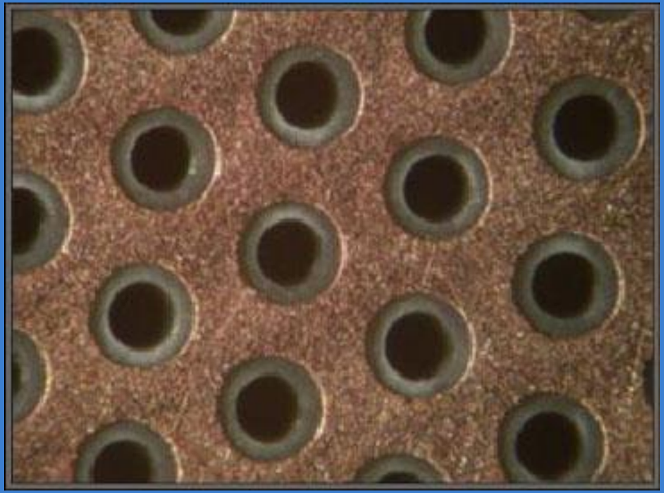
Spark studies in gas detectors



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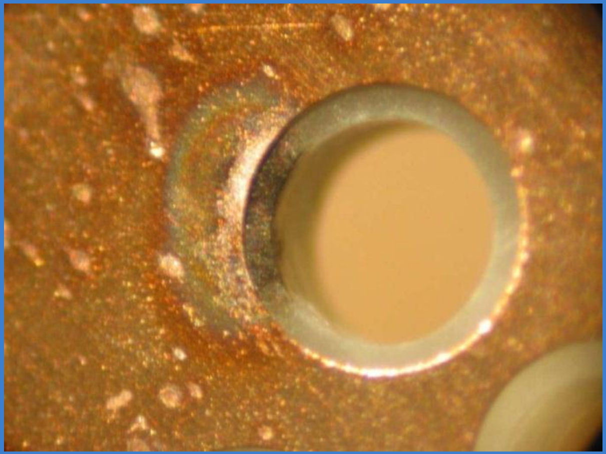
TE-MPE-EM

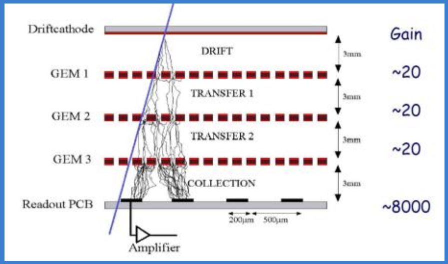
Outline

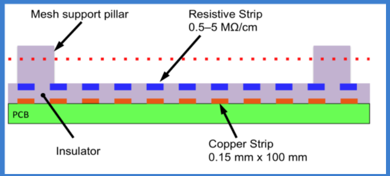
- Problems with sparks in TGEM
- *V-I* characteristic of DC discharge
- Sparks with tips in air
- Sparks with tips on PCB material
- Sparks in THGEM
- Perspective on future improvements

THGEM spark possibilities

Strong ionizing particles produce sparks.
Sparks damage the electrodes and are responsible of a low degradation of the gain.
The active element then drains steadily a DC current from the power supply.

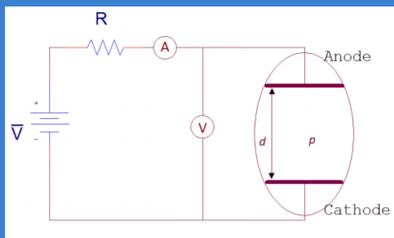






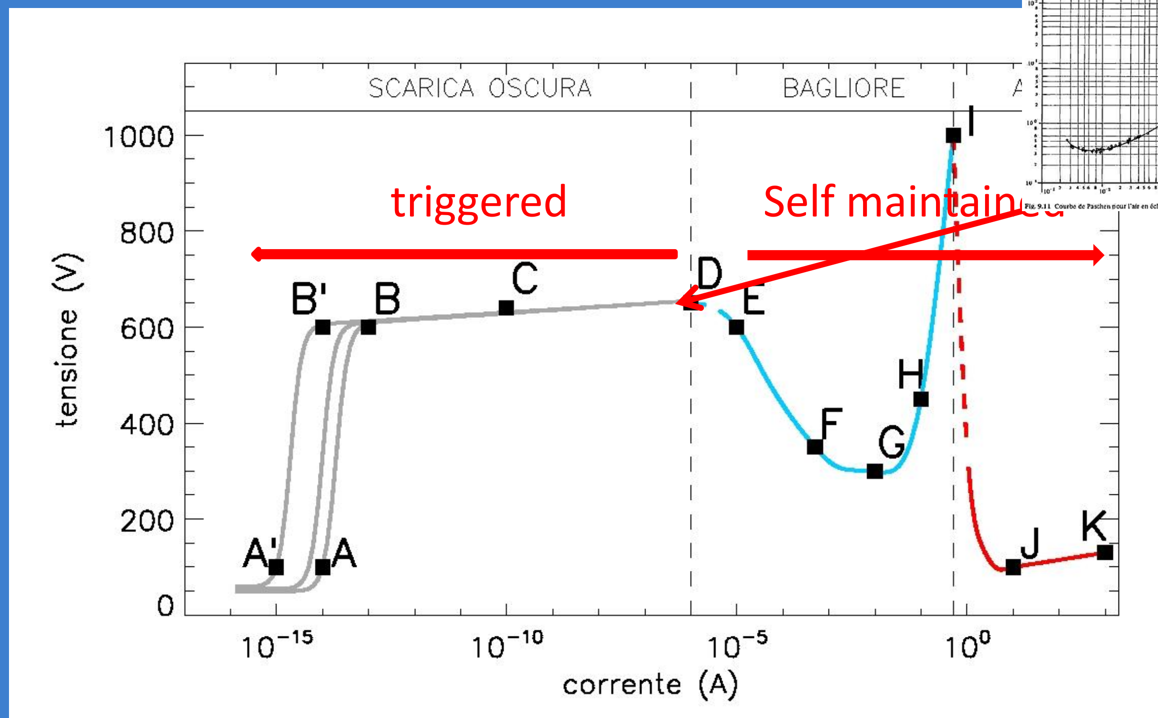
Is it possible to run a thick GEM with sparks like Resistive Micro megas detectors? Or the only solution is multiply the number of THGEM

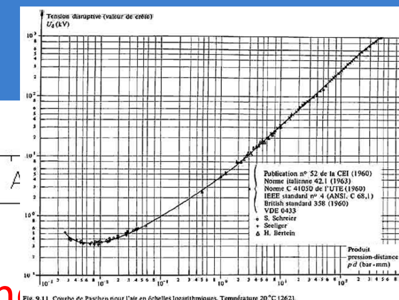
Voltage-Current Characteristic of the DC Electrical Discharges



- Non-self sustained: current only in presence of an external source of ionization

- Self maintained:
current flow lasts as long as the field is applied or charges are available

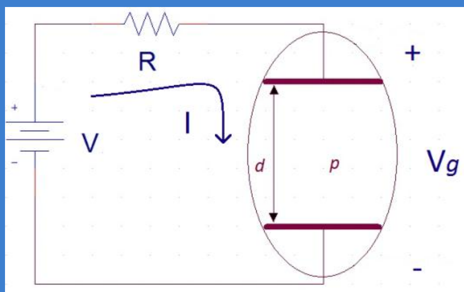




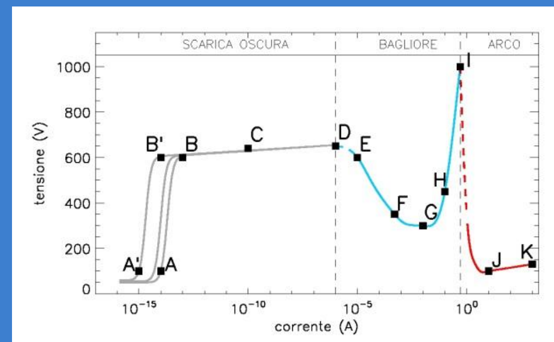
Gas Discharge Physics, Yuri P. Raizer
DC pulse-powered micro-discharges on planar electrodes, Yogesh B. Gianchandani

Working point:

the load line method

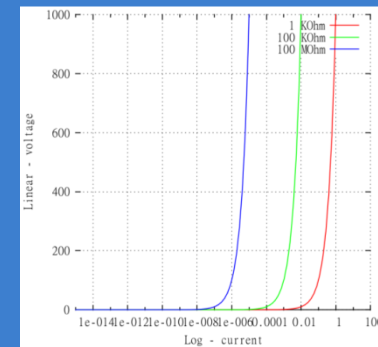


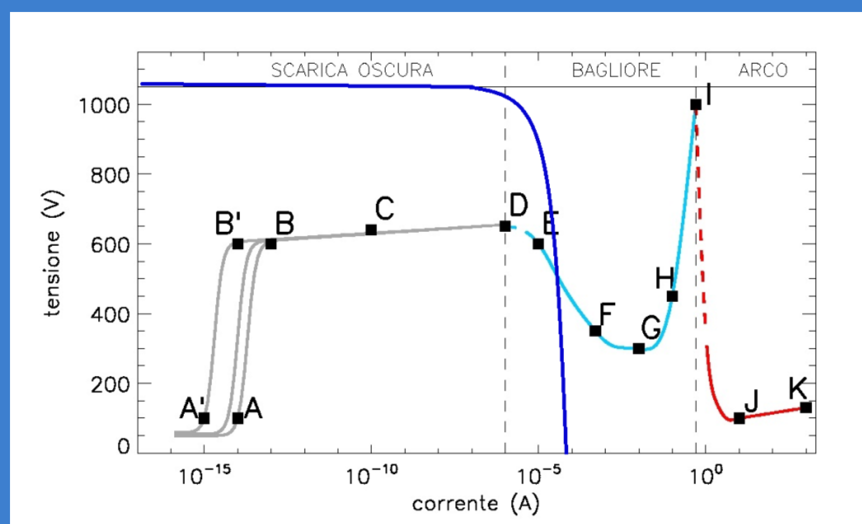
$$V - RI = Vg$$



$$V_g = f(I)$$

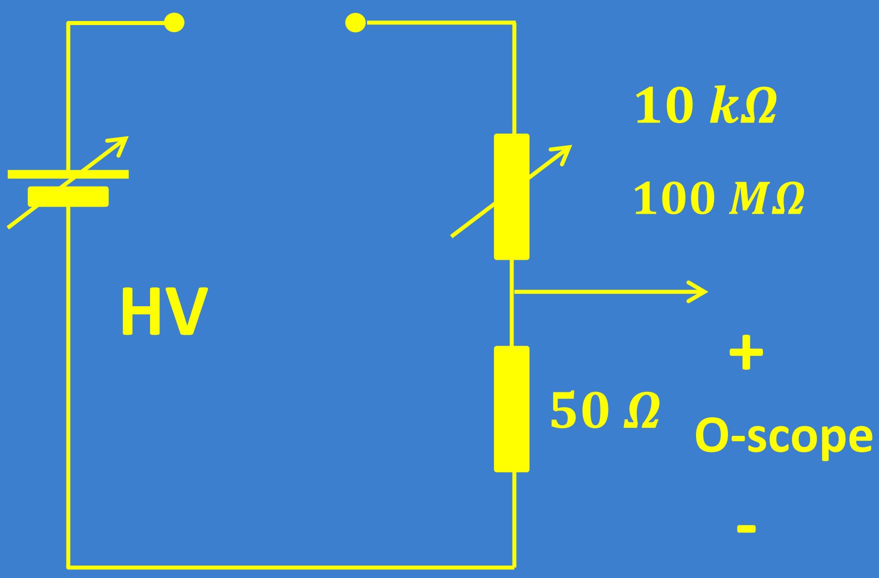
+

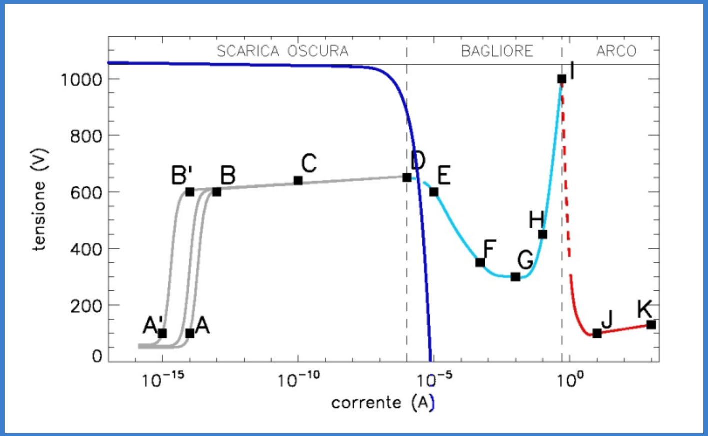


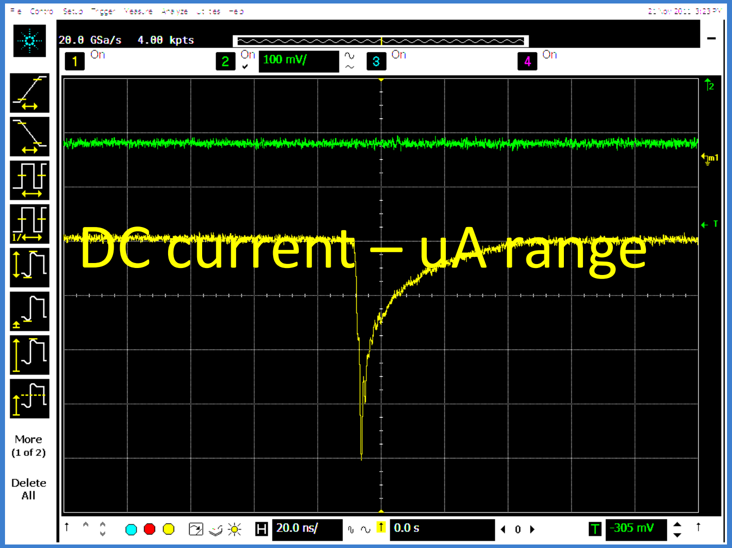


Sparks between two metallic tips in air

AIR, 1 atm **Low inter tips C**

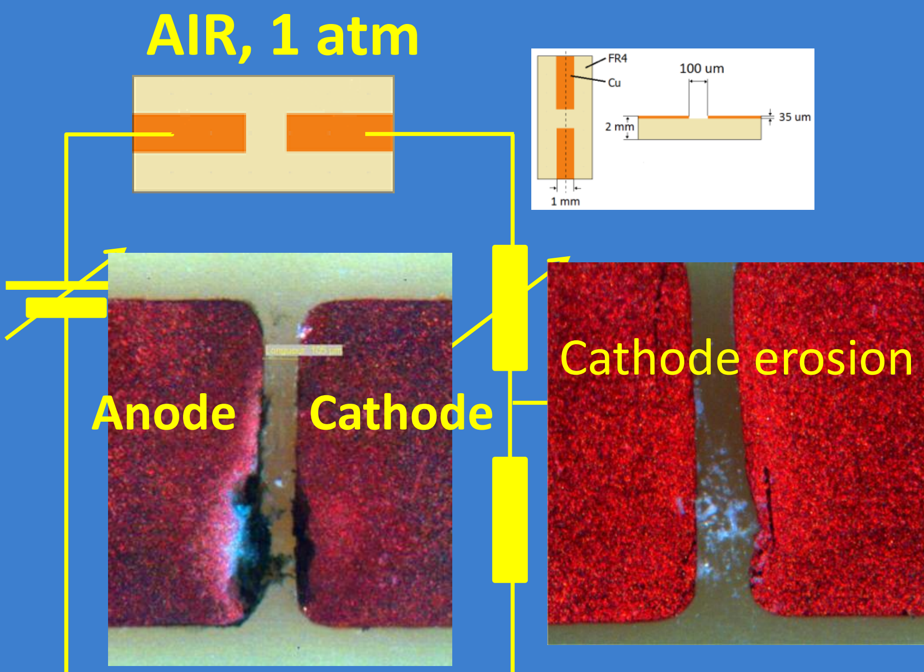


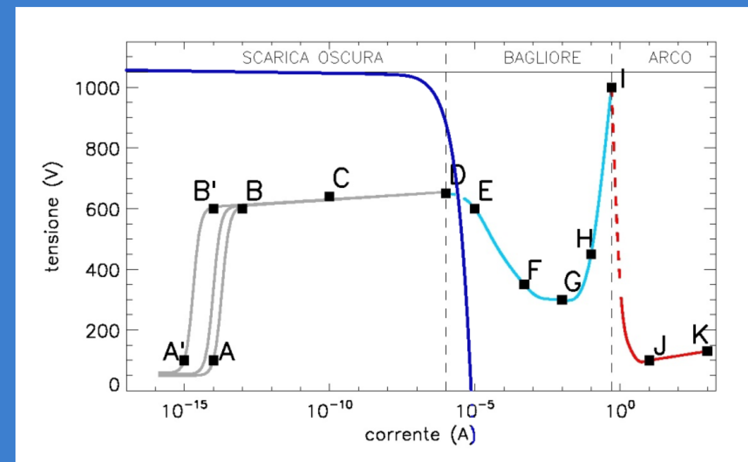


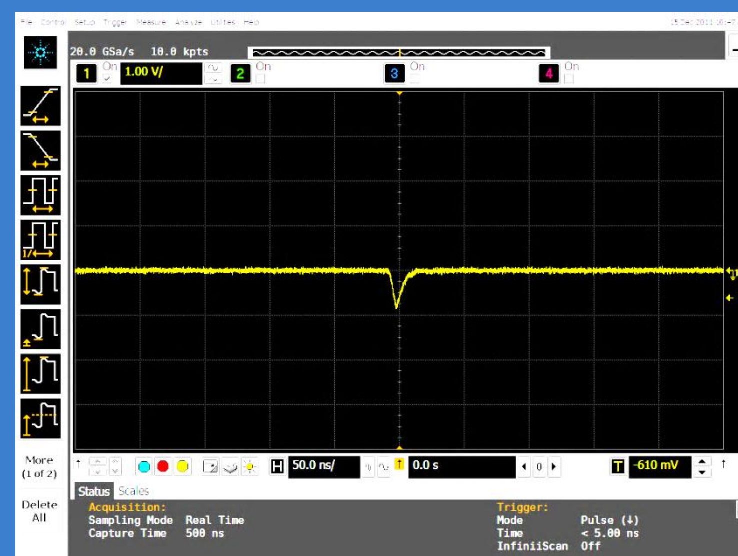


No change is observed.
The system is stably in one of
the regions of the I-V characteristic.

Sparks between copper lines on a PCB



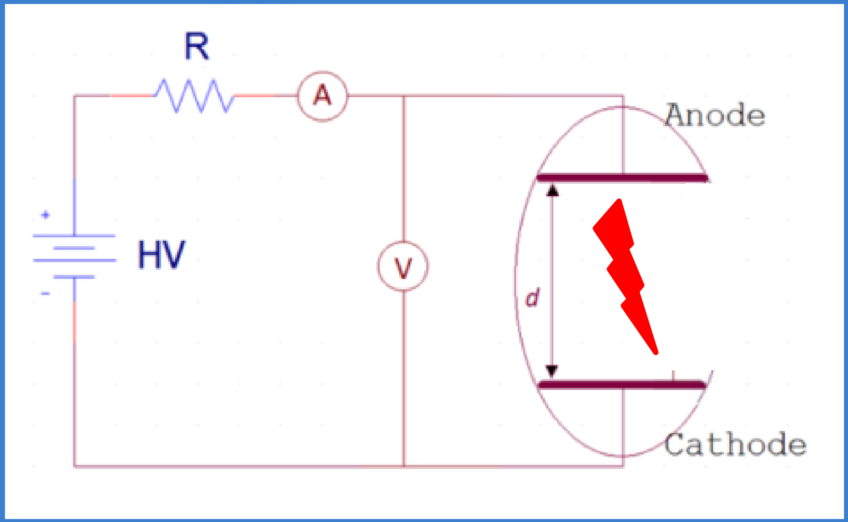




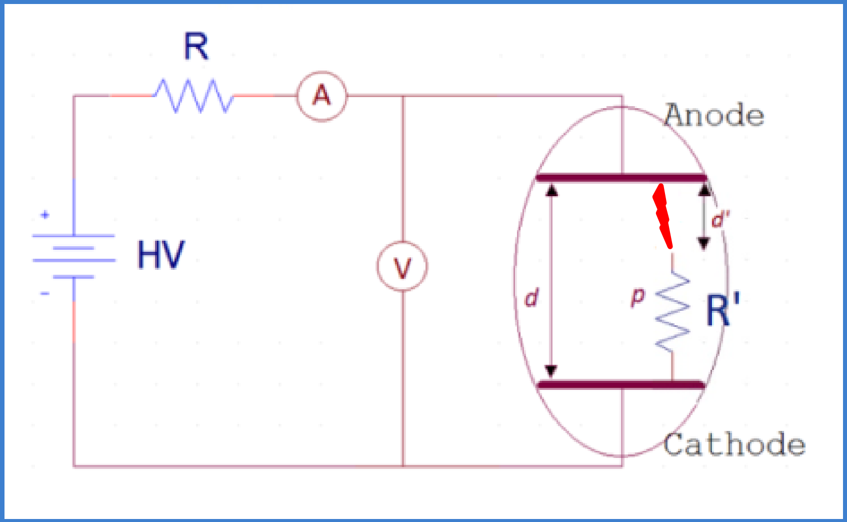
During the sparks the growth of a layer is observed all around the impact point of the discharge, especially on the anode.

- On the Nature of Copper Cathode Erosion in Negative Corona Discharge, Petrov, IEEE
- Theoretical study of factors influencing arc erosion of cathode, Zhou, IEEE

Introducing R’

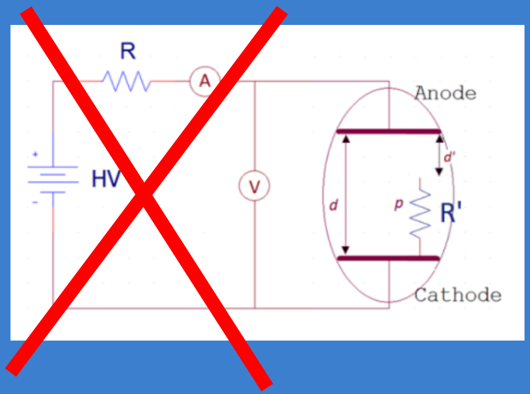


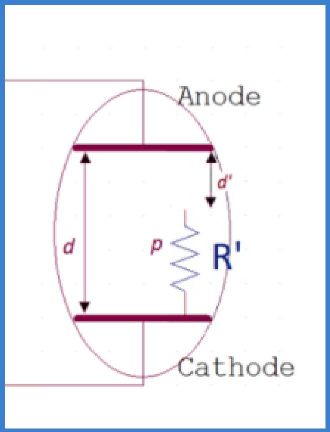
Before



After
R’ is created
Voltage breakdown reduced :d’

Large capacity system → THGEM





-If the capacity of the tips is high then this capacitor becomes the power supply for the spark
it can deliver more current than the power supply

-The spark current is then practically independent from external power supply

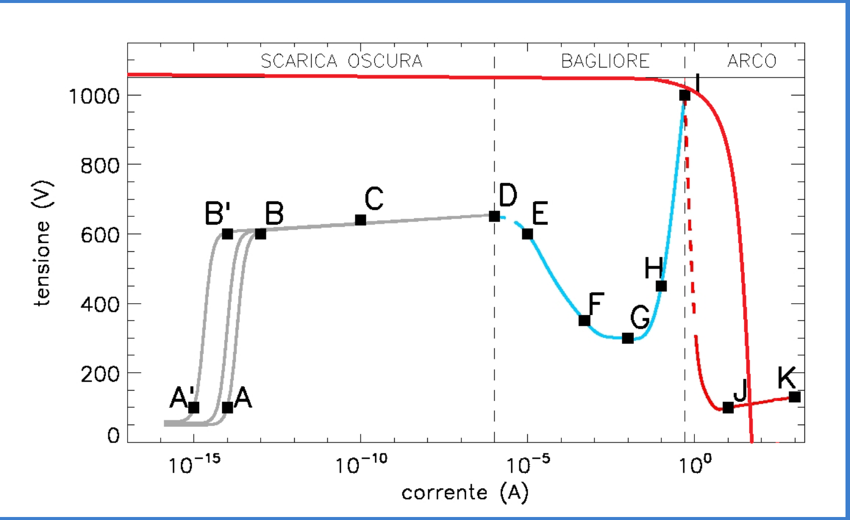
-The peak current only depends on: the capacitor value , R' and C voltage
(this current can not be measured in this configuration)

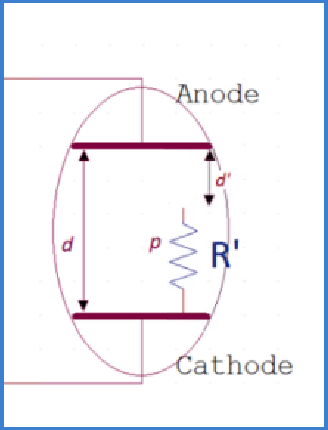
-The new Voltage breakdown will be define by d'

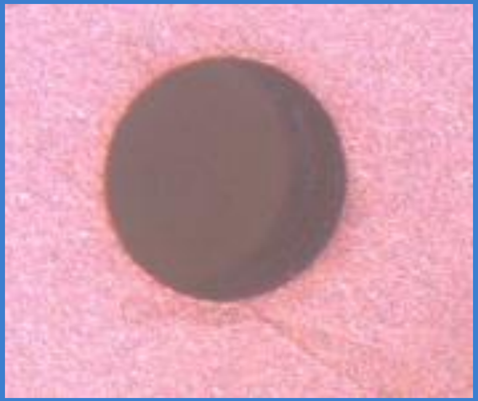
- The external power supply and R are just refilling the capacitor after a spark (defining the spark rate only)

THGEM test

initial situation: spark







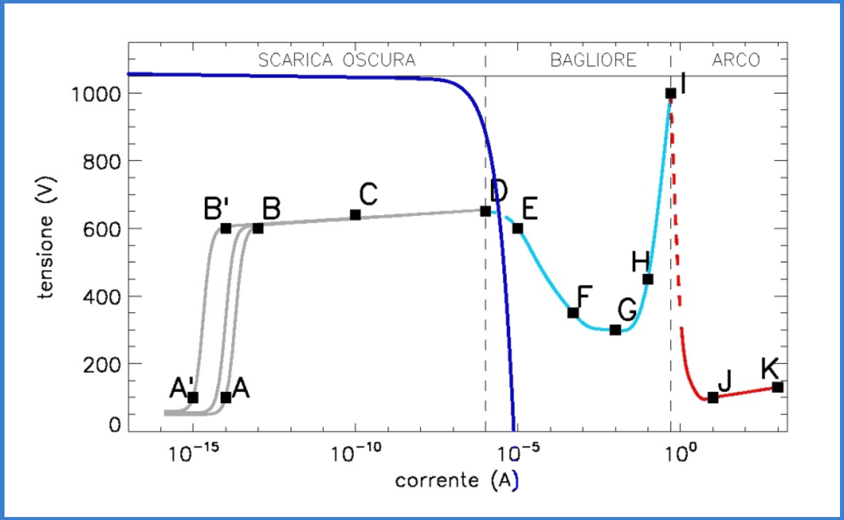
-At this stage R' is only the copper surface resistivity (below 10 Ω)

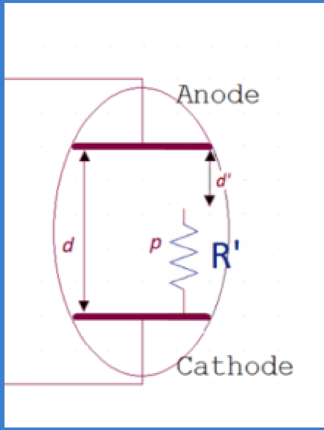
- Working point in spark region

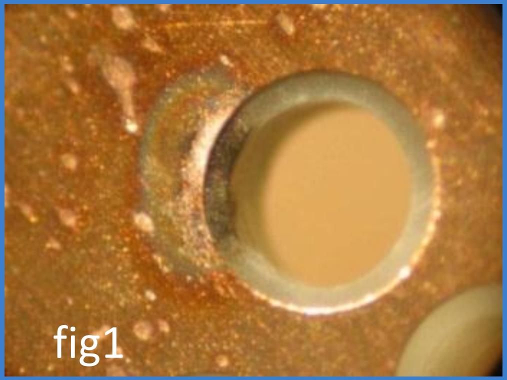
 -High current discharge (define by C and R')

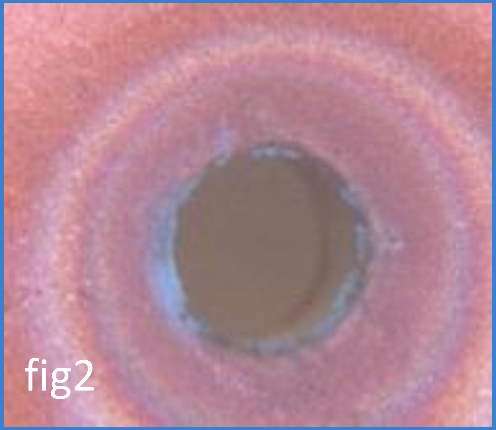
-The system seems to be stable with repetitive sparks and average currents of few hundreds of nA (the rate of sparking is define by the capacitor value and the serial resistor after the power supply)

After spark → glow discharge









The repetitive sparks starts to create a deposit fig 1

-R' is created and starts to grow (we think that the value is randomly changing)

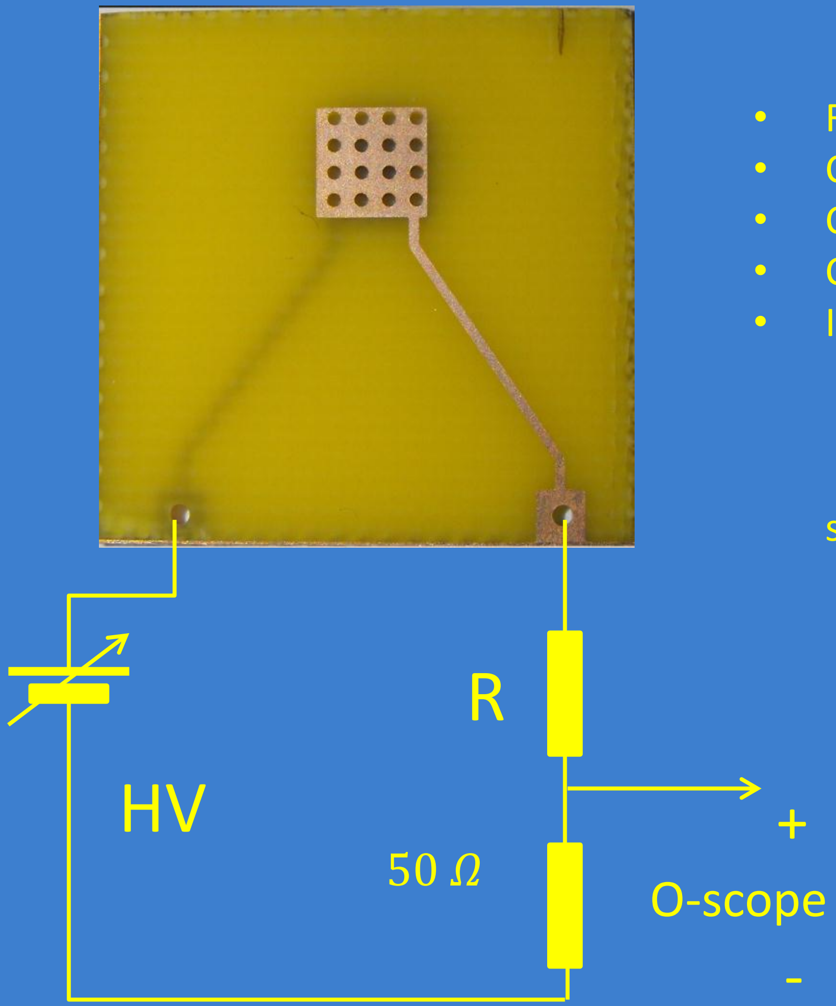
-The working point moves in the glow discharge region but still with pulsed current with increasing rate.

-At one point the external power supply can deliver the current defined by the working point

-The system then moves in a stable mode and draws many micro amps DC current

-The DC glow discharge starts to grow a new deposit all around the hole. fig2

Real samples tests



List of different trials

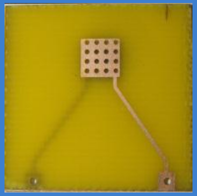
- Reduce the capacity by segmenting the THGEM
- Change metal
- Change dielectrics
- Change the hole shape
- Introduce resistive materials

R was adjusted to define a correct rate of sparks

First test : size effect

The THGEMs have been powered above the breakdown voltage in air
The number of sparks have been recorded
Regularly the voltage was decreased to check if the leakage currents were still below 5nA
The maximum accepted decrease was 0.9x the initial voltage

Standard	Small sample
$14400\ sparks$	$160000\ sparks$

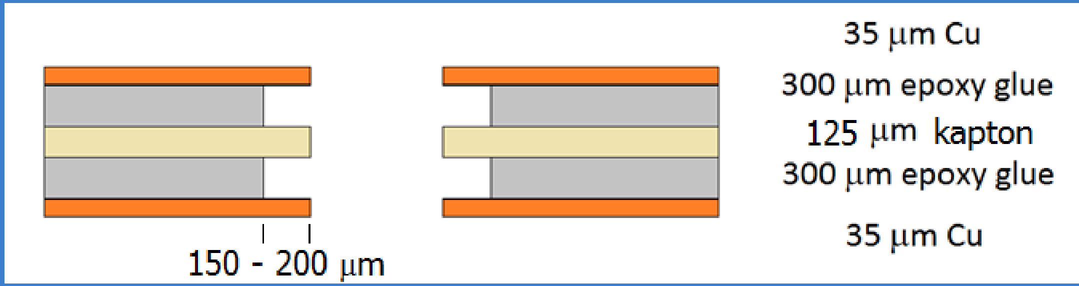


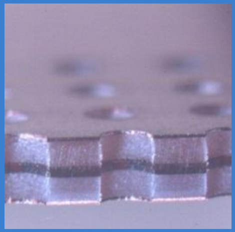
- 100mm x 100mm
- 8 mm x8mm

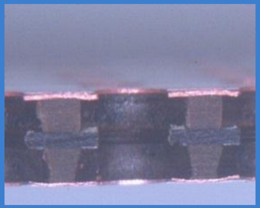
THGEM 10cm x 10cm → 1nF, HV=2KV , 5ns fall time 400 A peak current
8mm x 8mm → 10 A peak current

Material and shape effects

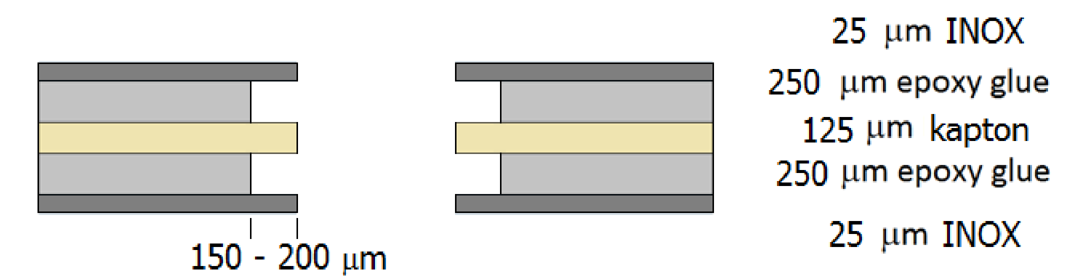
Creating a stack of materials which can be differently etched, in order to obtain free standing copper electrodes, to try to reproduce tips in air.

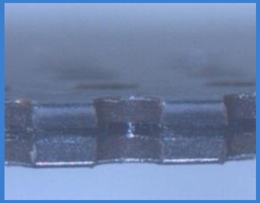


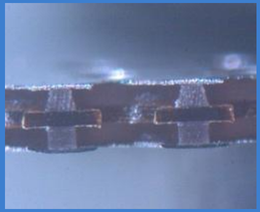




- Covering copper with nickel
- Resistive kapton as electrodes
- INOX (more difficult to work)





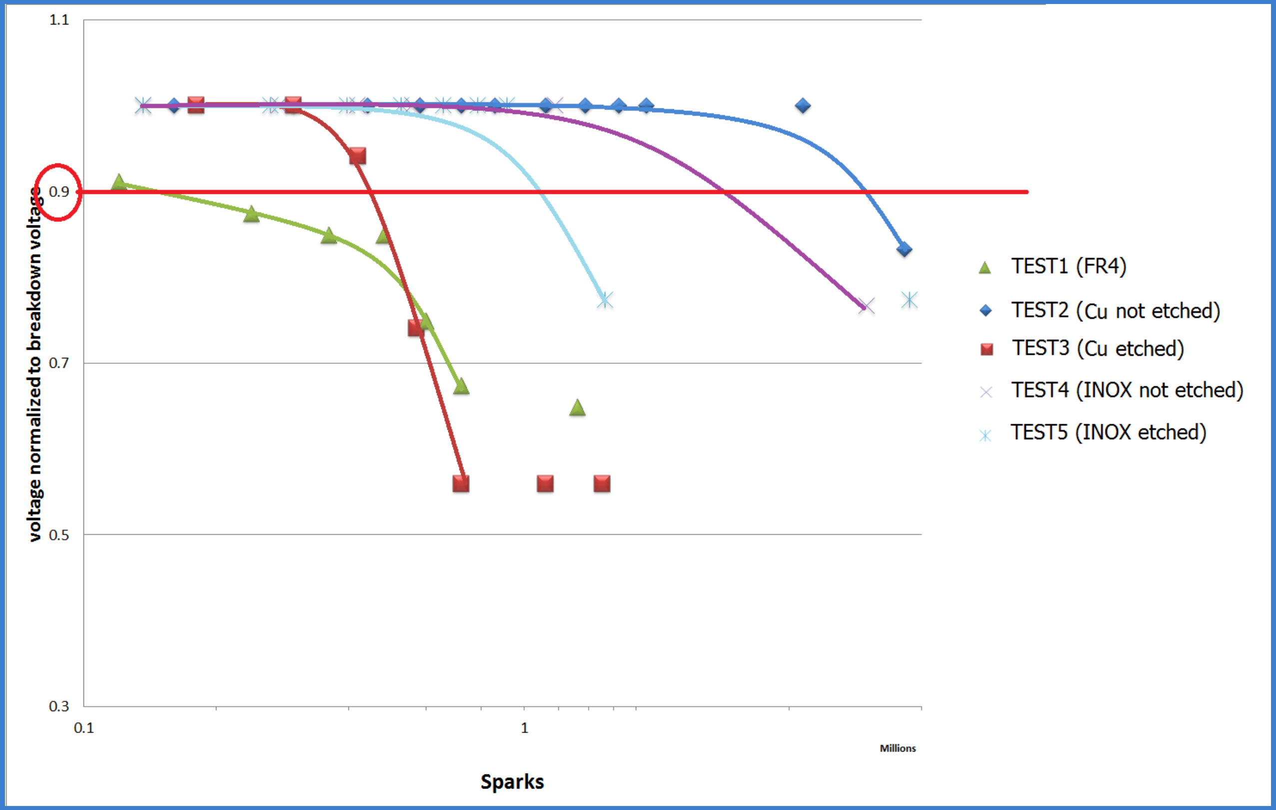


After long sparking period they all failed but some structures are 1000 time better than Cu on FR4 standard THGEM

Measurements

(Be careful low statistics)

Monitoring the breakdown voltage: threshold, $0.9 \times V_b$, below which the TGEM element is unusable. Then we could estimate the lifetime of the samples in a real heavily ionizing environment (our test is even harsher – defect driven).



TEST 1: copper on FR4

TEST 2: copper on epoxy glue and kapton layer not etched

TEST 3: copper on epoxy glue and kapton layer etched

TEST 4: INOX on epoxy glue and kapton layer not etched

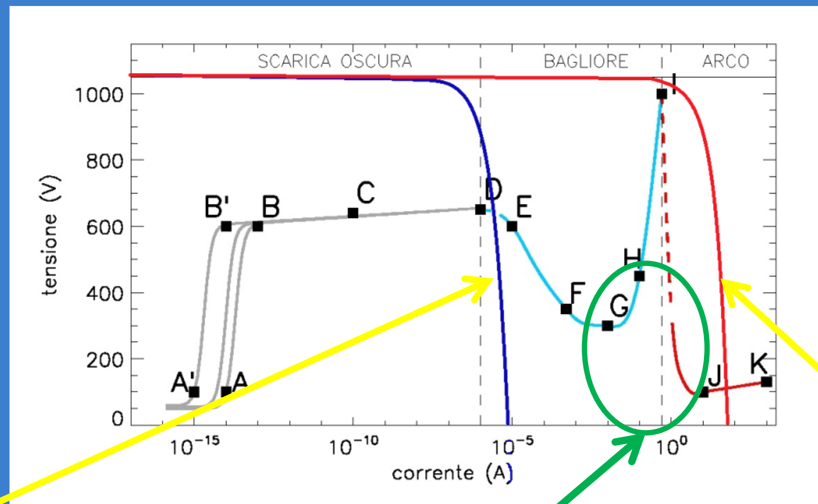
TEST 5: INOX on epoxy glue and kapton layer etched

Let's try to present the results in a different way.
What will be the life time of these different devices if they have to face a spark rate in the range of 200 sparks/s.m2

	Sparks @ $0.9 \times Vb$	Lifetime (years)
FR4 standard 10x10 cm^2	14.4k	0.09
FR4 segmented	$160k$	1.01
Cu + krempel etched	$452k$	2.87
Cu + krempel not etched	$6M$	38.05
INOX + krempel not etched	$3.2M$	20.29
INOX + krempel etched	$1.2M$	7.61

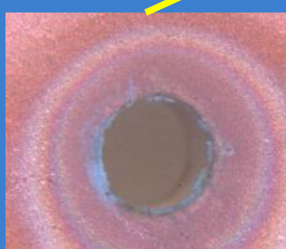
The number of trial should be increased to be more confident on these numbers

Can we go further?



High energy sparks
Low spark rate
Low average currents

?

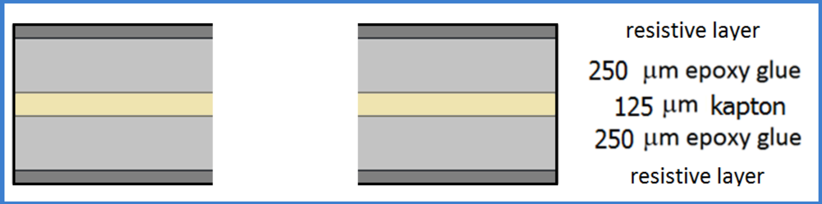


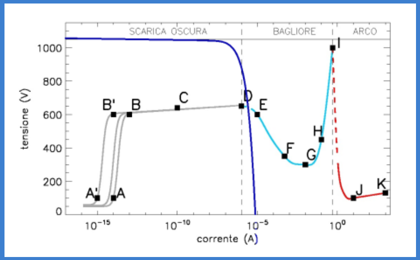
Glow discharge
DC current
High average currents

Low current medium rate sparks
Or high current glow discharge at medium rate
Adjust the max refilling current from power supply

Resistive electrodes

We have tested a few structures with full resistive electrodes (1 Mohms/square)
But we realized that the system is already in glow mode.



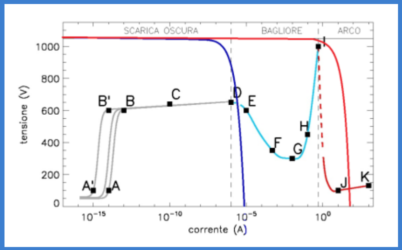


Due to the low local capacity of this system , the rate of the High current glow discharges is really high (the external powering system can refill fast).

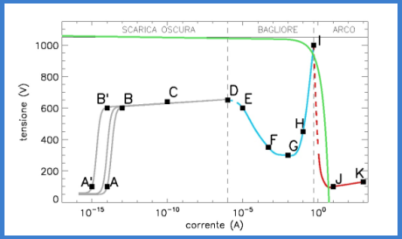
After strong periods of high rate repetitive glow discharges the device is rapidly damage and dies before a fine segmented metallic device

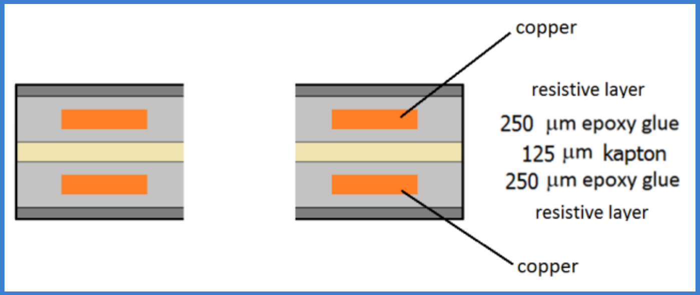
Next step: adjusting the impedance

It seems that metallic electrodes produces a too energetic spark
And the existing value of resistive materials put the device in deep glow discharge

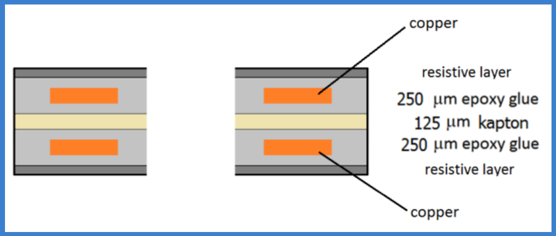


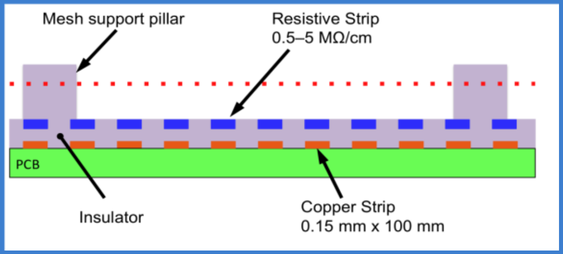
What if metallic electrodes are added in between? Changing geometrical dimensions , we can regulate the impedance, hence the working point.



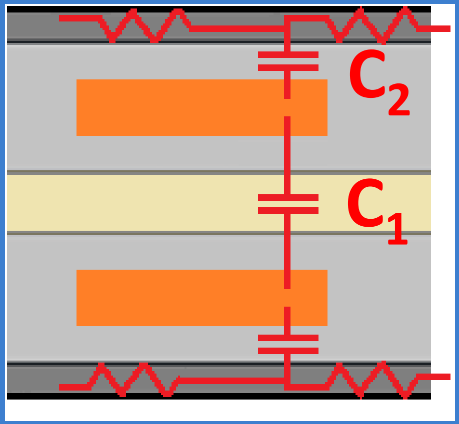


The electrical equivalent: a comparison with MICROMEGAS

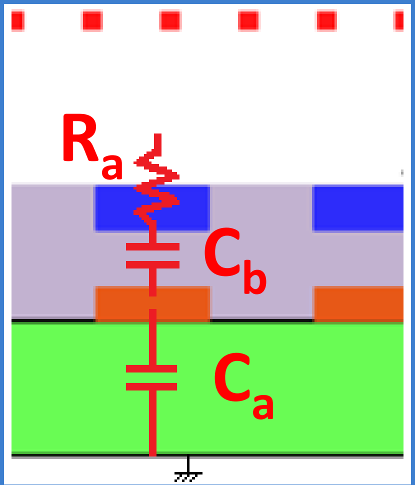




$R_2 \gg R_1$



discharge



Good choice of materials and geometrical parameters to have:

- C_1 large value
- $C_2 \cong C_b$
- $R_1 \cong R_a$

Conclusions

-We have a better understanding of the damaging phenomenum during sparks

-We have not found but confirm some existing observation:

segmenting the THGEM improove the robustness

Using other dielectrics also help a lot (chemical reactions , but difficult to predict)

Changing the shape of the hole does not seems to help

-We still think that the best working point has not been yet reached

we are looking for a structure with spark current in glow discharge mode but with a low rate of repetition

Thank you