# Wireless and chipless passive radiation sensors for high dose monitoring

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## I- INTRODUCTION

The safety of nuclear infrastructures may involve the monitoring of many parameters in harsh environments (high radiation level, high temperature, high pressure, ..). If technological solutions exist for transducers part in such environments, the electronic part used in reader is not appropriate and still a challenging task. Well-known solutions to remove the electronic part from the harsh environment consist of connecting the transducer and the reader by long electrical wires or performing ex situ remote sensing. However wires may practically be difficult to implement while ex situ measurements are not compatible with on line monitoring.
Wireless and passive sensors working in harsh environments could be an appropriate solution for the remote sensing of critical parameters. Passive sensors without electronics in the sensing unit are available (e.g., SAW sensors) but they suffer from short reading range (typically lower than 10 meters). In order to overcome this range limitation a new class of electromagnetic transducers was developed in the mid-2000s. The operating principle is based on the modification of the properties of high-frequency (>> 1 GHz) passive electromagnetic devices by the quantity to be measured. Based on this principle a wide range of sensing properties can be addressed and a large number of materials can be chosen. Moreover the use of high frequency allows reducing the size of the sensor elements (antenna, transducer) and enhancing the immunity to multipath.
Several principles of RF transducers have been already validated by LAAS-CNRS (e;g; pressure [1], temperature [2], stress [3]) as well as radar-based solution for the wireless long-range sensors interrogation [4].

The sensor dosimeter exploit here the known property of Hydrogen-Pressure Dosimeters (HPD) for which the polymer material dehydrogenates under nuclear irradiation. The transducer principle is described in Figure 1. The irradiation will generate the out-gazing (hydrogen) of the polymer inside a micro-chamber. The resulting overpressure leads to the deflection of a silicon membrane which modifies the resonant frequency of the RF resonator.

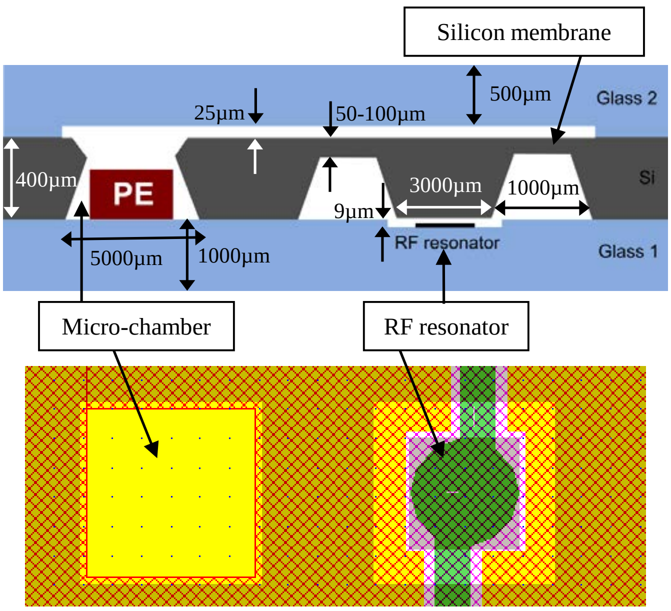


Figure 1.Cross section and mask view (glass 1 & Si) of complete sensor

## II- TESTS STRUCTURES

Tests structures (Figure 2) have been designed in order to quantify the HDPE outgazing inside a micro-cavity by measuring the deflection of a boss silicon membrane with a mechanical profiler (Figure 3). A specific set up using interferometry method has been also developed to evaluate the pressure generated inside the micro-cavity (Figure 4). The procedure consists in applying a pressure that pushes the membrane to recover a flat membrane. This condition is monitored thanks to the extinction of the Newton rings (Figure 5). An example of fabricated test structure is shown in Figure 6.

Irradiations have been performed up to 30kGy using 6MeV focused e-beam providing by electron accelerator (Figure 7). Membrane deflection and generated pressure around 0.2µm/$mg_{HDPE}$/kGy and 70mbar/$mg_{HDPE}$/kGy has been obtained for a 70µm thick membrane.

In order to characterize the hermetic sealing of the micro-chamber under hydrogen over-pressure, membrane deflection after irradiation has been recorded during 50 days. The variations of membrane deflection are randomly distributed and generally lower than ±5%, showing a good hermeticity during this period.

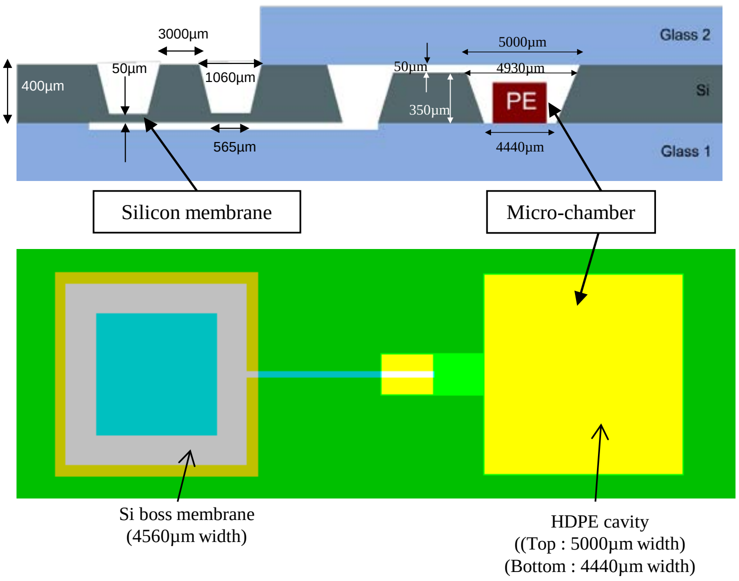


Figure 2. Cross section (top) and layout (bottom) of the test structure

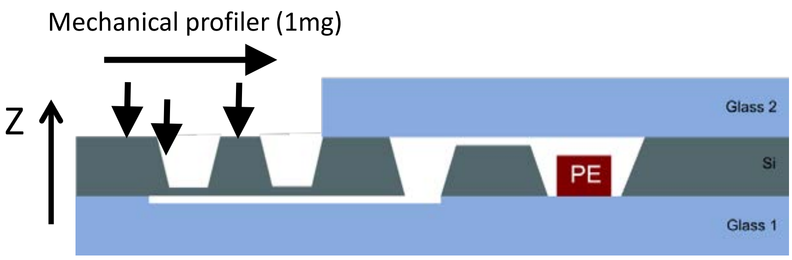


Figure 3. Set-up for membrane deflection measurement

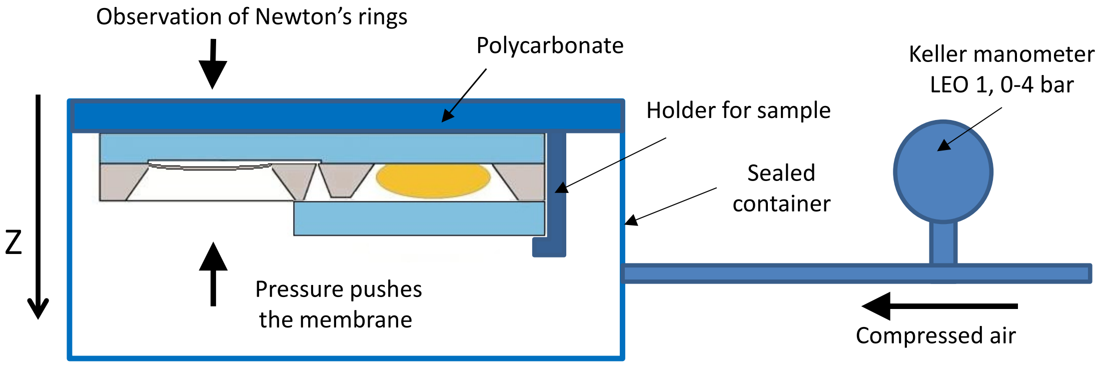


Figure 4. :Set-up for outgazing pressure evaluation

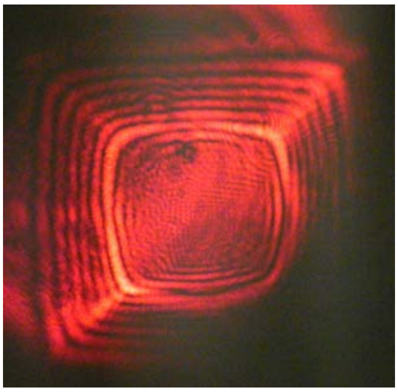

Figure 5. Example of Newton rings obtained with bent membrane

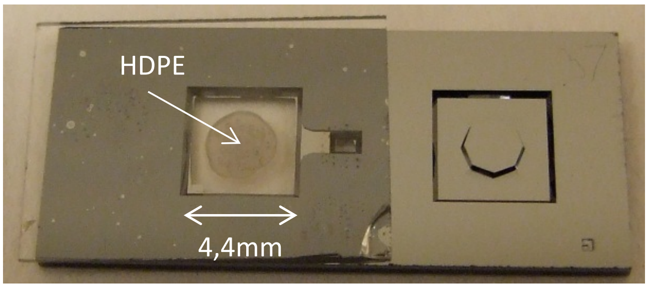


Figure 6. Photograph of test structure

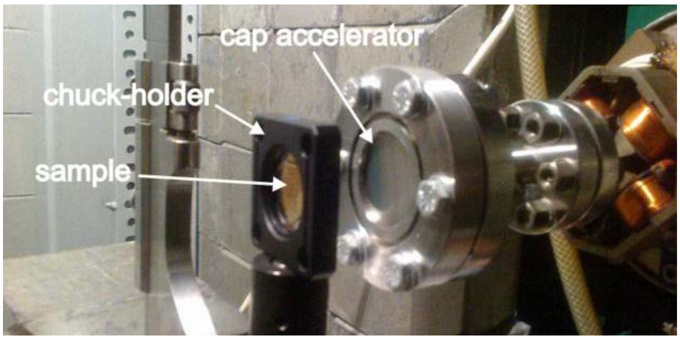


Figure 7 Set up for electron irradiation with accelerator

## III- REFERENCES

[1] M. Jatlaoui, F. Chebila, P. Pons, H. Aubert, Working Principle Description of the Wireless Passive EM Transduction Pressure Sensor. European Physical Journal - Applied Physics, Vol 56, N°1, oct 2011

[2] T. Thai, M. Jatlaoui, F. Chebila, H. Aubert, P. Pons, G. DeJean, M. Tentzeris, R. Plana, Design and Development of a Novel Passive Wireless Ultrasensitive RF Temperature Transducer for Remote Sensing. IEEE Sensor Journal Volume12, Issue 8, sept 2012, pp 2756-2766

[3] T. Thai, H. Aubert, P. Pons, G. DeJean, M.Tentzeris, R. Plana, Novel Design of a Highly Sensitive RF Strain Transducer for Passive and Remote Sensing in Two Dimensions, IEEE Transactions on Microwave Theory and Techniques, Issue 3, March 2013, pp 1385-1396

[4] H. Aubert, F. Chebila, M. Jatlaoui, T. Thai, H. Hallil, A. Traille, S. Bouaziz, A. Rifaï, P. Pons, P. Menini, M. Tentzeris, Wireless Sensing and Identification based on RADAR Cross Sections Variability Measurement of Passive Electromagnetic Sensors, Annals of telecommunications, vol. 68, no7-8, June 2013, pp. 425-435

[5] I. Augustyniak, P. Knapkiewicz, J. Dziuban, M. Matusiak, M. Olszacki, P. Pons, MEMS high-doses radiation sensor, International Conference on Solid State Sensors, Actuators and Microsystems (Transducers), June 16-20 2013, Barcelona, Spain

[6] E Debourg, I. Augustyniak, A Rifai, M. Matusiak, M.Olszacki, P. Knapkiewicz, J. Dziuban, H. Aubert, P. Pons, Wireless passive high-doses radiation sensor, IEEE Sensors, 3-5 Nov. 2014, Valencia, Spain

## IV- ACKNOLEDGEMENTS

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