Manufacturing of MOX gas sensors: towards plastic substrates?

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In this communication, we will present challenges and potential benefits related to the integration of MOX gas sensors on plastic foil. Major issues as metal-oxide curing and heating compatibility with plastic substrates will be addressed. Another important aspect related to gas sensors manufacturing on plastic foil compared to conventional manufacturing methods is their packaging, for which we have developed an encapsulation at the foil level. Besides their design and processing, we will demonstrate the proper operation of MOX devices made on polyimide sheets and discuss the reliability issue and lifetime. Ultra-low power drop coated MOX devices with an active area down to 15 µm have been realized with a power consumption in a temperature pulsing mode of operation in the sub-mW range.

In this presentation we will start by giving an overview on our activities on the manufacturing of smart sensing systems on flexible plastic foil. We are envisioning the direct printing of sensors on different types of products such as smart labels and tags. This technology could bring sensors where there is no sensor at the moment by significantly reducing their production cost. The objective is to integrate smart systems realized on flexible substrates that have sensing, communication and powering capabilities. Smart systems on plastic foil could represent one of the key technologies for the realization of cost-effective smart sensing labels that would contribute significantly the deployment of the Internet of Things (IoT).

We will describe in details our efforts we are dedicating on the development of gas sensors on plastic foil with a focus on the manufacturing of MOX gas sensors. We will address both the conventional thin film and printed fabrication processes highlighting the challenges to process at large scale sensors on plastic foil. We have proceeded to the design of ultra-low power micro-hotplates on polyimide (PI) substrate based on thermal simulations and characterization. A simulation method was implemented to investigate both the influence of the hotplates' downscaling and the bulk micromaching of the polyimide substrate to lower their power consumptions. The main parameters influencing significantly the power consumption at such dimensions were identified and guidelines have been established allowing the design of very small ($15\times15\ \mu m^2$) and ultra-low power heating elements (6 mW at 300°C). Besides the advantages brought by their simplified fabrication on plastic foil, low cost, compatibility with wireless applications (e.g. RFID), we have also demonstrated the operation of the smallest MOX sensors based on the drop coating of gas sensitive layers. A complete sensor solution is presented including its packaging at the foil level and the driving/readout circuitry. The latter, based on a ultra-low power microcontroller, allowed the sensor to operate in pulsed temperature mode to reduce the power consumption in the sub-mW range. Gas measurements under CO, CH_4 and NO_2 have proven the proper operation of the sensor. These devices are being developed targeting wireless applications.

To summarize, the design and fabrication of ultra-low power metal-oxide (MOX) gas sensors on plastic foils envisioning their fabrication at large scale and low cost. The performances of the devices, their operation and read-out electronics, their reliability as well as their packaging on plastic foil will be highlighted. We will conclude on the actual state of the art of this technology and what we can expect as next development steps to get closer to fully printed compatible MOX gas sensors on plastic foil.