Deposition and Electrical Characterization of Nanostructured Sensing Materials on Microstrip Resonators

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***Abstract*—This project is about the development of microstrip resonators working in the frequency range of 3 GHz - 6 GHz and their employment in the investigation of the sensing properties of nanostructured materials towards gas. The materials are deposited as films on the gap of the resonators by drop coating aqueous solutions of Ag@α-Fe_2O_3 nanocomposite having a core–shell structure. Here are reported sensing data about humidity in the range of 0% to 70%. It can be seen how an increasing of humidity brings to a decreasing of the resonance value.**

***Index Terms*—Microstrip resonators, gas sensors, nanostructured materials.**

I. Introduction

The research of new topologies of sensors with increasing low power consumption features is today one of the areas of greatest interest in the market. Low power sensors can be easily connected in sensors networks, with the right balance between sensor performance and battery lifetime. In such a frame, relatively new category of sensors can be represented by microwave devices with interesting properties in terms of fast response, really low power, fully compatibility with wireless technologies and room temperature operating value. These devices can be included in conductometric transducers category, with a slightly different mechanism of transduction than traditional ones, because in this case change of permittivity of sensitive layer is involved in the transduction process. So, the adsorption of molecules on the surface of the sensing layer and correspondent variation of the permittivity is a phenomenon which operates only in the second order as a conductometric transducer [1]. In particular, the possibility to balance between the sensing material properties and the resonator configuration for design of the sensor make them very versatile for different applications. Microstrip technology, widely employed in the design of microwave resonators and filters, can be successfully used in the development of such sensors. In this project, we investigate a resonant microstrip structure with a circular disk geometry by coating it with a sensitive layer. In such a context, microstrip resonators are designed and realized in a frequency range spanning from 3 GHz to 6 GHz, then sensing films are deposited on the resonator's surface. Accordingly with the geometry ensuring the motion of an electromagnetic wave in the microwave range through the sensing layer, the reflected wave on the material should be modified, namely attenuated and/or out of phase. The real part of the permittivity is linked to a capacitive effect of molecules whereas the imaginary part of permittivity is linked to conductivity. However, the final response towards gas of the sensor realized can be evaluated by measuring the reflection coefficient of the device with a VNA (Vector Network Analyzer).

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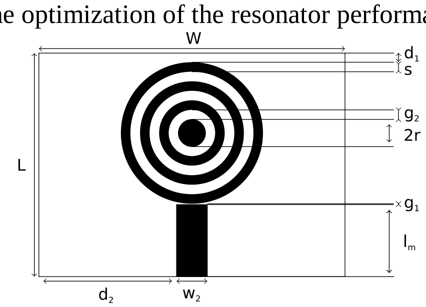
II. Resonator Design And Realization

In Fig. 1 is reported the design of the microstrip resonator transducer. It consists of a resonant disk with external rings coupled to a microstrip line through a small gap (approximatively 200 µm), with a characteristic impedance of 50 Ω. An Electronic CAD software allowed the evaluation and the optimization of the resonator performance.



Parameter	Value (mm)
W	67.2
L	49.26
d_1	2.0
d_2	30.22
g_1	0.2
g_2	2.1
l_m	15.86
2r	6.0
s	2.1

Fig. 1. Resonator topology.

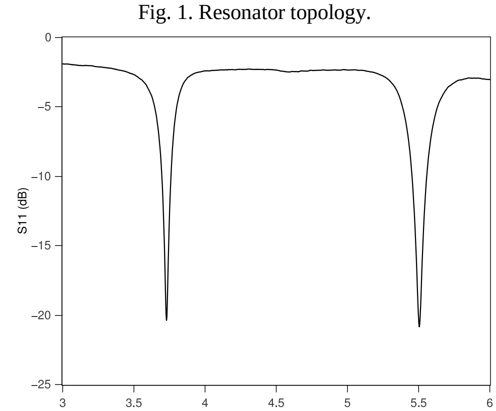


Fig. 2. Resonator S_{11} measurement in the 3 GHz – 6 GHz frequency range.

The resonator was realized with the LPKF Protomat S103 rapid prototyping system on an FR4 substrate, with a relative dielectric constant ε_r of 4.3, a thickness of 3.2 mm, and two copper layers of 35 µm. The prototype was equipped with a SMA connector to provide the connection with the VNA Agilent 8753ES. In Fig. 2 is reported the S_{11} measurement in the 3 GHz – 6 GHz frequency range, in the graph are reported two resonant frequency values at 3.729 GHz and 5.505 GHz respectively.

III. Experimental Results

The resonator was functionalized by drop coating on the gap an aqueous solution of Ag@α-Fe_2O_3 nanocomposite having a core–shell structure. The nanostructure was synthesized by a two-step reduction-sol gel approach [2]. The presence of Ag@α-Fe_2O_3 nanoparticles brought to a reduction of the resonance frequency values.

Fig. 3. Developed resonator in the testing chamber

The prototype was characterized towards humidity vapors at several concentration values in a range spanning from 0% to 70%. The samples were placed in a test chamber with controlled atmosphere provided with an RF feed-through for the VNA connection. The concentration values are set by means of a fully automated gas control system equipped with certified gas bottles, permeation tubes and a bubbler in a thermostatic bath. In Fig. 4 and Fig. 5 it is reported the magnitude and phase of S_{11} towards humidity, it can be seen how the presence of humidity brings to a decreasing of the resonance frequency value of the device.

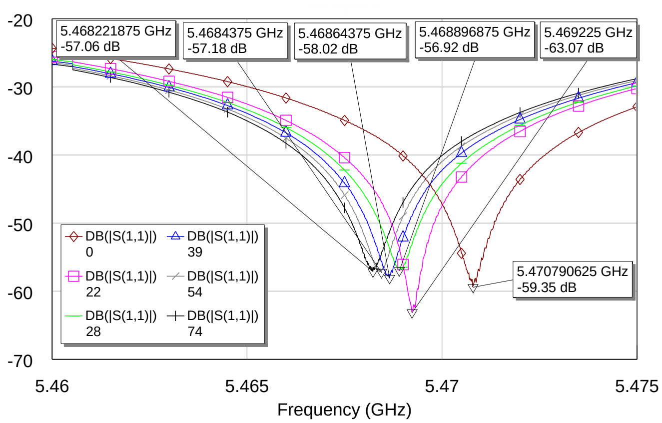


Fig. 4. S_{11} Magnitude of 5.47 GHz resonator vs. humidity

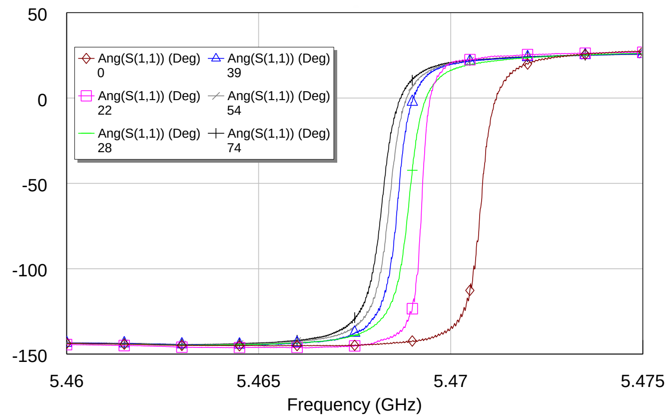


Fig. 5. S_{11} Phase of 5.47 GHz resonator vs. humidity

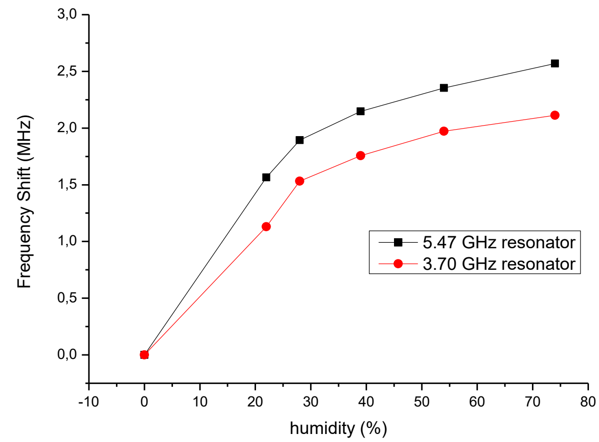


Fig. 6. Frequency shift vs. Humidity for 3.70 GHz and 4.7 GHz resonance values.

In Fig. 6 is reported the resonance frequency shift for both resonance values. By comparing the two data sets, it can be evaluated how the higher resonance value brings to a larger frequency shift.

IV. Conclusions and Future Work

The MTT-S Scholarship program allowed me to improve my knowledge in microwave field. This report summarizes the main results achieved during last year in the realization of microstrip resonators and their employment as resonant transducers for gas sensing. Then, preliminary data towards humidity were reported, and further activities are in progress to evaluate the response to several gas targets. During this period, I had the opportunity to design, develop and test different resonant structures. For this pourpose, the MTT-S undergraduate/pre-graduate scholarship award let me to achieve good results and encouraged me to pursue my career in research activities. I consider this award the best beginning for my career in Microwave topics.

References

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