable to work as a photo-definable dielectric interlayer, as a passivation layer for packaging as well as a resist

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for patterning of the metal layer, offering excellent resolution and aspect ratios > 1. FCT is suitable to reliably integrate the RFID antenna and the electrical interconnections into a flexible substrate.

### INTEGRATION AND ENCAPSULATION

Commercial or custom ICs, including control electronics and MOX gas sensors will be initially integrated into the flexible circuit by adapting conventional assembling technologies such as flip-chip bonding.

Subsequently, the applicability of different solutions like e.g. adhesive films with anisotropic electrical conductivity [5] will be conceived. The most suitable technique will be chosen, depending on the components to be integrated and on the application requirements.

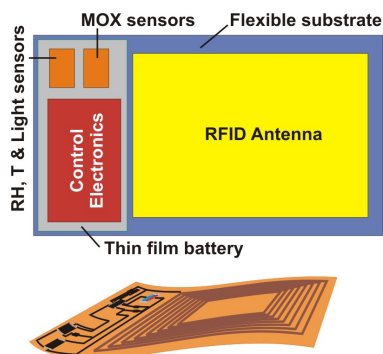


Fig. 1: Vision of a sensing flexible tag for food logistic applications: main functional blocks

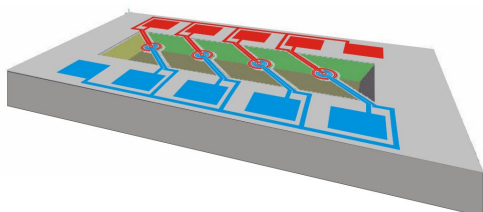


Fig. 2: Anisotropic etch simulation of front-side micromachined hotplate arrays

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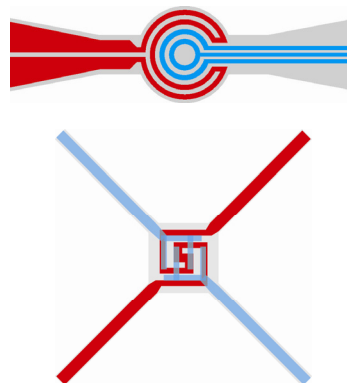


Fig. 3: Circular and rectangular hotplate geometries

- Step 1: Preparation of the carrier
- Step 2: Deposition of the first metallic layer
- Step 3: Patterning of the first metallic layer using PI2731 as photoresist
- Step 4: Deposition of the first dielectric layer of PI2731
- Step 5: Patterning of the first dielectric layer to open vias
- Step 6: Repetition of the steps 2-5 until the desired number of layers
- Step 7: Final curing of the structure

Fig. 4: Process flow for the realization of a flexible circuit on Polyimide