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On the development and characterization of PMA-based SAW sensing devices

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Abstract

Surface Acoustic Wave (SAW) sensors are diffused in the market due to their characteristics in terms of sensitivity, power consumption, attitude for being organized in arrays and wireless networks. In this work is reported about the development and the response towards ethanol of a sensing device realized by inkjet printing a poly(methacryl)acid (PMA) layer on a TO39 packaged SAW resonator working at a nominal frequency of 433.9 MHz. This kind of package allows to be easily opened for sensing film deposition on the piezoelectric substrate to develop a SAW-based sensor.

"Keywords: SAW, ethanol sensors"

1. Introduction

Surface Acoustic Wave (SAW) sensors are diffused in the market due to their characteristics in terms of sensitivity, power consumption, attitude for being organized in arrays and wireless networks. SAW sensors have been developed for gas and organic volatile compounds(VOCs) monitoring, many of them use polymer films as sensing layer [1,2]. The most affordable way to realize a SAW sensor is to choose a commercial SAW resonator as a transduction substrate, and to deposit on it an appropriate sensing film.

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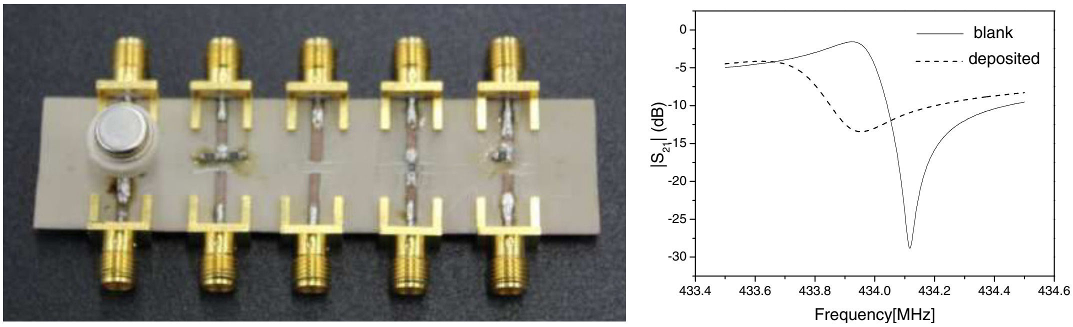
The development of new sensing green bio-compatibles materials brought to an increasing of sensing devices for several gas targets. In this work a Poly(methacryl)acid (PMA) based sensing layers is employed to realize ethanol sensing devices, starting by inkjet printing a PMA (30% water solution of sodium stabilized PMA, Mw = 9500, by means of an home-made inkjet system. PMA is a well know bio-compatible material often employed in drug delivery [3].

2. Experiments

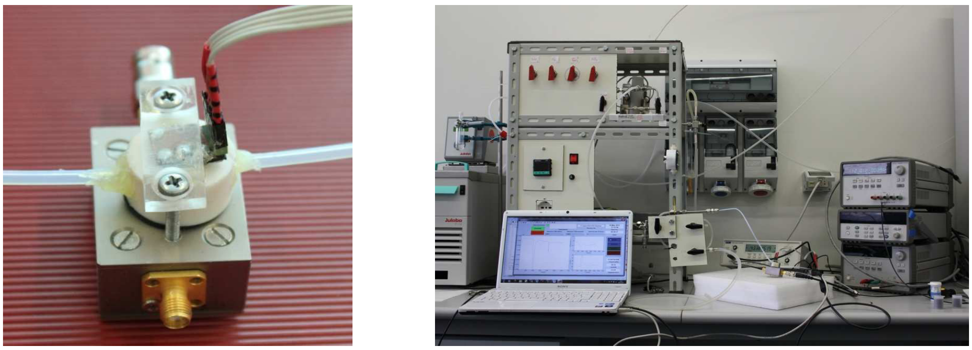
The sensing devices were developed by starting from TO 39 packaged SAW commercial resonators with nominal operating frequency value of 433.9 MHz. This kind of package allows to be easily opened to reach the piezoelectric substrate. By mean of a home made inkjet printing system it is possible to deposit a sensing layer on the resonator, realizing a SAW sensing device.



(a) (b)

Fig. 1. (a) On board Test Fixture and Calibration Kit; (b) Example $|S_{21}|$ measurement before (blank) and after (deposited) inkjet deposition procedure of the sensing film.

To develop a RF oscillator circuit for SAW devices several steps were needed: at first was performed an electrical characterization/modeling of the packaged resonator; then a suitable amplifier with the right gain specifications had to be chosen. Then it is important to reach the right tradeoff for RF passive components values to set the most suitable operating point for the amplifier and to create the passive ring network of the Pierce oscillator. Finally a well-designed layout on high frequency substrate was simulated and implemented.



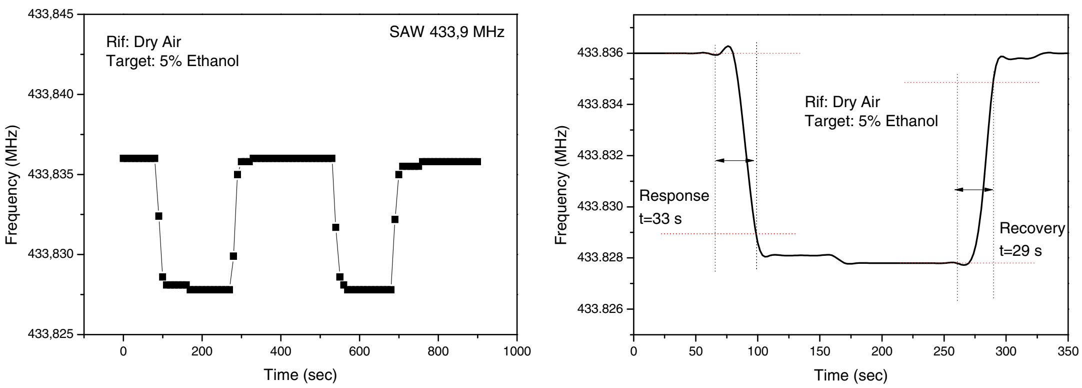
(a) (b)

Fig. 2. (a) Measurement Chamber with SAW device and Sensirion SHT21; (b) The whole measurement set-up including the flowmeter array for gas control.

The SAW resonator with an operating resonance frequency of 433.9 MHz was characterized by means of S-parameters, measured with an Agilent 8753E Vector Network Analyzer. Deembeding was performed by SOLT calibration procedure using a home-made test fixture and calkit for TO39 packaged devices (Fig.1). The S parameters were employed to evaluate the variation of the insertion loss (IL) before and after film deposition and to choose the correct gain to satisfy the Barkhausen oscillation conditions. A BFR92P npn bjt transistor was chosen to obtain desired gain of 25 dB at the working point. In this way all losses due to sensing film deposition, loading mass process and mismatching are compensated, allowing oscillations. The oscillator circuit were mounted on a RF box with SMA connectors (Fig. 2.a), provided of a suitable test chamber (3cc volume) on the top. The test chamber has been equipped with a commercial humidity/temperature sensor, SHT21 (made by Sensirion), and interfaced with Arduino Uno microcontroller board. The resonance value is measured by means of a TF 930 frequency counter of ITT. A GUI, developed with Matlab tool, is able to handle and record the data coming from both sensors by USB protocol. The measurement chamber is connected to an automated laboratory gas system setup (Fig. 2.b) able to set the right ethanol concentration value by means of a mass flow controller array, a cryostat bath and a bubbler.

3. Results

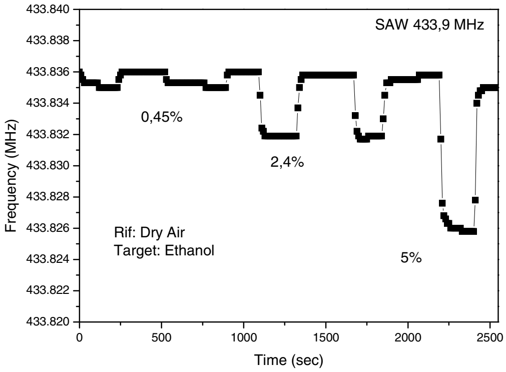
The measurement data show a clear sensing effect towards ethanol of the deposited film. As an example in Fig. 3.a it can be seen the real time response to 5ppm ethanol pulses. The transduction mechanism is likely both related to a mass effect and a swelling one of the polymeric sensing film. The sensor shows a good signal repeatability and stability. Furthermore, as shown in Fig. 3.b, it exhibit also a fast response and recovery (response/recovery time values are 33 sec. and 29 sec. respectively).



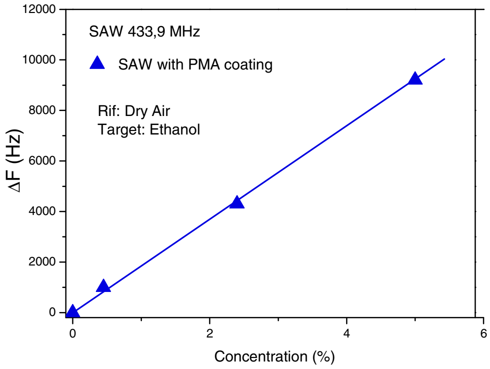
(a) (b)

Fig. 3. (a) Repeatability test to 5ppm ethanol – dry air cycling; (b) Dynamic response and response/recovery time evaluation.

In Fig. 4.a it can be seen the frequency variation towards ethanol in all range of concentration investigated. A detectable signal was seen also at the lowest concentration (0.45%). In Fig. 4.b is reported the calibration curve of the fabricated PMA-coated SAW sensor, evidencing the good linearity of the signal response in a wide ethanol concentration range.



(a)



(b)

Fig. 4. (a) Resonance frequency variation towards ethanol concentration; (b) Calibration curve comparison of SAW devices towards ethanol.

4. Conclusions

Here have been reported the experimental activities regarding the development and characterization of SAW sensors, based on commercial resonator coated with PMA-based sensing films. The sensing film deposition is performed by a home-made inkjet printing system. The characterization system is based on Pierce like oscillator circuit to reveal the frequency shift when the sensor is exposed to ethanol vapors. The results have been highlighted the promising properties of the PMA-based SAW sensor for ethanol detection.

Acknowledgements

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