MEMS Packaging reliability assessment Residual Gas Analysis (RGA) of gaseous species trapped inside MEMS cavity

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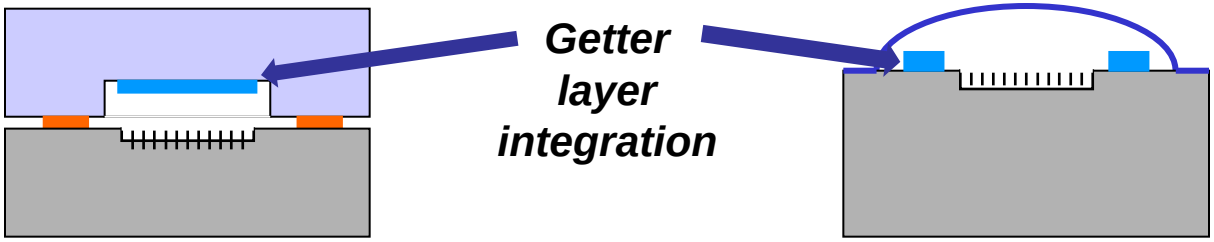
OUTLINE

Vacuum requirements for MEMS packaged devices

- **Micro Electro Mechanichal Sensors (MEMS) such as accelerometers, gyrometers, switches, µbolometers usually require a minimum vacuum level** *** $P \leq 10^{-2}$ to 10^{-3} mb**

** avoid damping, sticking or conductives loss and chemical or moisture effect…).*

Wafer Level Package (WLP)



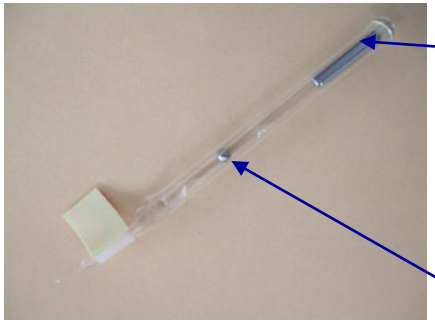
Thin Film Package (TFP)

- **Tools required to control atmosphere inside MEMS sealed cavities**
- **2 main goals**

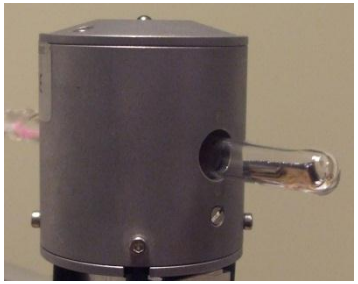
- **1) Materials outgassing or pumping & compatibility with process**
- **2) Residual Gas Analysis of atmosphere inside MEMS sealed cavities**

Tools developed at LETI for atmosphere control

1) Materials outgassing or pumping & compatibility with process

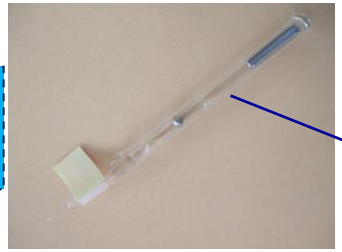


- Sample under specific gases (N_2, Ar, CO_2, CH_4, C_2H_6,…)
- Thermal activation to study outgas or getter effects
- Pressure measurement with spinning rotor gauge

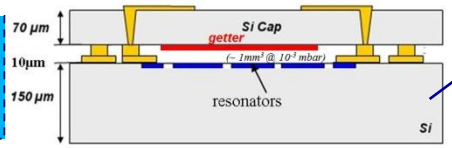


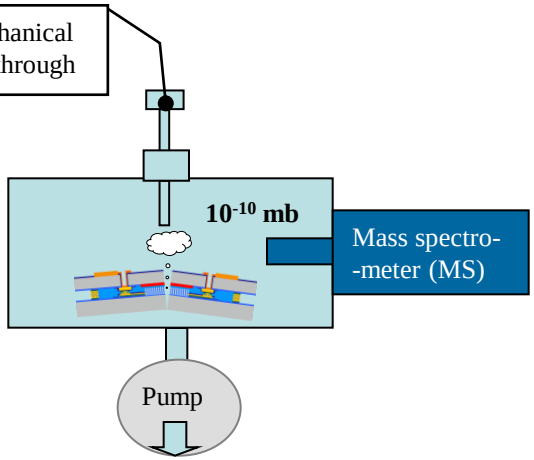
2) Residual Gas Analysis in UHV chamber

V=2.5 cm^3, P=10^{-3} mb
N_moles ~ 10^{-10}

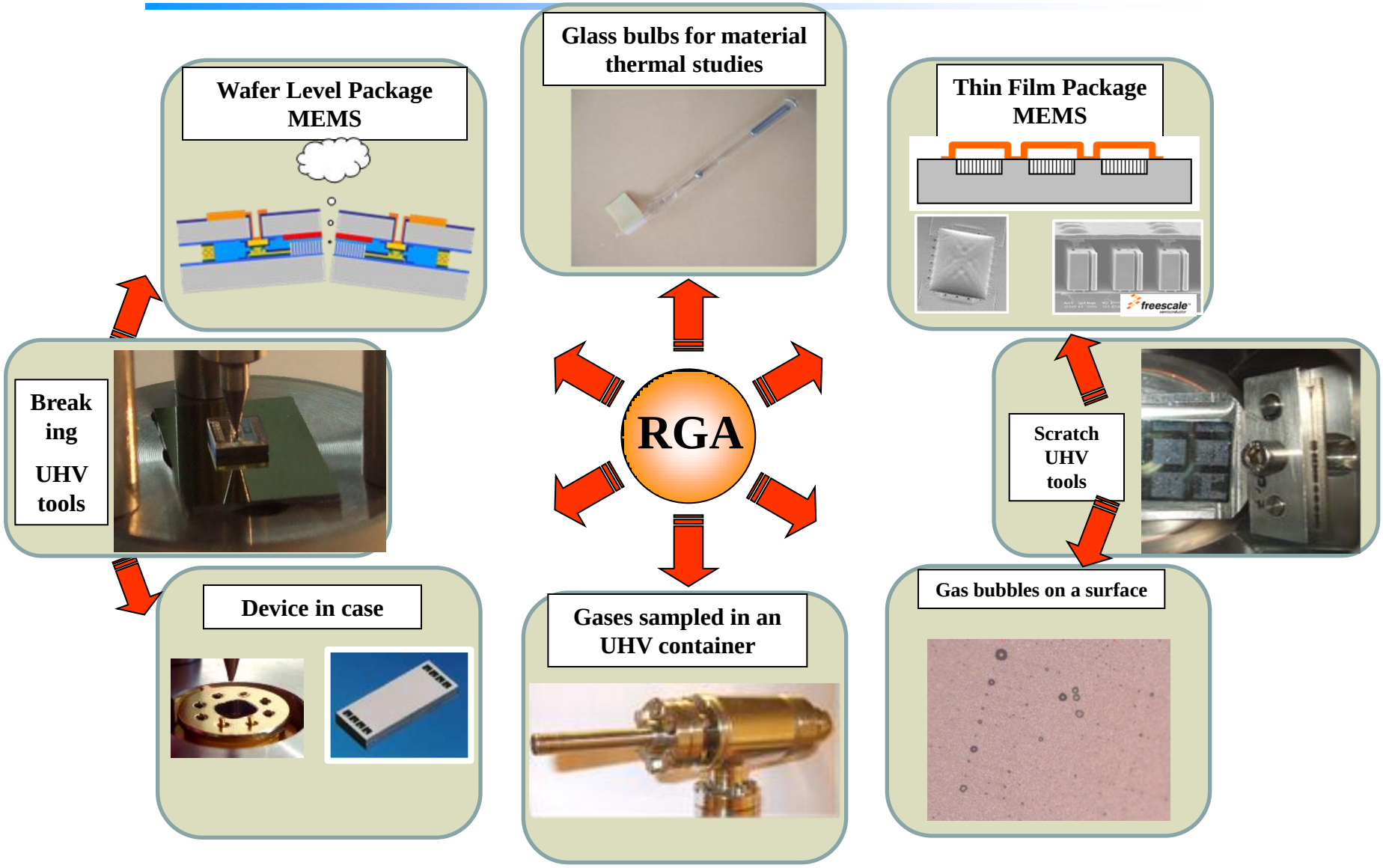


V=1 mm^3, P=10^{-3} mb
N_moles ~ 4 10^{-14}



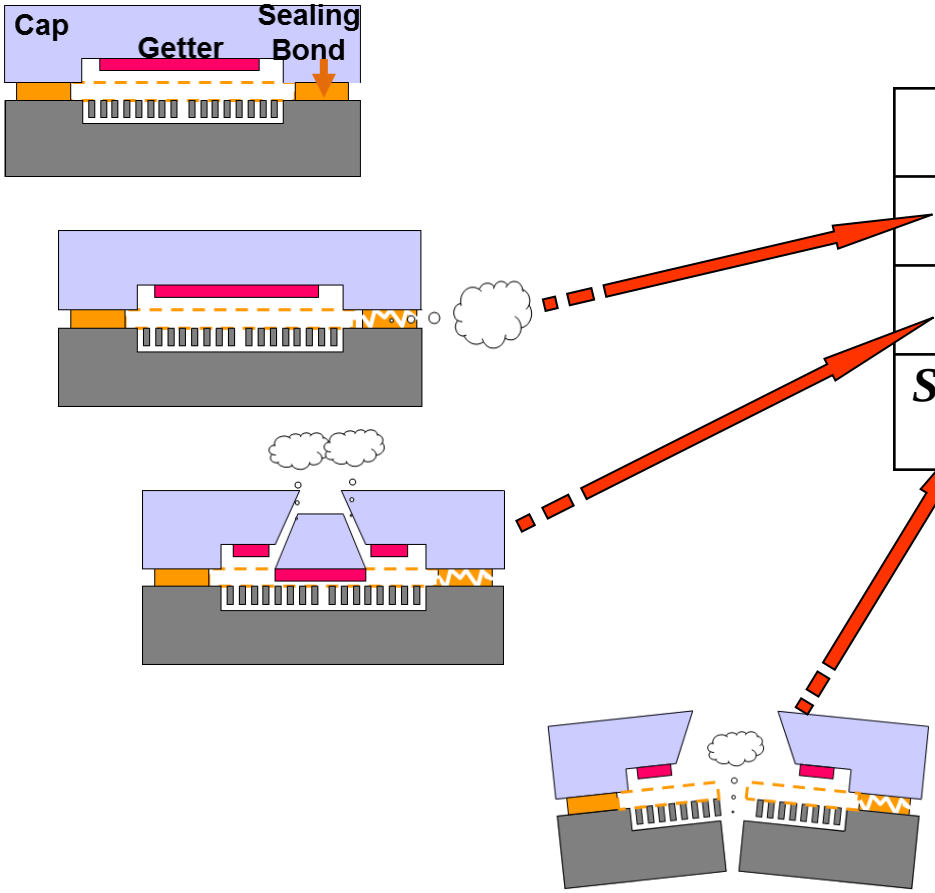


RGA applications:



RGA applications: an exemple on a sealed MEMS

Question: Identified on a sealed MEMS the # outgassing sources



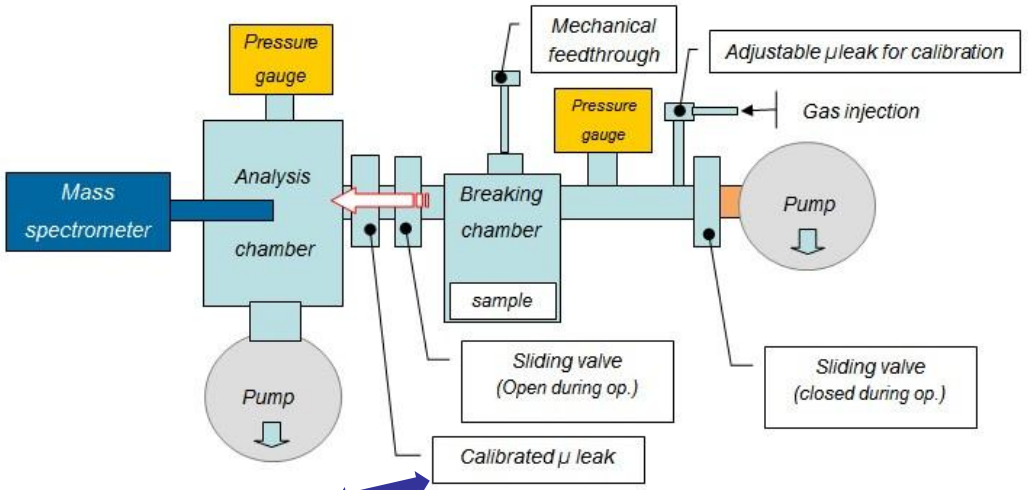
moles	CH_4	N_2	Ar	C_2H_6	…
cavity	?	?	?	?	
cap	?	?	?	?	
Substrate	?	?	?	?	

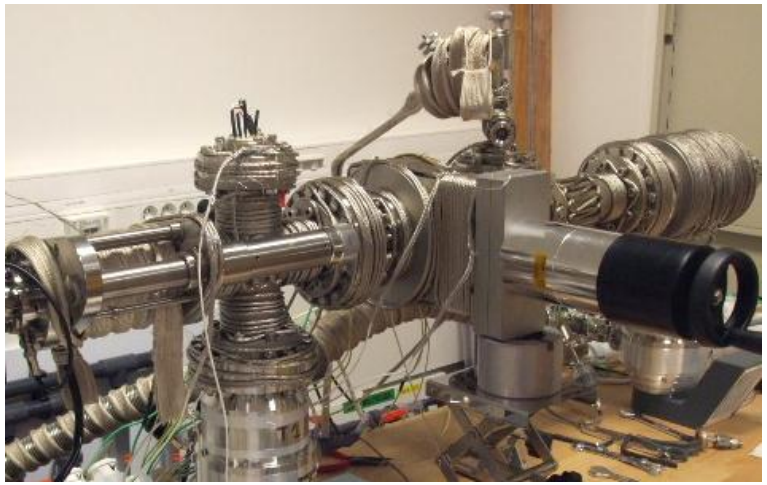
Possible in some case

with specific tools

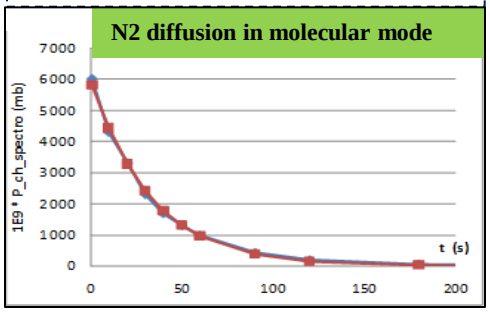
RGA Bench

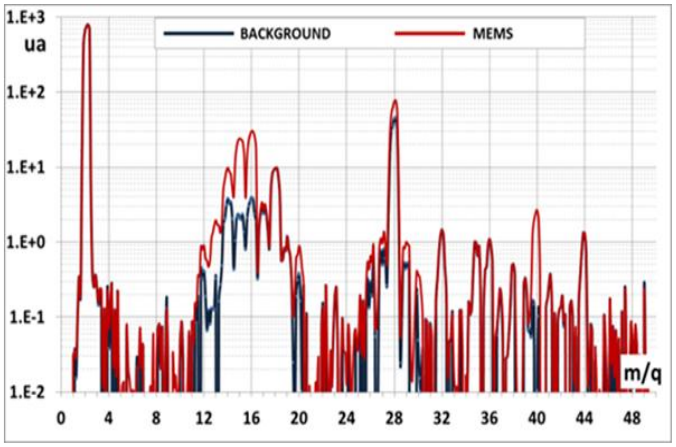
Schematic of the set-up.





Gases diffuse through a calibrated µleak (diaphragm)





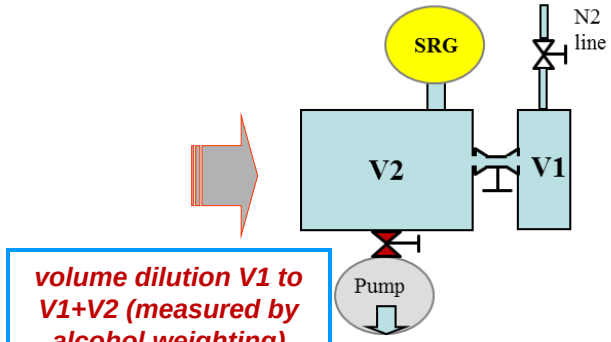
Typical spectrogram performed during an RGA experiment

Gases partial pressure inside MEMS cavity?
RGA bench needs "calibration" and qualification

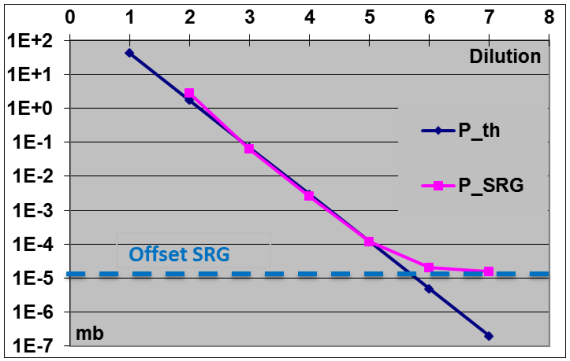
RGA bench "calibration"

- **1) "Calibration" of mass spectrometer**
- 2) Bench Qualification: Sensitivity, Linearity and Resolution

1)Spinning Rotor Gauge (SRG) qualification



volume dilution V1 to V1+V2 (measured by alcohol weighting)



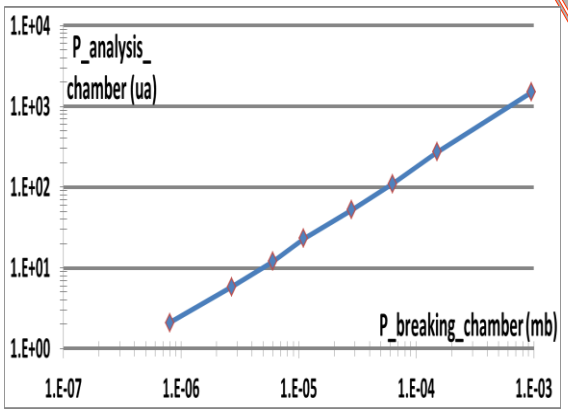
SRG qualified with N2

+

P_ratio_N2

2) P_ratio = P_breaking_chamber / P_analysis_chamber?

Pressure ratio between breaking & analysis chamber adjusted & checked on a large pressure range



Spectro "calibrated" on N_2
on Faraday cup and 3 Secondary Electrons Multipliers (SEM) ranges

RGA bench qualification

- 1) "Calibration" of mass spectrometer
- **2) Bench Qualification: Sensitivity, Linearity and Resolution**

1) Theoretical Sensitivity

Using volumes V1, V2 already accurately measured, volumic dilution & qualified SRG gauge allows V_breaking_chamber measurement

P_ratio already measured

V_breaking chamber value

S_th = 10.4 mb/mole

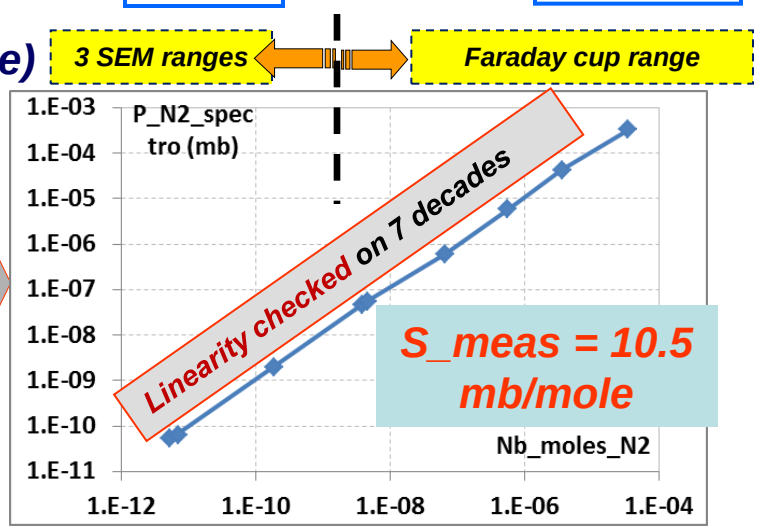
Gay Lussac law

Spectro

In breaking chamber

2) Checking Sensitivity & Linearity (RGA mode)

Using qualified SRG gauge, small volume & successive volumic dilutions we checked the RGA bench linearity for N_2 at very low number of moles (10^{-12} range)



3)Resolution = Nb_moles ⟺ to noise=s / S_measured = **4 10^{-13} moles for N_2, 4 10^{-14} for Ar**

RGA bench operation & data processing 1/2

a) Spectrum at breaking time– background spectrum (BG) or

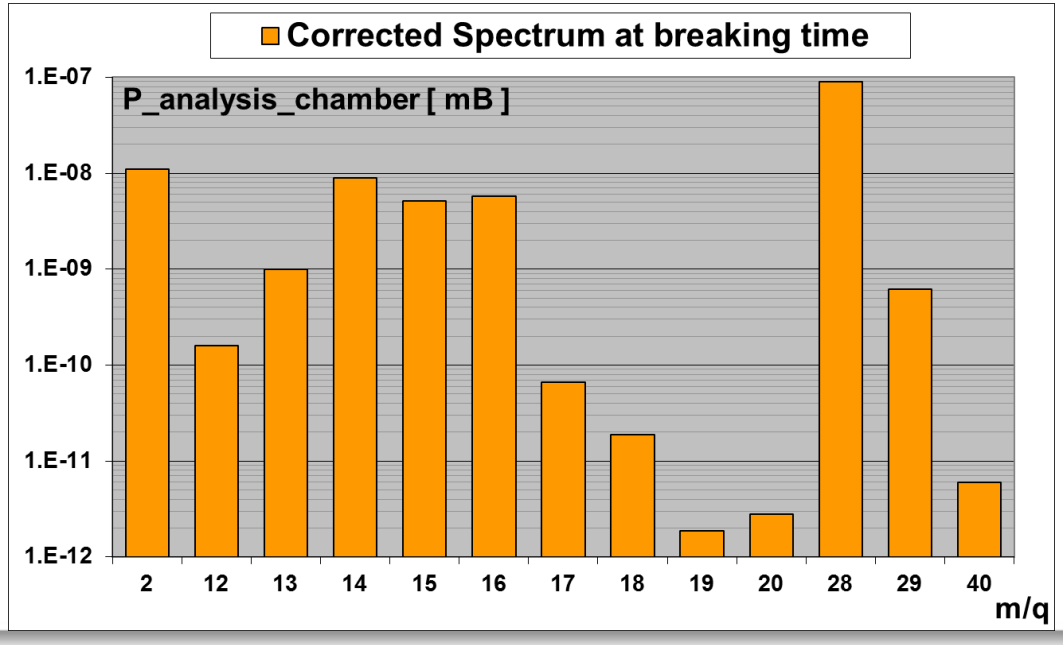
Spectrum at breaking time– spectrum at 2nd breaking

b) Correction from diffusion times through diaphragm ($M^{1/2}$).

c) Noise calculation s on each amu using 50 BG spectra

d) Selection of peaks with Signal/Noise > 3.

e) Corrected spectrum at breaking time

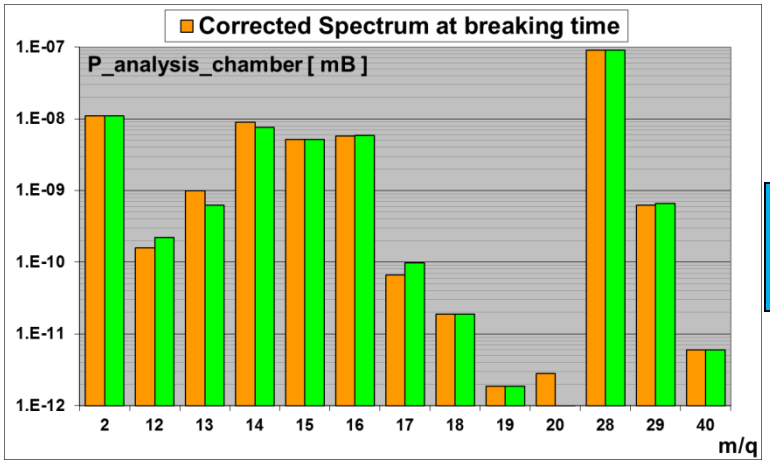


Need of a solver to fit a solution according to molecule's cracking pattern: Each peak can be issued from # gases (ex: peak 28 from N_2, CO , CO_2, C_2H_6 and derivative molecules, …

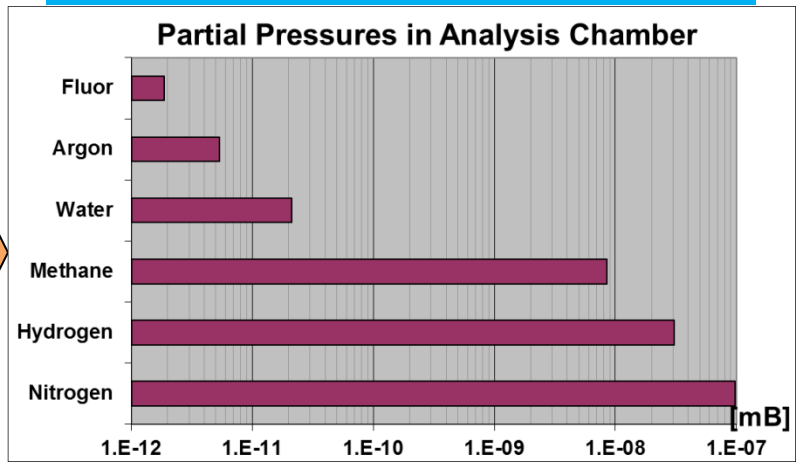
RGA bench data processing 2/2

LETI solver uses gases cracking pattern tables to determine gases molecular's ratio.

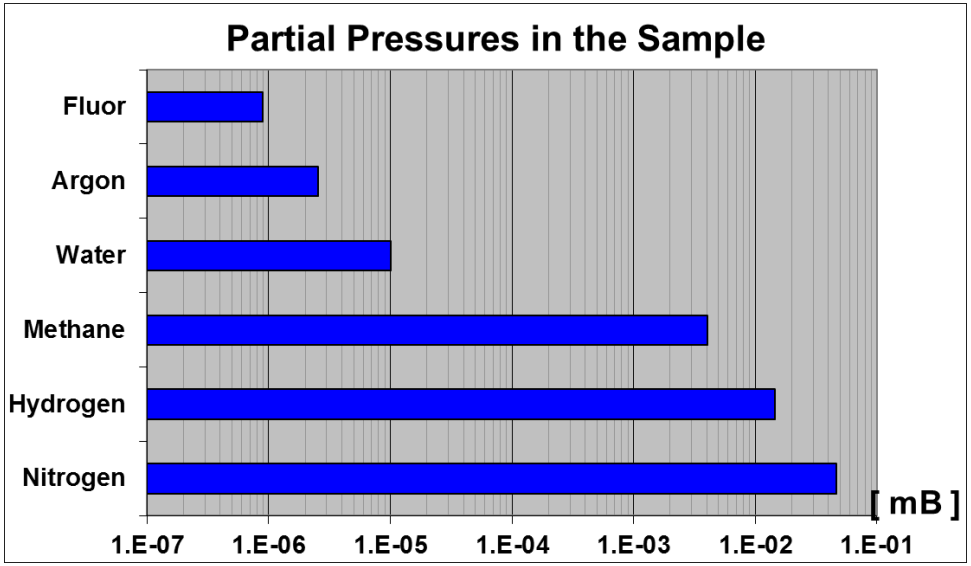
Corrections using ionization cross sections for identified gases.



ionization factors correction

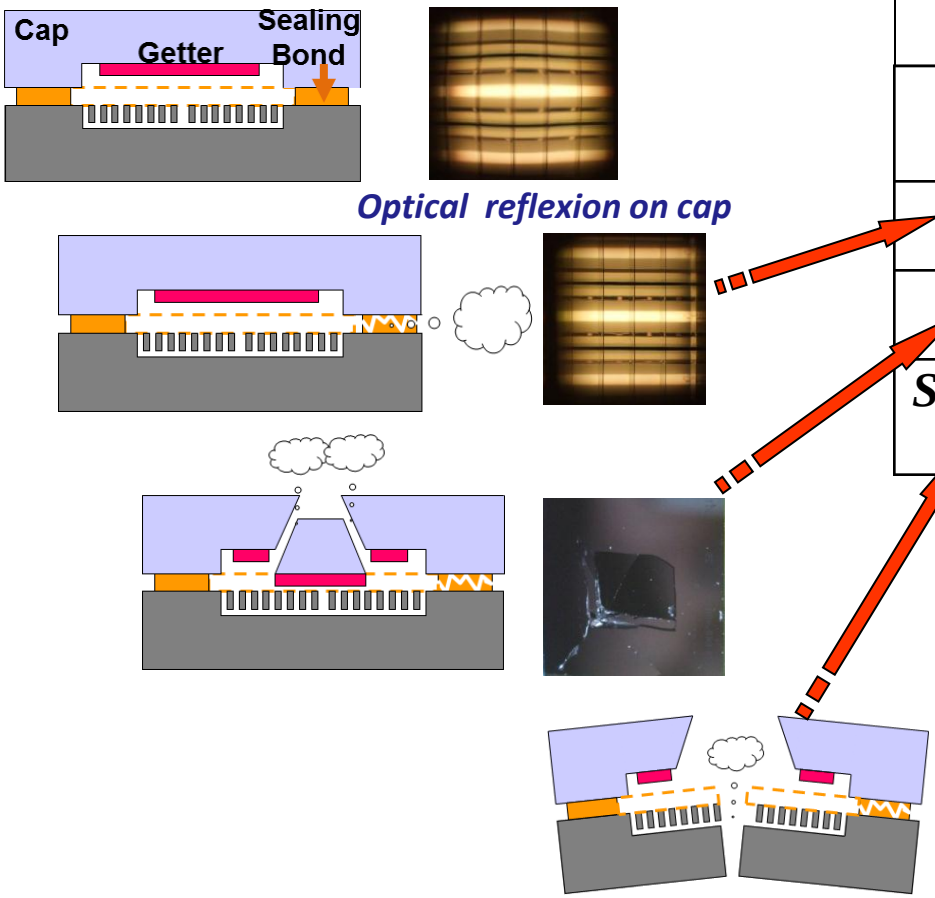


Using Sensitivity for identified gases & the volume of the sample



RGA analysis: Some results

Specific UHV tools & micrometrics mechanical feedthrough to "open" MEMS



Thinned cap device					
10^{-12} moles	CH_4	N_2	Ar	C_2H_6	Sum
cavity	6.9	5.5	0.4	0.2	13
cap	0.1	0	0.1	0	0.2
Substrate	0	0.3	1.4	0	1.7

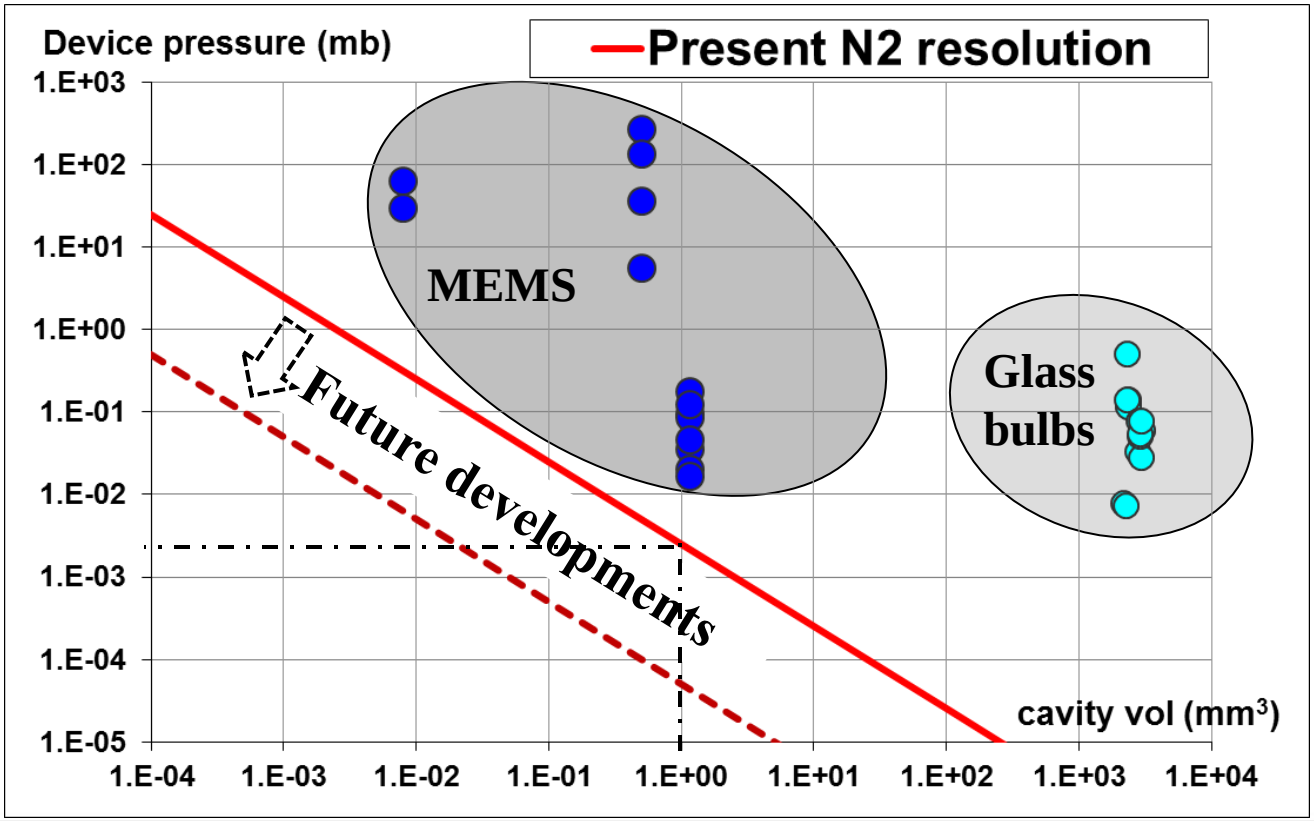
Summary

RGA bench & tools available at LETI

(1 mm³, 10⁻² to 10⁻³ mb resolution)

material compatibility with process

analyse partial pressures in sealed Mems



Conclusions

- *LETI developed a "calibrated" & qualified RGA test bench to assess MEMS reliability in the low pressures & volume ranges (mm^3, 10^{-3} mb ranges)*

- *RGA tools are of great importance to study and check materials compatibility with MEMS processes and control atmosphere inside packaged devices….*

- *Future developments will focus on a new RGA test bench with enhanced resolution*

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THANK YOU FOR YOUR ATTENTION

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