ePIC MPGD-DSC workfest

Resistive detectors instabilities

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outline

- Cause of resistive detectors instabilities
- Clean room
- Detector qualification test at CERN
- Humidity absorption and desorption of PI
- Air Vs humid Air
- Moisture barriers
- Real time measurement of humidity trapped in materials
- Conclusion

Cause of instabilities in resistive detectors

- 1/ Dust → during the detector assembly
  - Detectors should be assembled under clean room condition
    - All parts must be rinsed with US DI water and dried , in the clean room .
    - In case of leakage current , tacky rollers can help but this is not always efficient.
    - In case of problem a new US or High-pressure DI water rinse should be performed.
    - In case of re-opening the user should be prepared to re-US clean the detector
    - Avoid copper alloys for screws or nuts , only SS
  - Gas filters
    - Putting gas filters prevents dust entering in the gas volume.

- 2/ Humidity → during operation
  - Part of the humidity comes with the gas
    - But gas RH is quite easy to measure and adjust.
  - The greater part comes from ambient Air humidity, passing through the materials !
    - Difficult to measure , difficult to estimate
    - And some polymers are strongly storing moisture (PI , Photoimageable coverlay)

Clean room

- Detectors are sensitive to dust ranging from 5um (invisible) up to 100um
- Clean room class → particles per cubic foot

Too good

Too good

perfect

Possible

difficult

impossible

Federal Standard 209E Class Limits						
FS209E	Particles / ft³					ISO Equivalence
	≥0.1µm	≥0.2µm	≥0.3µm	≥0.5µm	≥5.0µm	
Class 1	35	7.5	3	1	N/A	ISO 3
Class 10	350	75	30	10	N/A	ISO 4
Class 100	N/A	750	300	100	N/A	ISO 5
Class 1,000	N/A	N/A	N/A	1,000	7	ISO 6
Class 10,000	N/A	N/A	N/A	10,000	70	ISO 7
Class 100,000	N/A	N/A	N/A	100,000	700	ISO 8

Detector qualification test at CERN

Detector open in oven @ 90deg

-1 hour drying time before applying any voltage
-apply voltage , massive electrical cleaning →10uA leakage current allowed
-after 1 day : air RH negligeable and detector humidity trapped negligeable → 660 to 680V (1nA)

Chemical removal of evaporated materials.

-Potassium permanganate followed by Chromic acid passivation

Detector closed in oven @ 50deg

-soft electrical cleaning allowed: 50 to 100nA during 5 sec max. More than 5 sec → reduction of 100V
-After 2 days : air RH stabilized at 15% and detector humidity stabilized at 15% → 760V (1nA)

Detector closed in oven @ 35deg

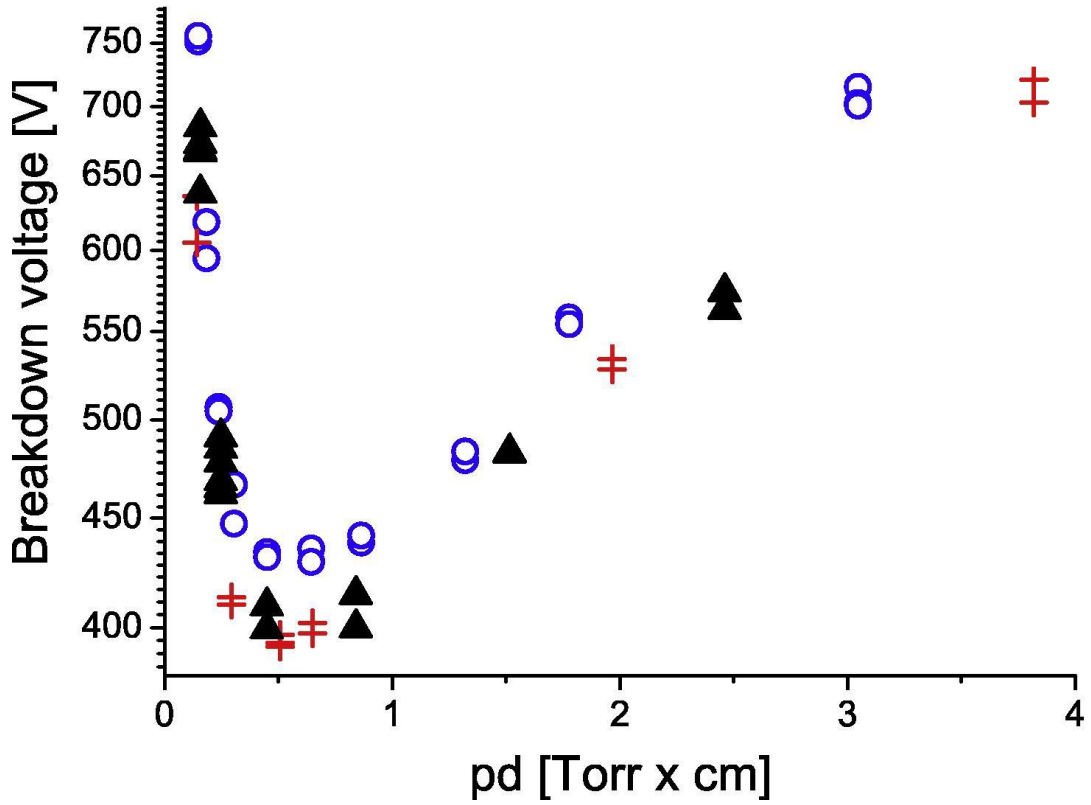
Immediate test : air RH immediately raise to 20% , detector (memory of 15%) → more than 800V (1nA)
After 2 days : air RH is stabilized at 20% , detector humidity is stabilized at 20% → 750V (1nA)

Detector closed out of the oven @ 25deg 50%RH

After 15 min : air RH immediately raise to 50% , detector (memory of 20%) → 790V (1nA)
After one day , we start to see a serious impact on the maximum voltage → 700V (1nA)
After 2 days → 650V (1nA)
After one week even at 500V the detector start to show dangerous instabilities (uA peaks)

Humid air seems to have a higher breakdown voltage
Moisture seems to come back in the detector within a day
Humidity trapped in materials is the main problem

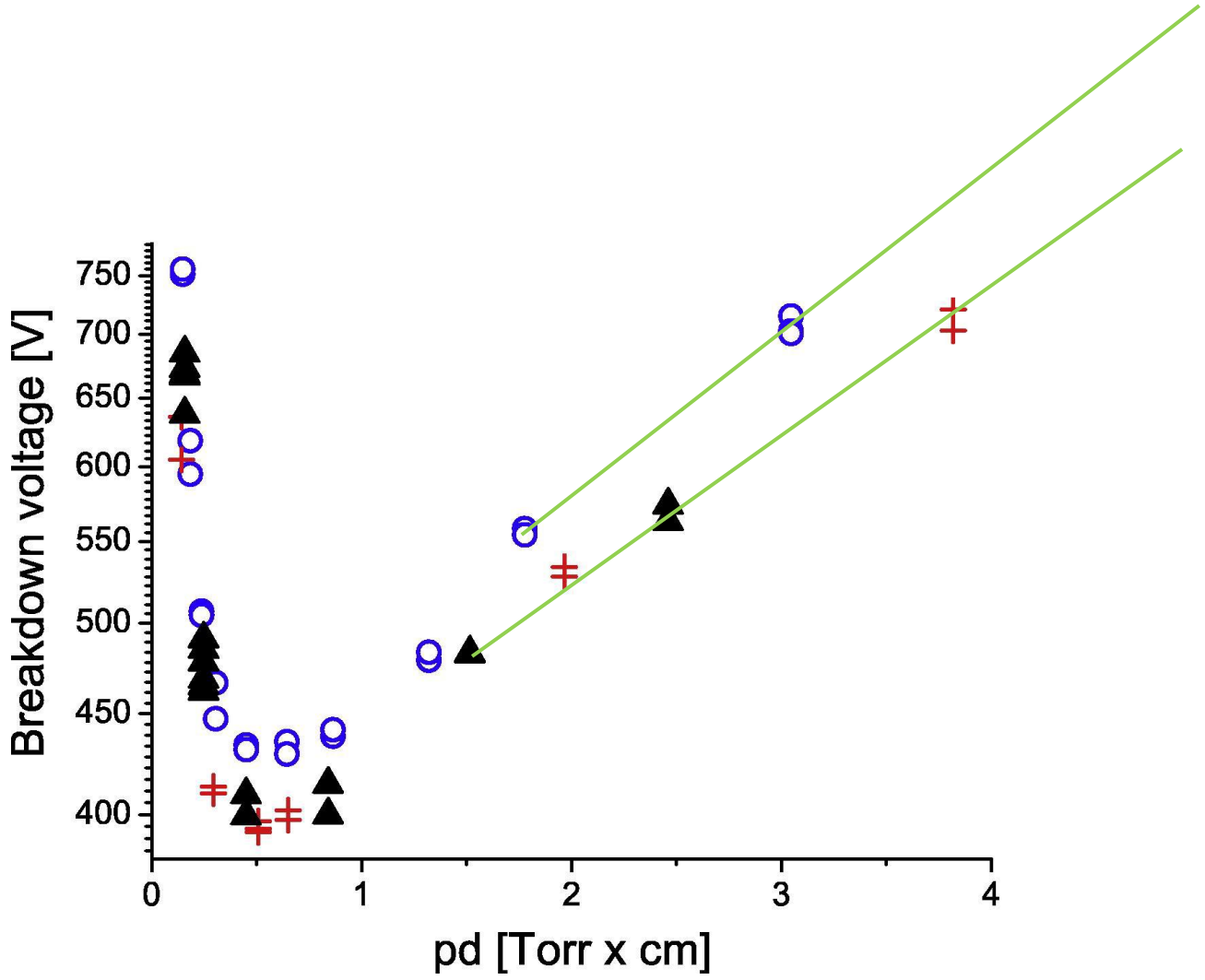
Air Vs Humid Air



Ambient Air (40% RH)
Synthetic Air (mix of pure gases)

Air breakdown voltage is influenced by the effect of humidity. Water vapor has a higher breakdown strength than air, so a mixture of water vapor and air (i.e. higher humidity) has a higher breakdown voltage. Water also recombines very quickly after dissociation, which increases its breakdown strength (less likely that there are free ions floating around to support an avalanche).

Air Vs Humid Air



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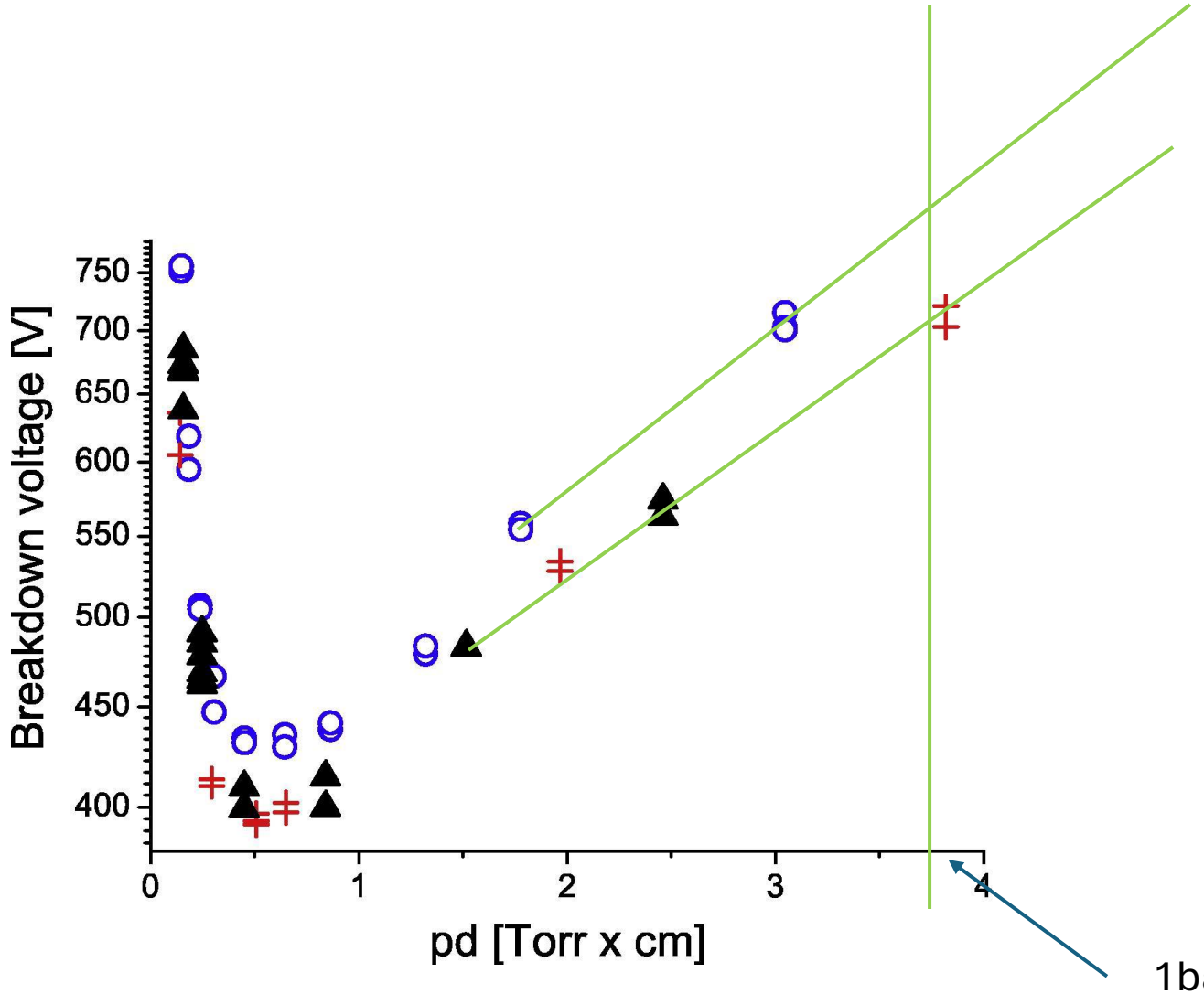

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1bar x 50um = 3.75 Torr x cm

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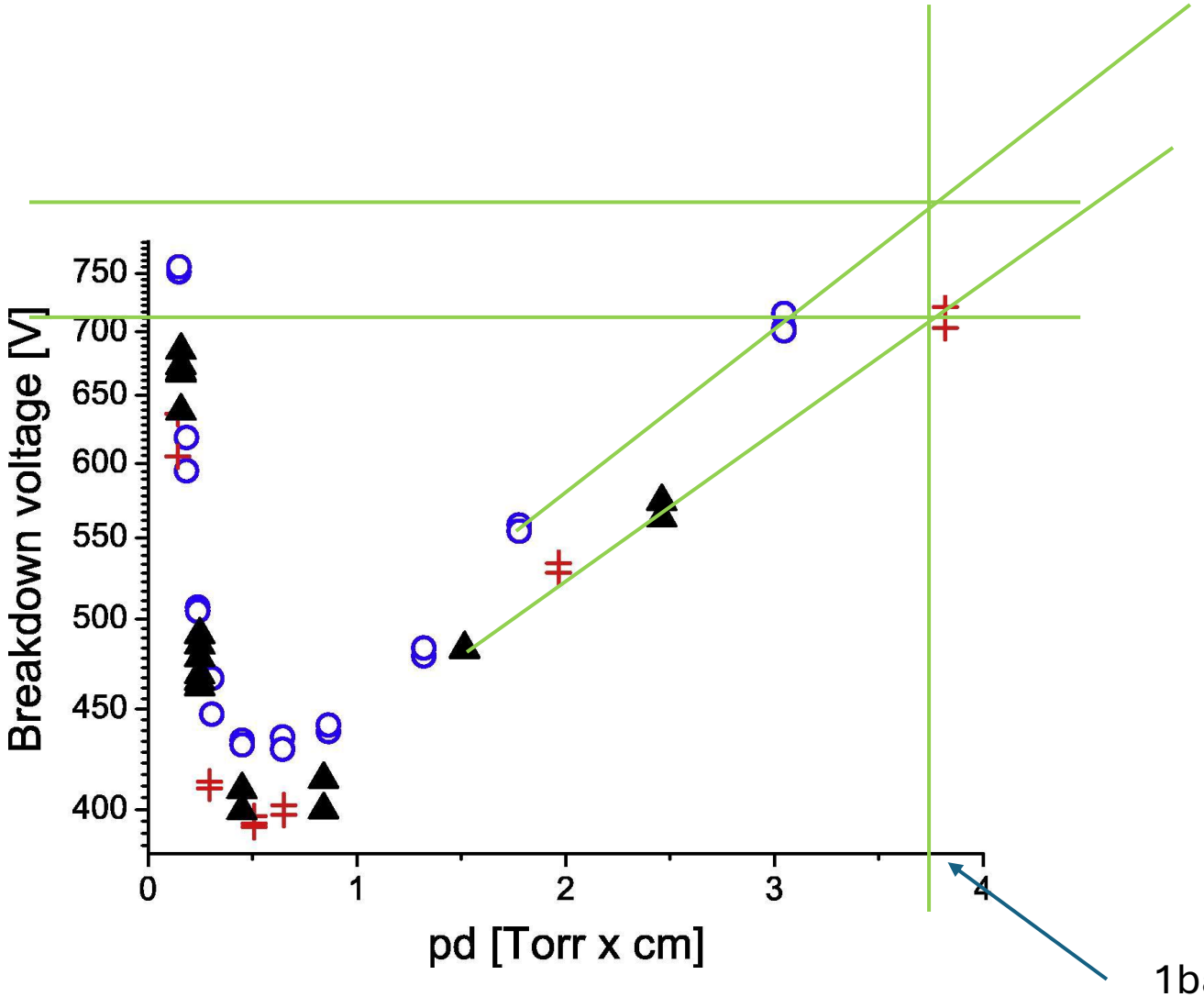

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@25 deg , air (40% RH) : more than 800V
@25 deg , air (0% RH) : 720V
Numbers are consistent with observation on the detectors.

1bar x 50um = 3.75 Torr x cm

Humidity absorption/desorption of PI

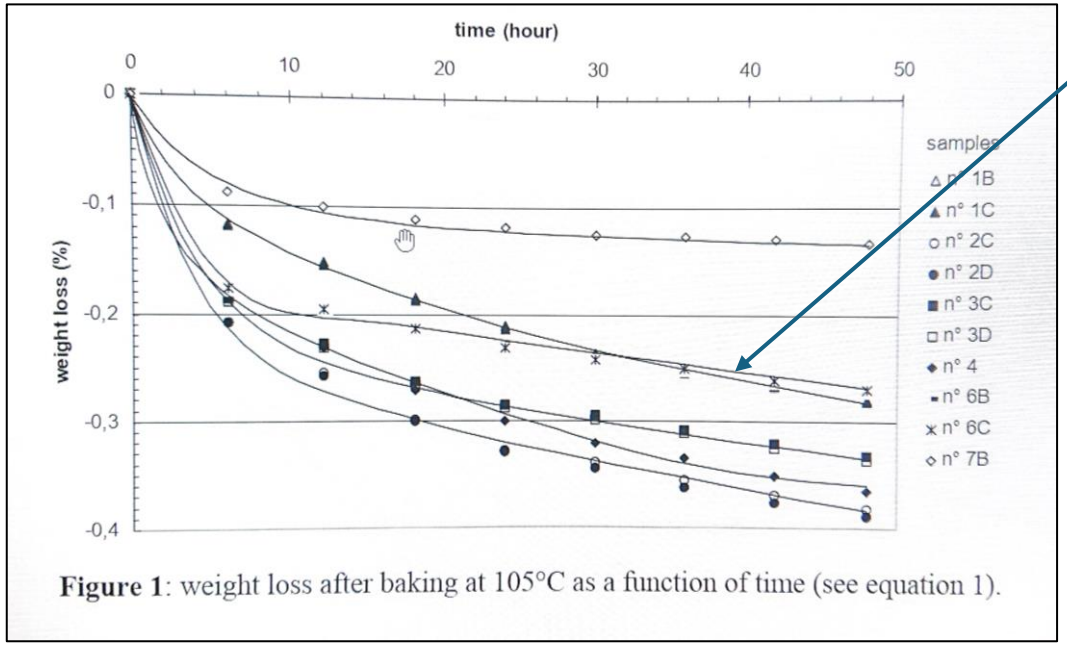


Figure 1: weight loss after baking at 105°C as a function of time (see equation 1).

- 2mm PI plate
  - Weight loss at 105 deg → around 0.3% after 48 Hours.
  - Weight loss at 120 deg → around 0.3% after 12 Hours.
  - Rule : multiply the time by 2 if you decrease the temperature by 7deg.
  - 0.3% weight recovery after 1 month .
- 50um PI
  - Thickness 40 time less than previous numbers
  - Same drying should be obtained after 1h at 105deg .
  - @ 50 deg , it should take 5 days to get the same drying.
  - weight recovery time for 50um PI should be 24h.

These numbers are in adequation with the detector behavior

- looking at Air Vs Humid Air curves , humidity storage in PI
and measurements with detectors

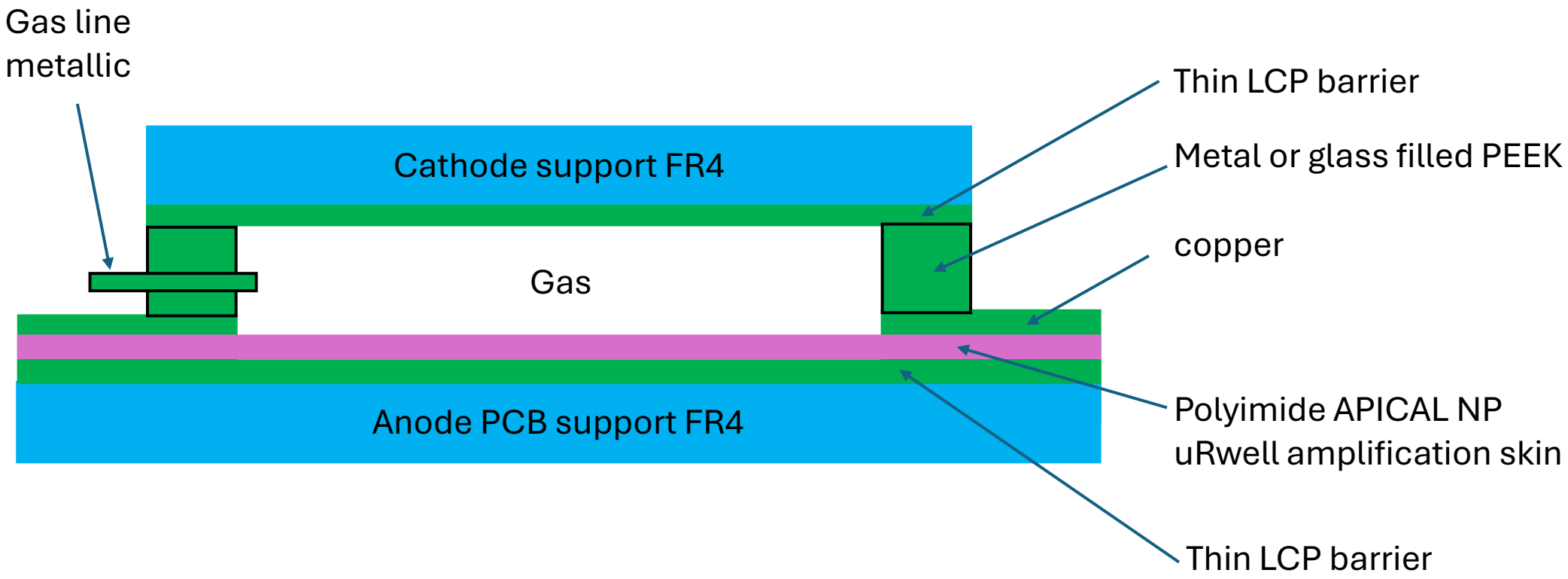
The conclusion is clear :
Instabilities are triggered by water in materials , not directly by gas RH !
At the opposite, some water in the gas improves the Vmax

Any detector must be dried before powering it (at least 50 deg-5 days).
Or stored a long time in air with RH below 20%.
The detector should be as hermetic as possible to ambient moisture penetration ,
such that the desired level of moisture is adjusted with the gas.

Moisture barriers

Copper : not measurable
Teflon 0.01%
LCP: 0.1%
Glass filled PEEK: 0.11%
Best Polyurethane : 0.3%
STD Epoxy : 0.4%
Best Polyamide : 0.7% (Rilsan tubes)
STD polyimide Apical NP: 3%

water absorption
of different materials

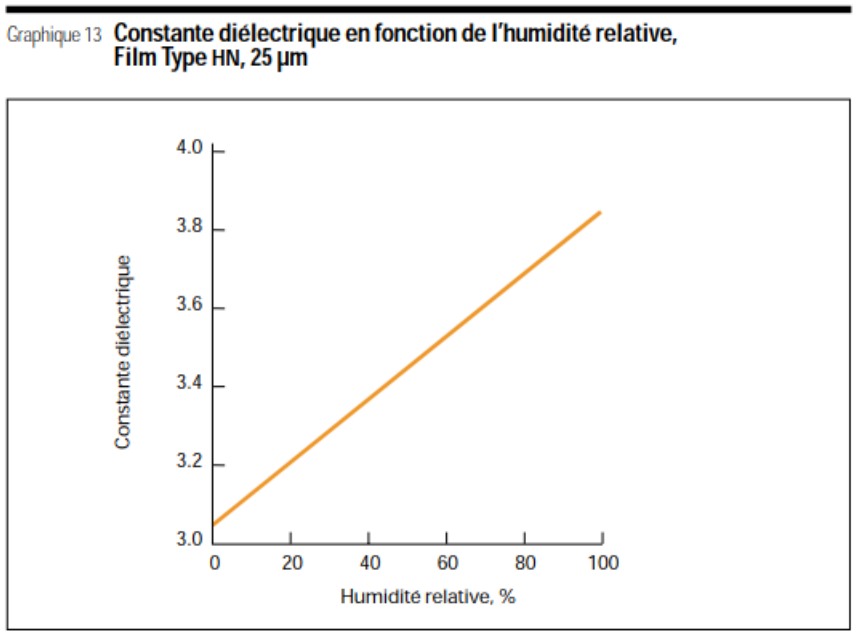


Real time measurement of humidity trapped in materials

Top C electrode

-Capacitor produced with the PI
-The value is proportional to the trapped humidity .

Bottom C electrode



Between 10 and 40% RH
+10% variation on Dk

conclusion

- Dust is a problem but only during detector assembly
- Working gas moisture is not the main problem
- Moisture penetrating the detector through materials is the problem
- There is ways to limit the moisture penetration
- There is may be a way to do a real time measurement of the moisture of critical materials.