# H2MEMS Project: Resonant MEMS for detection of hydrogen release in radioactive waste disposal facility

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# H2MEMS Project: Resonant MEMS for detection of hydrogen release in radioactive waste disposal facility

Invited Talk[1]

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***Summary*— The H2MEMS project aims at developing and optimizing hydrogen sensors based on resonant MEMS for detection of hydrogen release in radioactive waste disposal facility. The principle adopted is based on measuring physical properties of the gas (mass density, viscosity, sound velocity and sound absorption) without requiring any sensitive layer. For this purpose, resonant microcantilevers and CMUT were used.**

***Keywords*— resonant MEMS; CMUT; microcantilever; gas detection; resonant frequency; quality factor; time of flight; viscosity; mass density; sound attenuation; hydrogen detection**

## I. Introduction

ANDRA, the French National Radioactive Waste Management Agency, is in charge of finding, implementing and ensuring safe management solutions for French radioactive waste, in order to protect the present and future generations of the risks of nuclear wastes. As part of this mission, ANDRA prepares the industrial phase of the CIGEO project (industrial center for geological disposal). This repository will contain underground facilities designed to store tens of thousands of cubic meters of high-level and intermediate level long-lived radioactive waste. These wastes are mainly issued from the French nuclear power plants. The CIGEO project is intended to confine them for many years with a goal of ensuring a sustainable, safe and reversible storage [1]. One of the key elements of the overall monitoring strategy of geological disposal is the observation and survey of the subsurface installations. The monitoring devices in such context must resist to the harsh environmental conditions existing in a repository, especially levels of radiation that may accelerate sensor material deterioration. Adapting available sensors or developing new sensors is necessary to meet the technical requirements of the application. This is of particular importance in the case of chemical sensors to increase their durability and to limit the need for maintenance.

In such context, hydrogen release is expected from the radioactive waste disposal facility. It originates from (i) radioactive waste release and (ii) anoxic corrosion of metallic materials. Since hydrogen gas is flammable at concentrations between 4 and 75% vol. in air, monitoring its concentration in this environment is crucial. For this particular application, the H2MEMS project has developed and optimized hydrogen sensors based on resonant MEMS. Resonant MEMS are particularly performant for gas sensing but must be adapted for such a particular application. To achieve this goal, four laboratories, partners of the H2MEMS project, have proposed the use of uncoated sensors.

In fact, the principle adopted in the framework of this project is based on measuring physical properties of the surrounding gas (mass density, viscosity, sound velocity and sound absorption) without requiring any sensitive layer. The absence of the sensitive coating, which is subjected to sorption or redox phenomena in classical chemical sensors, leads to a more reliable and reversible behavior.

## II. Methods

Two kinds of resonant MEMS have been used in the H2MEMS project:

- Silicon and silicon carbide microcantilevers with electromagnetic actuation and piezoresistive or inductive read-out. The details of the manufacturing process for silicon and silicon carbide microcantilevers can be found in [2] and [3], respectively. The typical

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dimensions of the microcantilevers are: 1mm x 1mm x 10µm.

- Silicon nitride capacitive micromachined ultrasonic transducers (CMUT). The fabrication process based on surface micromachining can be found in [4]. The typical dimensions of each membrane of the CMUT are: 32µm x 32µm x 450nm. Each CMUT is composed of thousands of membranes (the size of the chip is 8mm x 1mm).

When using microcantilevers, the hydrogen detection principle is based on the measurement of both resonant frequency and quality factor variations, which allows to estimate simultaneously the gas mass density and the gas viscosity [5].

In the case of the use of CMUT, it is also possible to achieve hydrogen detection using the measurement of the resonance properties of the MEMS devices [6]. Another innovative way to achieve hydrogen detection using CMUT is the measurement of acoustic wave properties such as time of flight and attenuation. This can be done both in time [7] or frequency domains [8, 9].

## III. DISCUSSION

For the dedicated application of radioactive waste disposal facility, selectivity is not a real concern and a major specification as only hydrogen concentration may change significantly in such radioactive environment. However, within the H2MEMS project, discrimination between different gas mixtures using resonant MEMS without sensitive coating has been studied. The discrimination has been achieved, using either the microcantilever based sensors or the CMUT based sensors, by combining the measurement of two physical properties of the surrounding gas [5, 9, 10]: either the mass density and the viscosity, or the time of flight and attenuation. This has been demonstrated using four different binary gas mixtures at different concentrations (Figures 1-2).

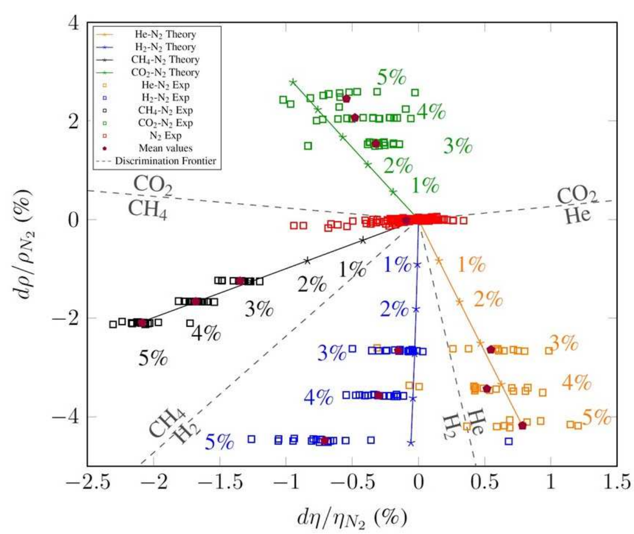


Fig. 1. Discrimination of different gases with the simultaneous measurements of mass density and viscosity using microcantilevers.

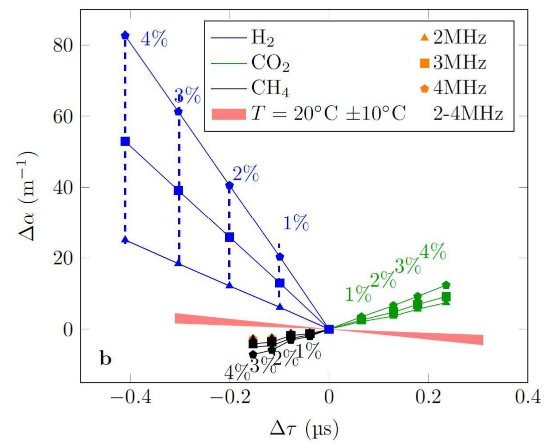


Fig. 2. Discrimination of different gases with the simultaneous measurements of time of fligth and attenuation using silicon nitride CMUT.

## IV. CONCLUSION AND PERSPECTIVES

Reliable detection of hydrogen has been achieved using either microcantilevers or CMUT. To go further for the targeted application, similar tests have to be done with materials more appropriate to harsh environment such as silicon carbide or diamond. Moreover, dedicated electronics has to be developed for this harsh environment.

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