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Perspectives on GEM degradation research with high resolution material analysis techniques

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University of São Paulo

University of Nottingham
UK | CHINA | MALAYSIA

Research on GEMs at the University of São Paulo

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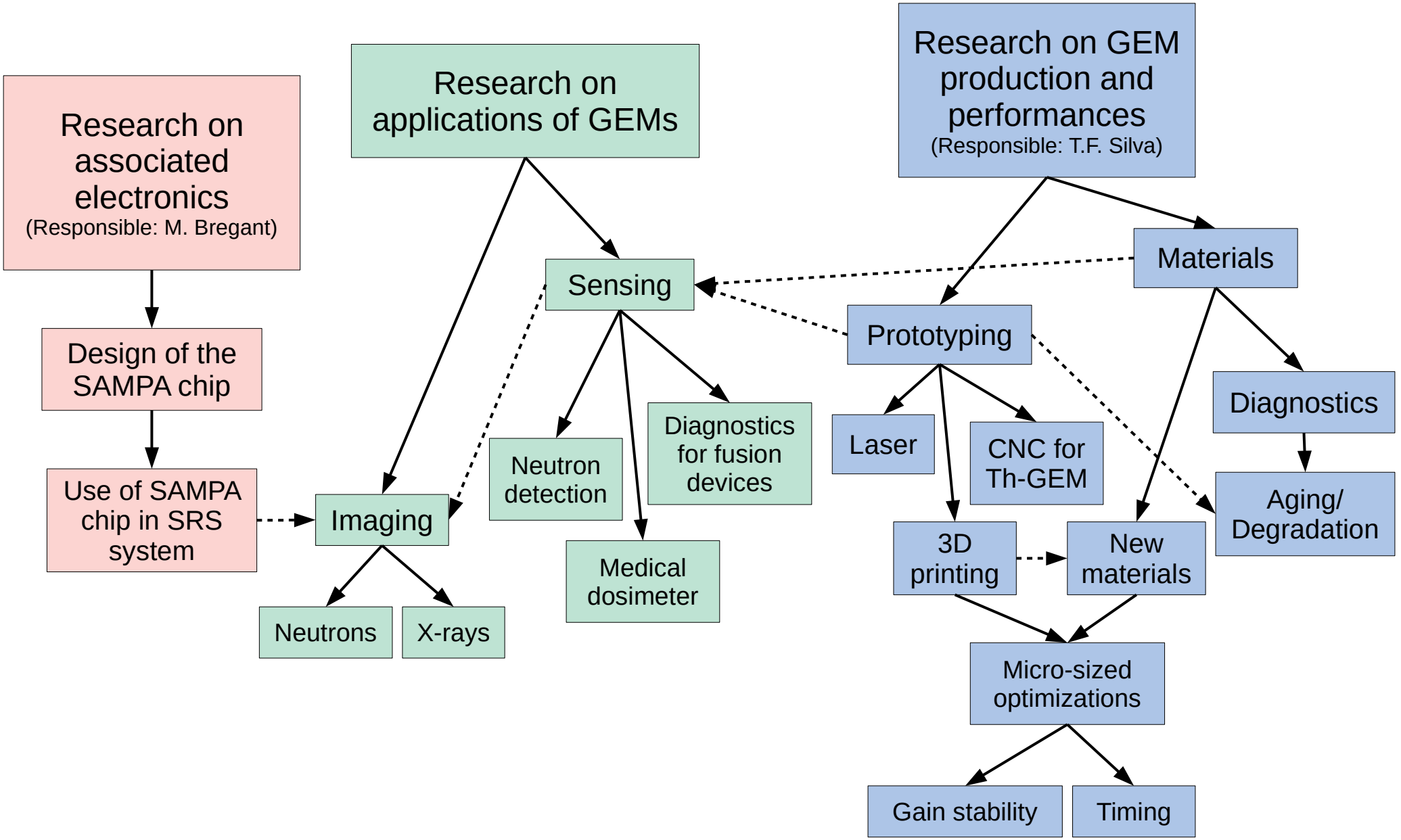
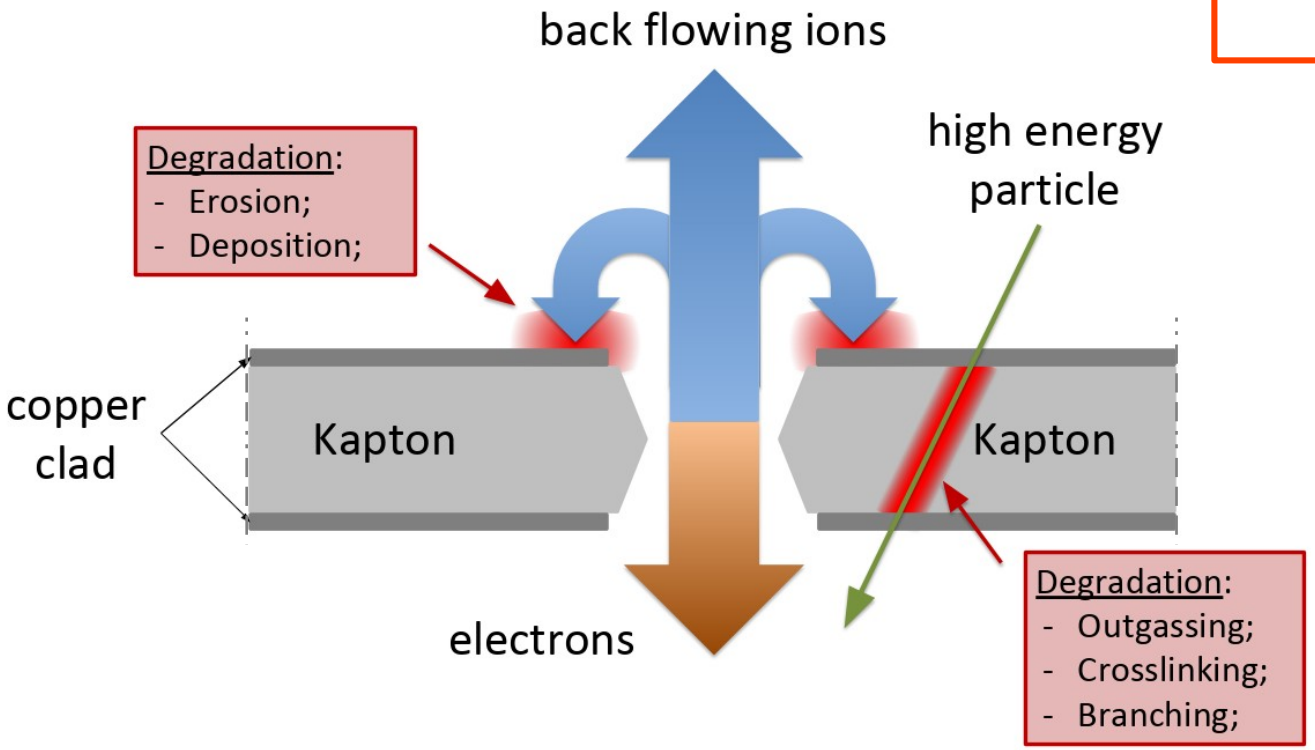


Research on GEM detectors

Search for a conceptual model of GEM detector degradation

- **Low energy ions can damage the copper clad**
- **High energy particles** can pass through the copper clad and **damage the Kapton**

- **Degradation consequences:**
  - **Charging up effects**
  - **Losses of gain**
  - **Losses of insulation**
  - **Sparks**
  - **Aging**



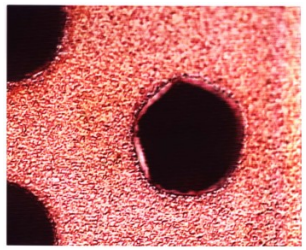
The questions we are trying to answer are:

1. How far this consensus goes? (How accurate it is?)
2. What are the extreme consequences of this model?

Search for a conceptual model of degradation

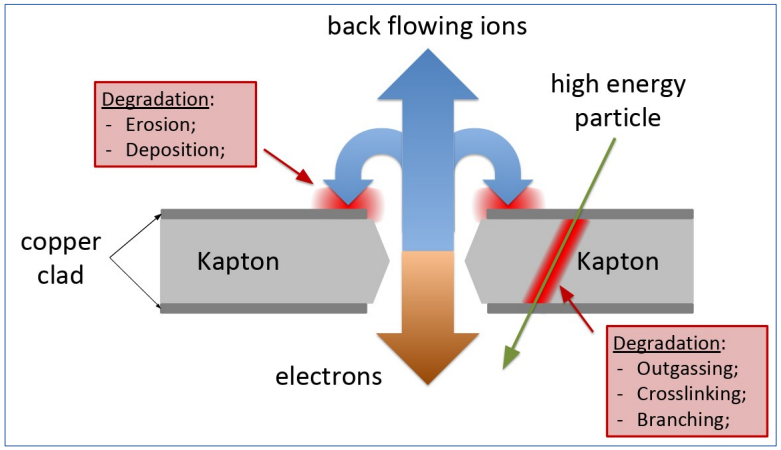
Physical sputtering and adsorption

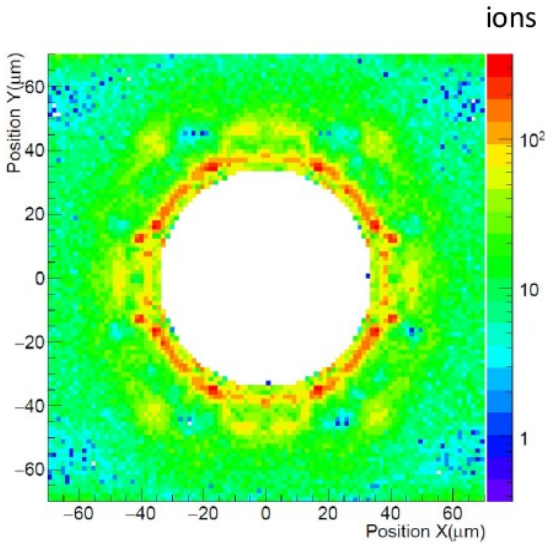
- **Low energy ions** (produced during the avalanche) **flow upwards** to the drift region
- A **fraction** of this ions **hits the upper copper clad**. They can:
  - ✗ Erode the copper clad
  - ✓ Be adsorbed at the surface

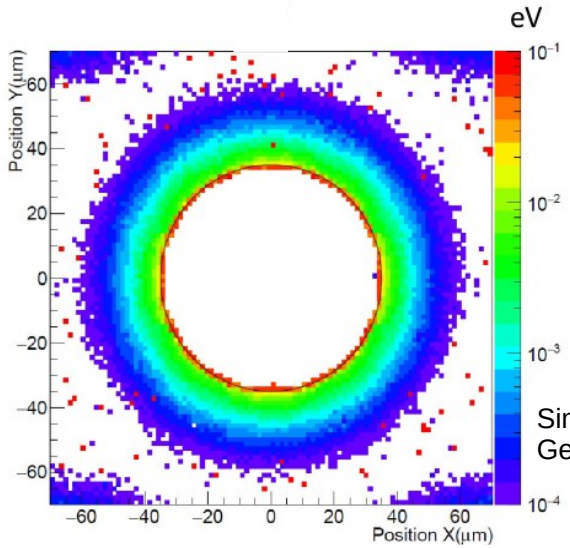


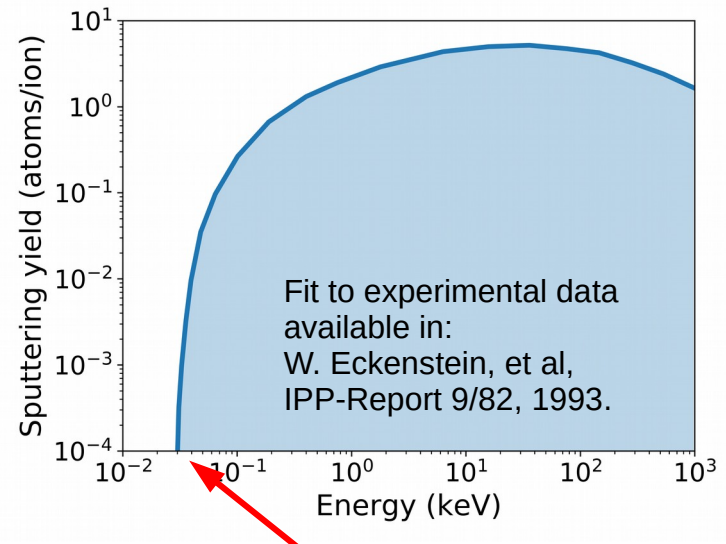
Apparent **roughness** at the surface and **accumulation** of material at the border.

P. S. Barbeau, et al, "An aging study of industrially produced micropatterned gas detectors," in 2003 IEEE Nuclear Science Symposium. (IEEE Cat. No.03CH37515), 2004, pp. 3723–3725.









Simulation by:
Geovane G.A. de Souza

Search for a conceptual model of degradation

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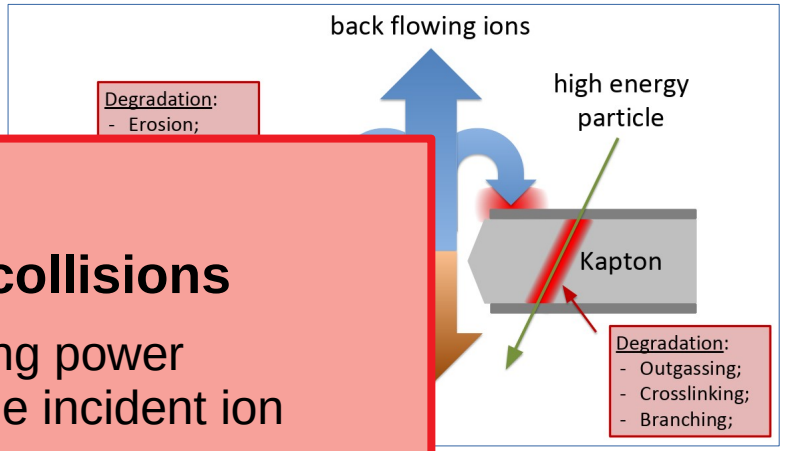
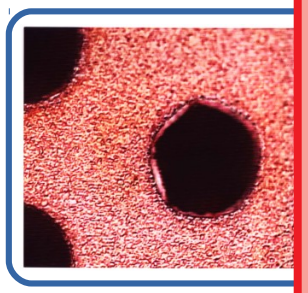


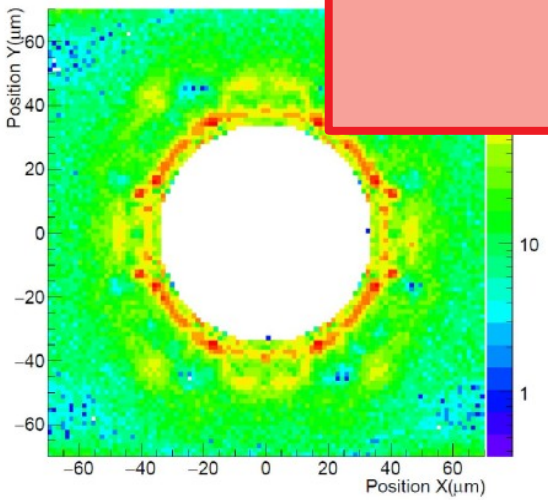


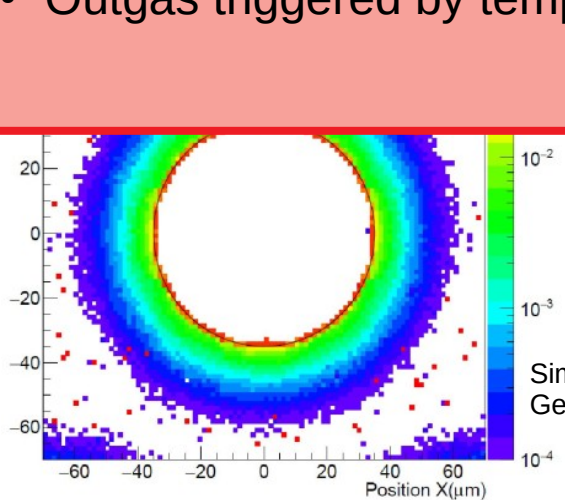
Physical sputtering: binary collisions

- Related to the nuclear stopping power
- Only relevant to low energies of the incident ion

Adsorbption: chemical attachment to the surface

- Low energy process
- Outgas triggered by temperature





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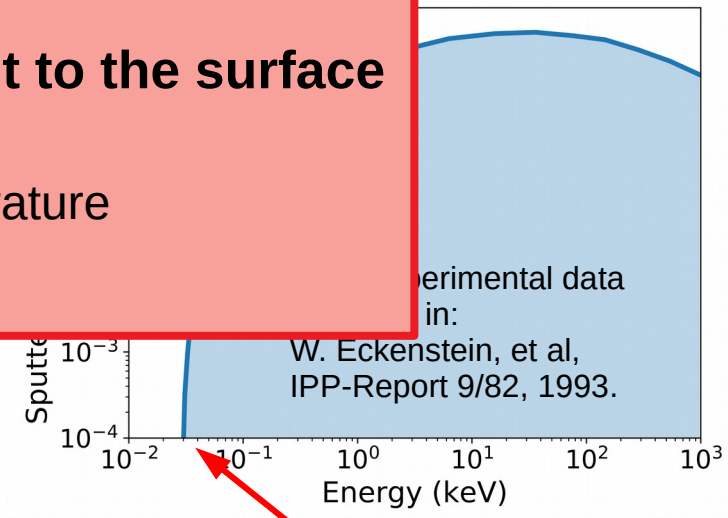


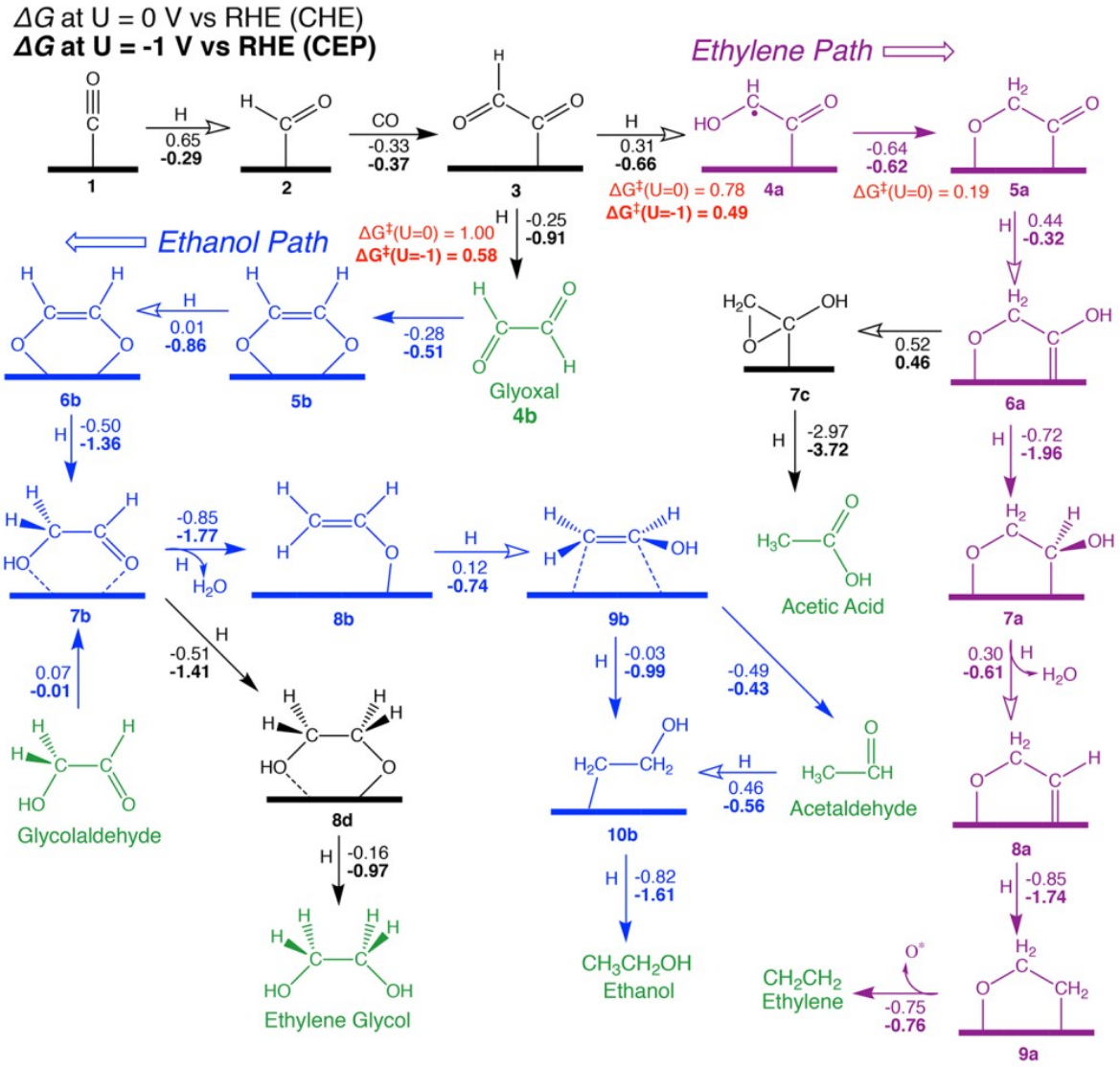
erimental data
in:
W. Eckenstein, et al,
IPP-Report 9/82, 1993.

Threshold at 27 eV!

Search for a conceptual model of degradation

The role of hydrogen in the organic layer formation

- With **no availability** of H_2 only **simple organic molecules** are deposited at the vicinity of de holes
- Depending on the **surface characteristics**, the organic deposition can evolve to a much more **complex organic molecules if there is H_2 availability**
  - **Gas cleaning is important**
  - **Humidity**
  - **The Kapton releases H_2 under radiation**

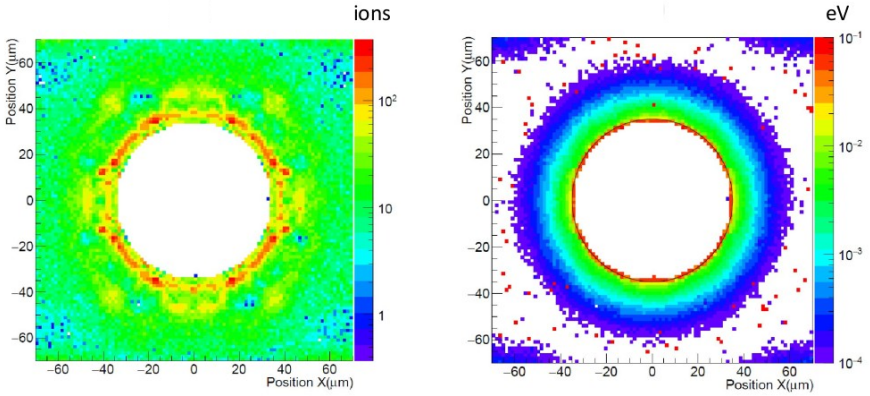


A.J. Garza, A.T. Bell, M. Head-Gordon - ACS Catal., 8, 1490−1499, 2018.

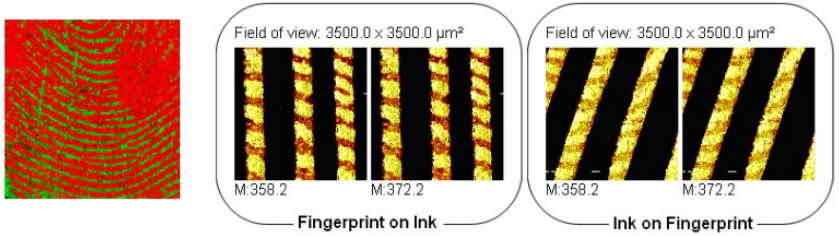
Search for a conceptual model of degradation

Advanced surface analysis for GEM studies

- **High resolution material analysis techniques:**
  - Use **extremely sensitive** technique **ToF-SIMS** and measure maps of **organic compounds** in the **vicinity of the holes**
  - Compare the **measured pattern** with **simulations**

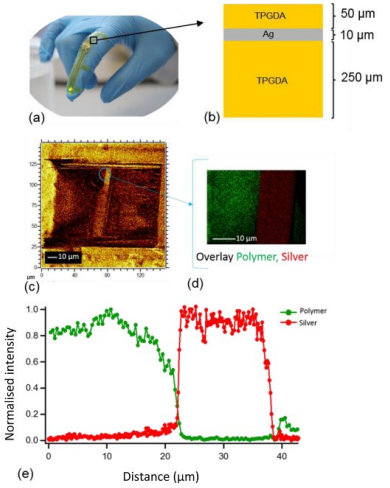


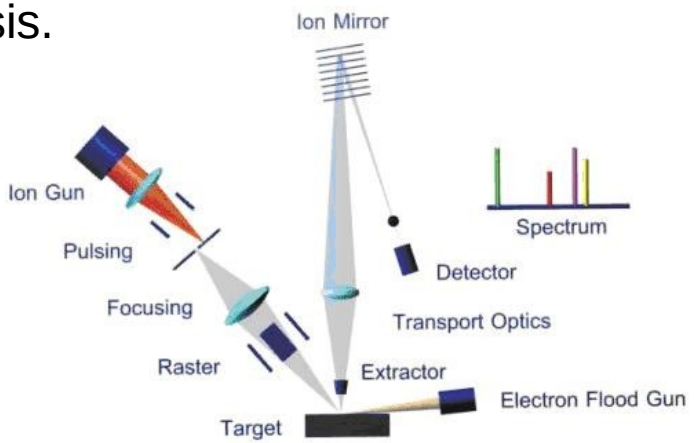
Example of ToF-SIMS application:



M.J. Bailey et al., Analyst, 2013,138, 6246-6250 .

University of Nottingham is our collaborator in this project. They offer the state of the art on ToF-SIMS analysis.





Time-of-flight Secondary Ion Mass Spectrometry (ToF-SIMS)

M. Tiddia et al. , ACS Appl. Mater. & interfaces, 11, 4, 4500–4506, 2019.

Search for a conceptual model of degradation

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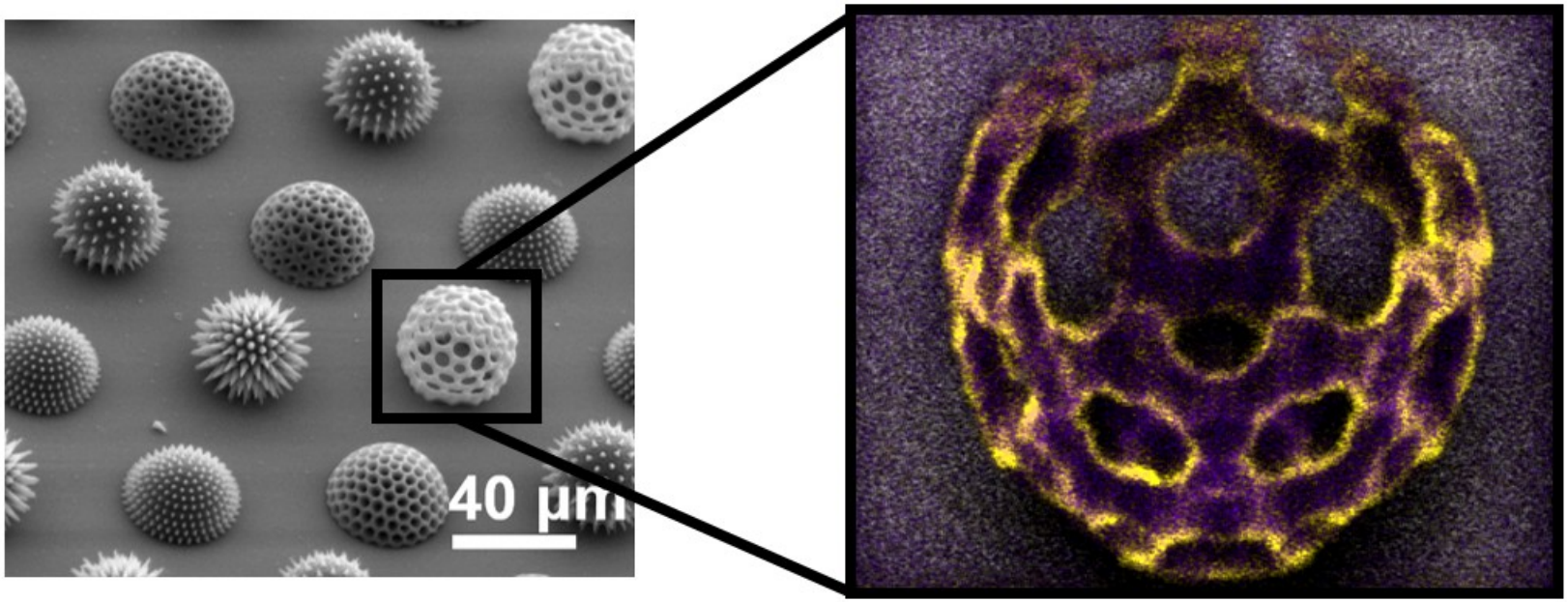
Structure etched with Ar1500+ ion beam and ToF-SIMS imaged in delayed extraction



Dr Qin Hu – CfAM Nottingham

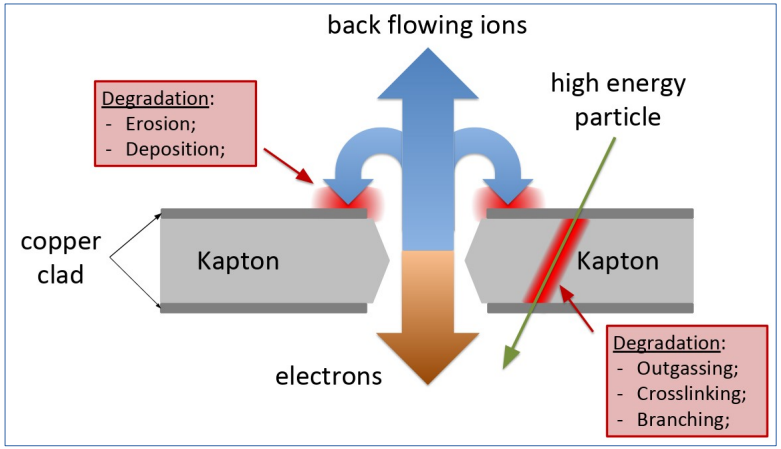
CH^- C_2HO^- SiO_2^-

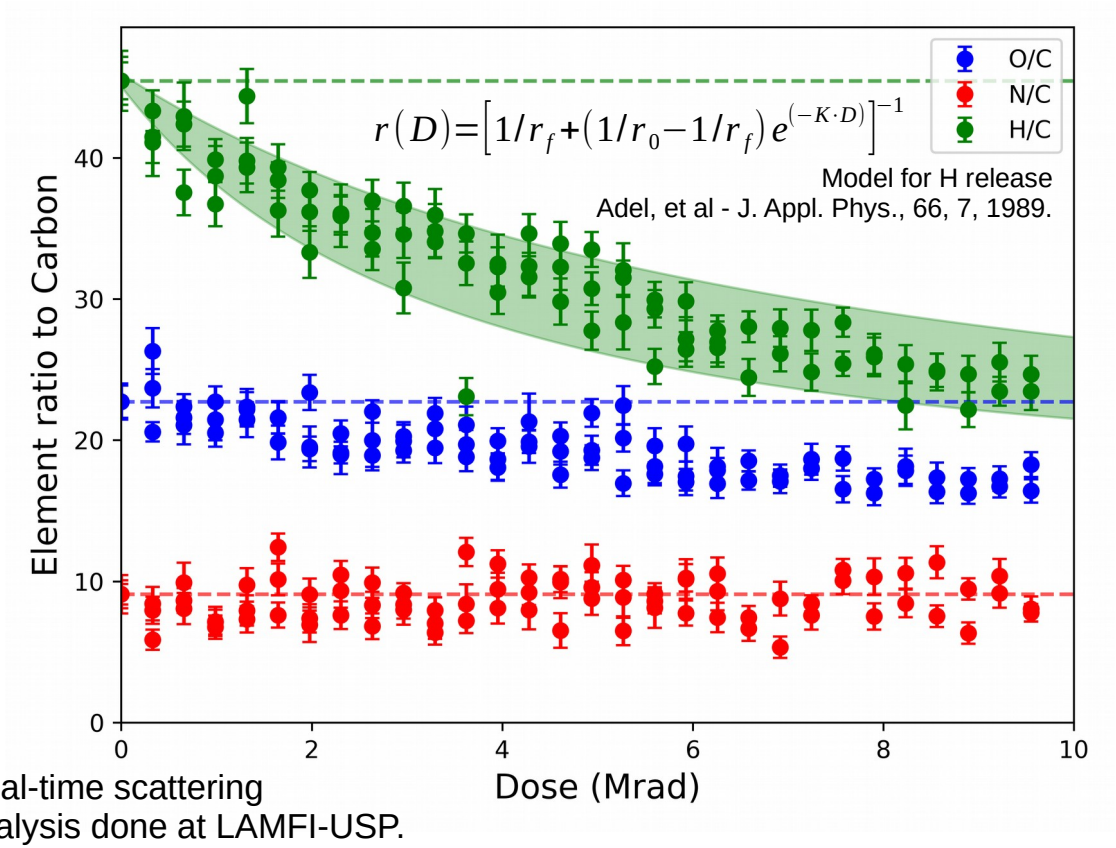
- More sensitive than electron microscope
- Compound information rather than elements

Search for a conceptual model of degradation

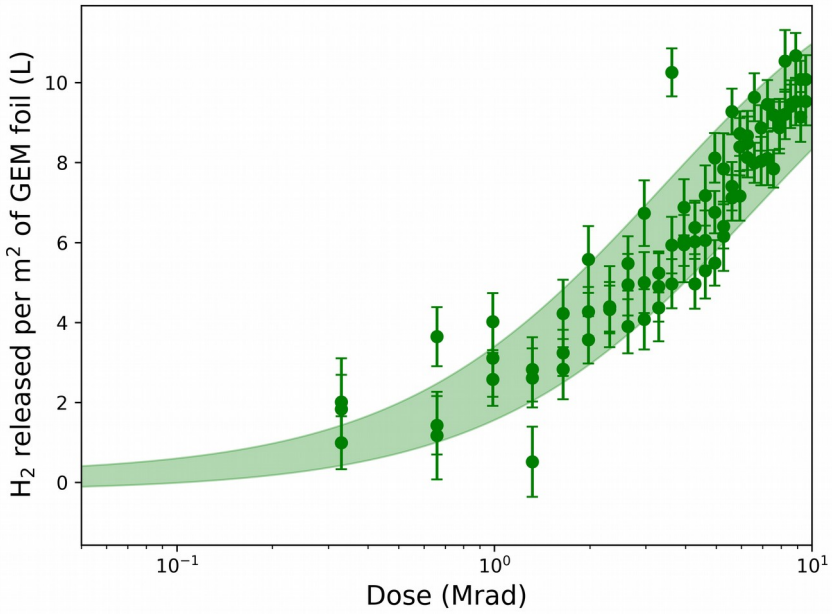
Kapton as a source of hydrogen

- **High energy particles** pass through the copper clad and produce **molecular breakup**
- The **rearrangement** produce:
  - A new polymer (crosslinking and branching)
  - Outgas (H_2, CO, CO_2, O_2, N_2, etc)





Real-time scattering analysis done at LAMFI-USP.



These doses are very high!

Sampa chip is designed to stand for 10 krad!

Search for a conceptual model of degradation

Kapton as a source of hydrogen

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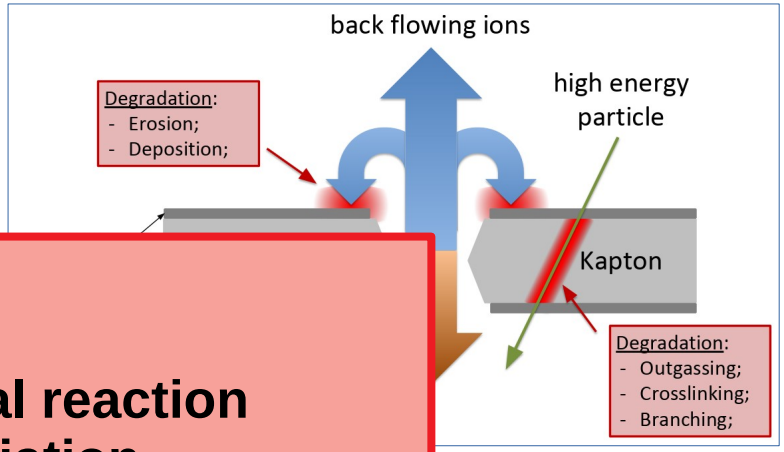
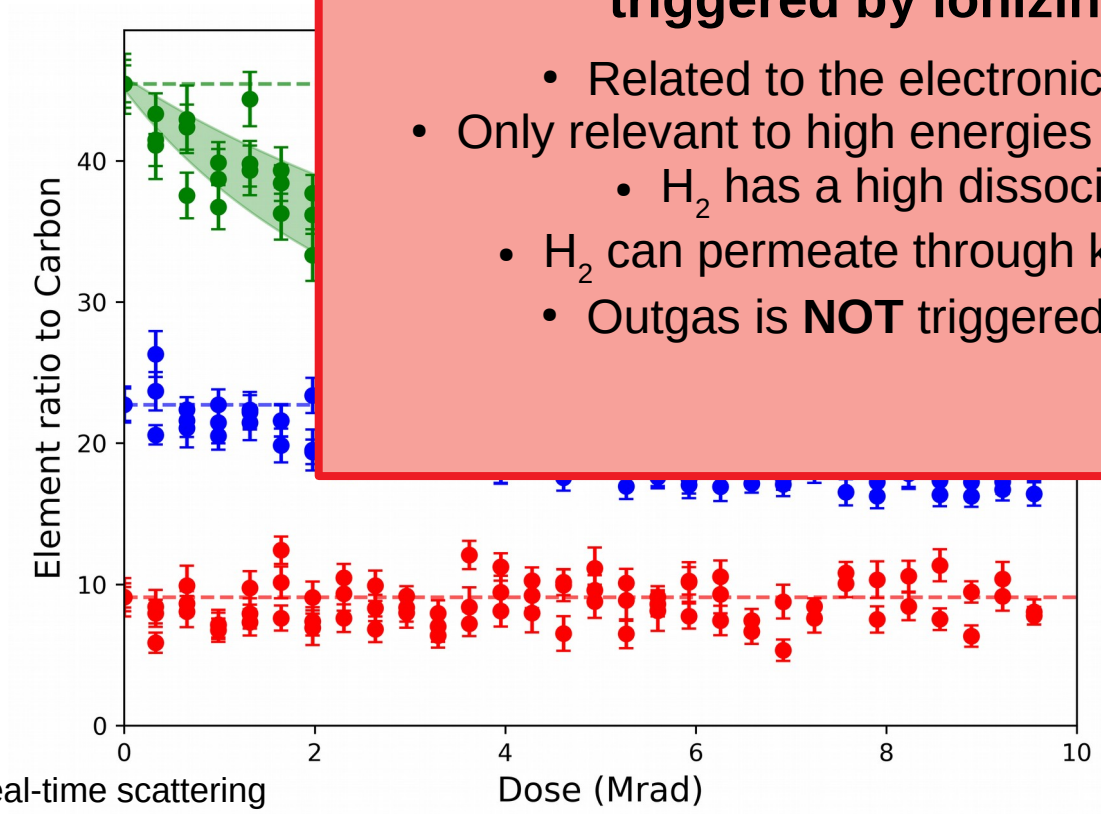
  - ✔ Outgas



Chemical sputtering: chemical reaction triggered by ionizing radiation

- Related to the electronic stopping power
- Only relevant to high energies of the incident particle
- H_2 has a high dissociation energy
- H_2 can permeate through kapton and copper
- Outgas is **NOT** triggered by temperature



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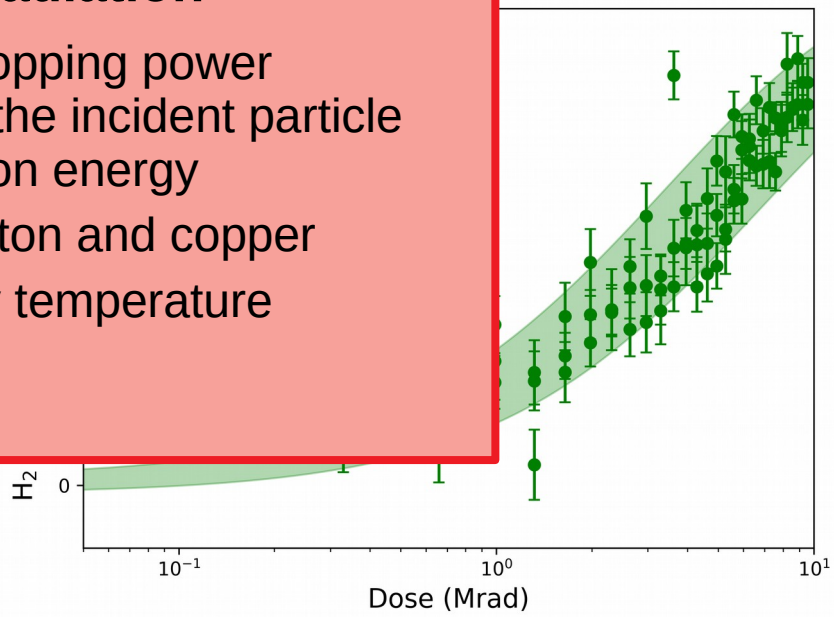

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Search for a conceptual model of degradation

Searching for interesting spots

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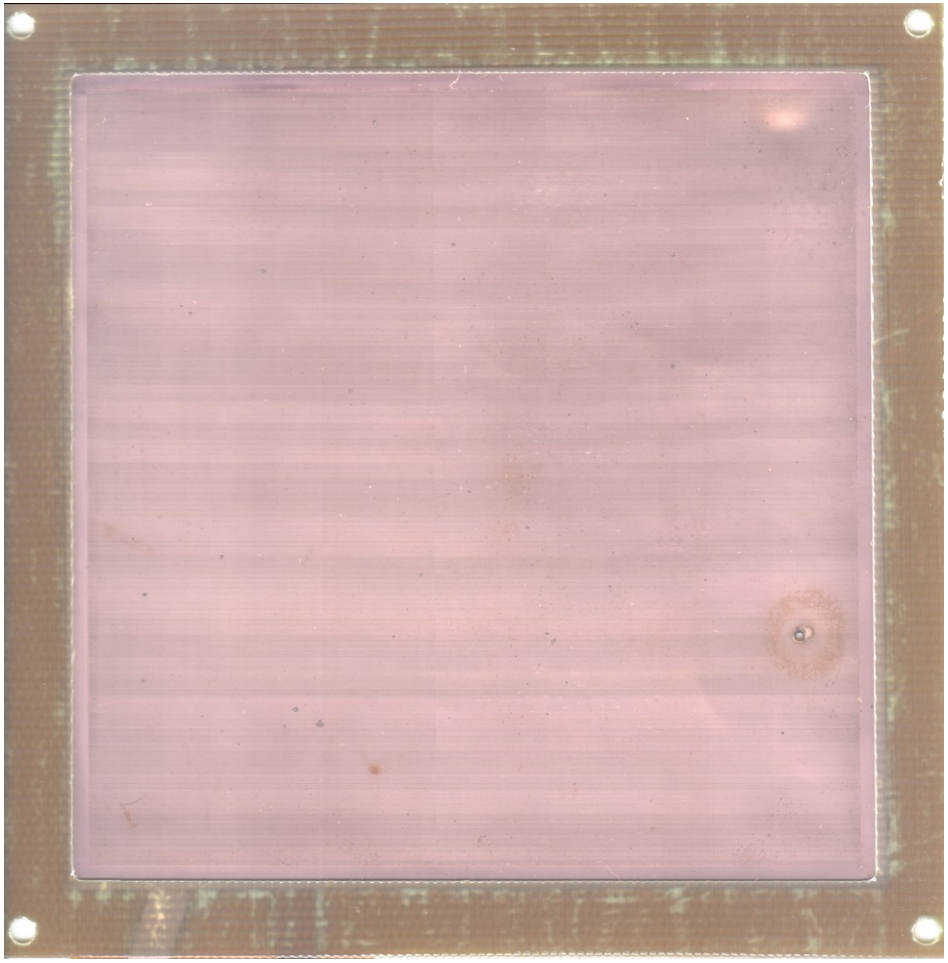
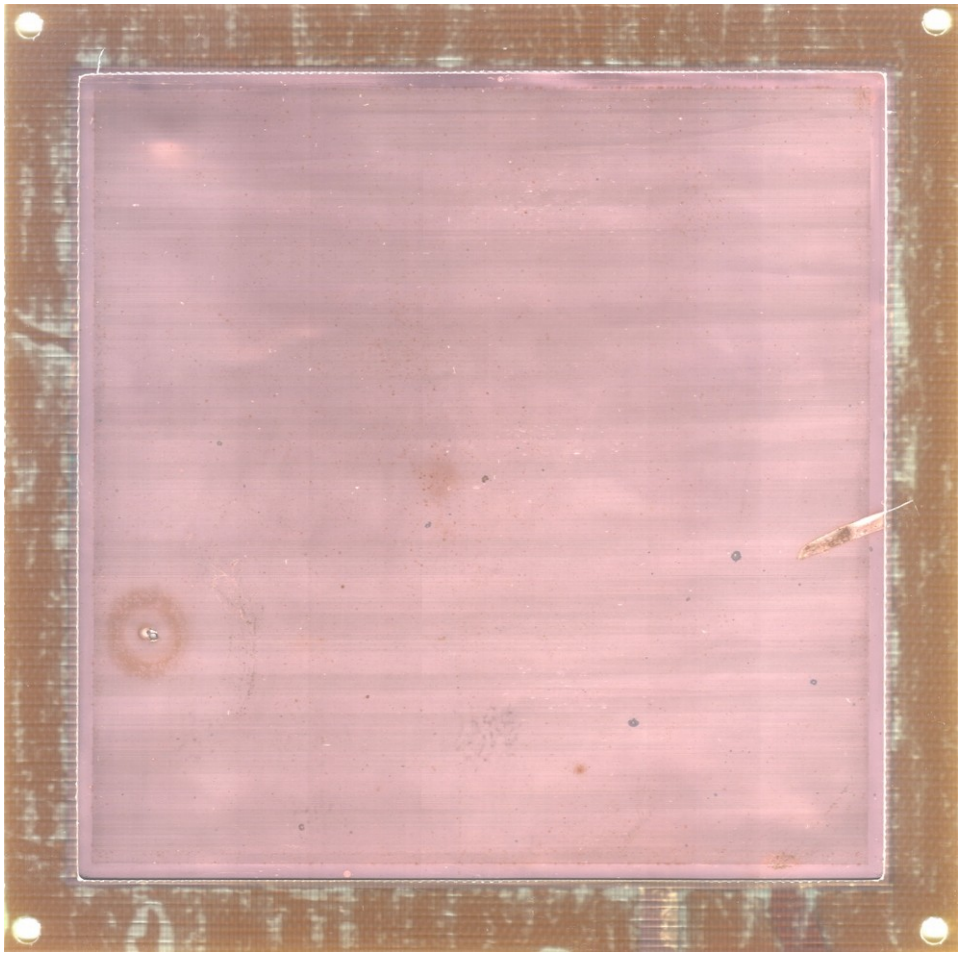
Optical images of used GEMs





Search for a conceptual model of degradation

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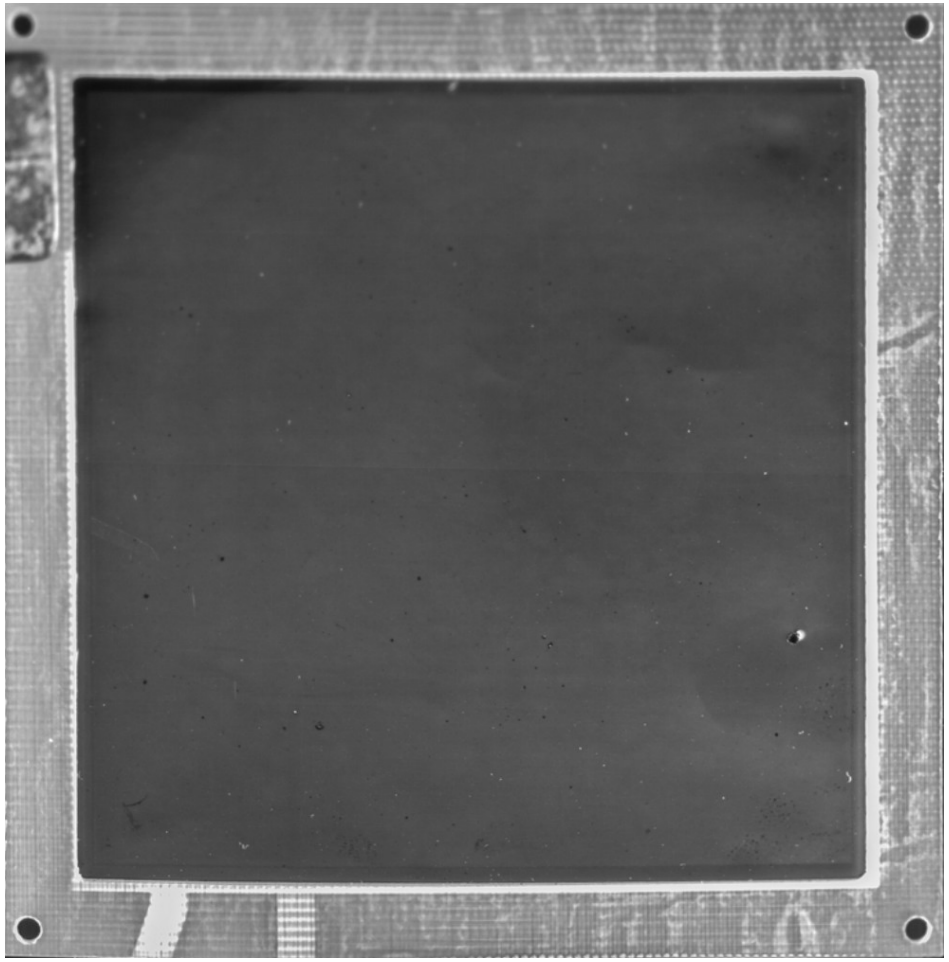
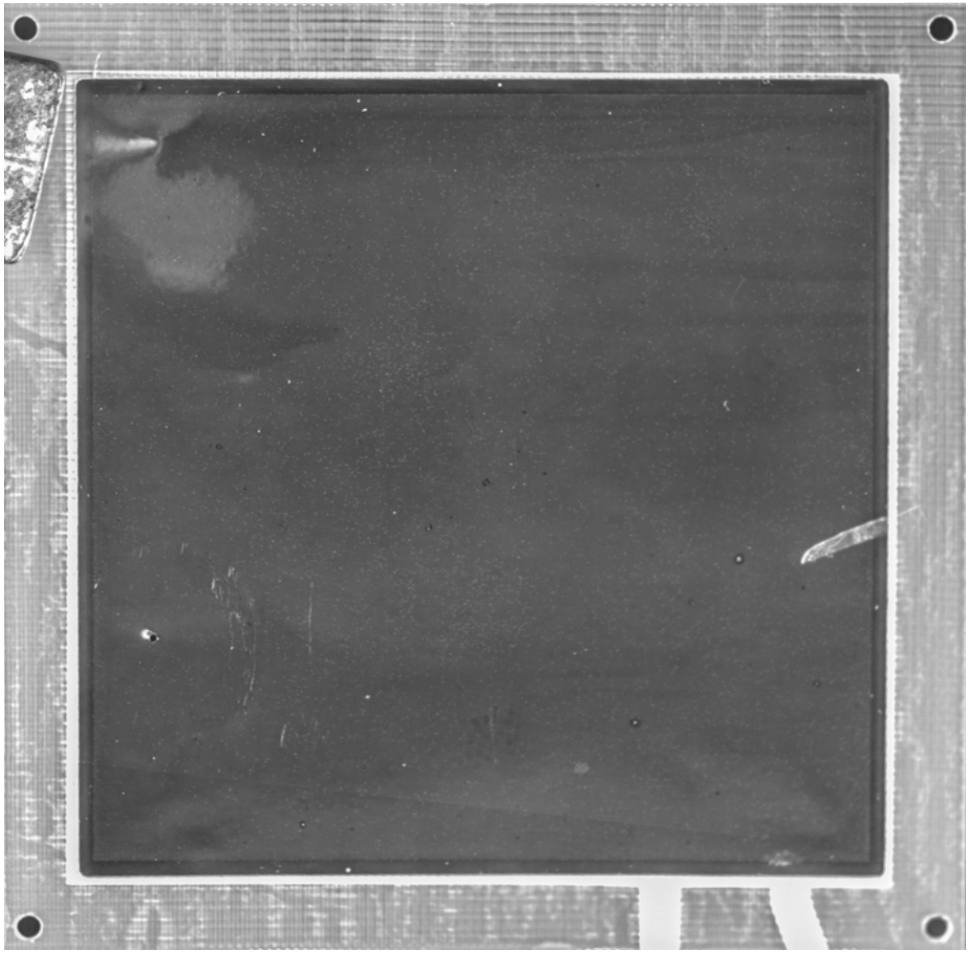
IR images of used GEMs





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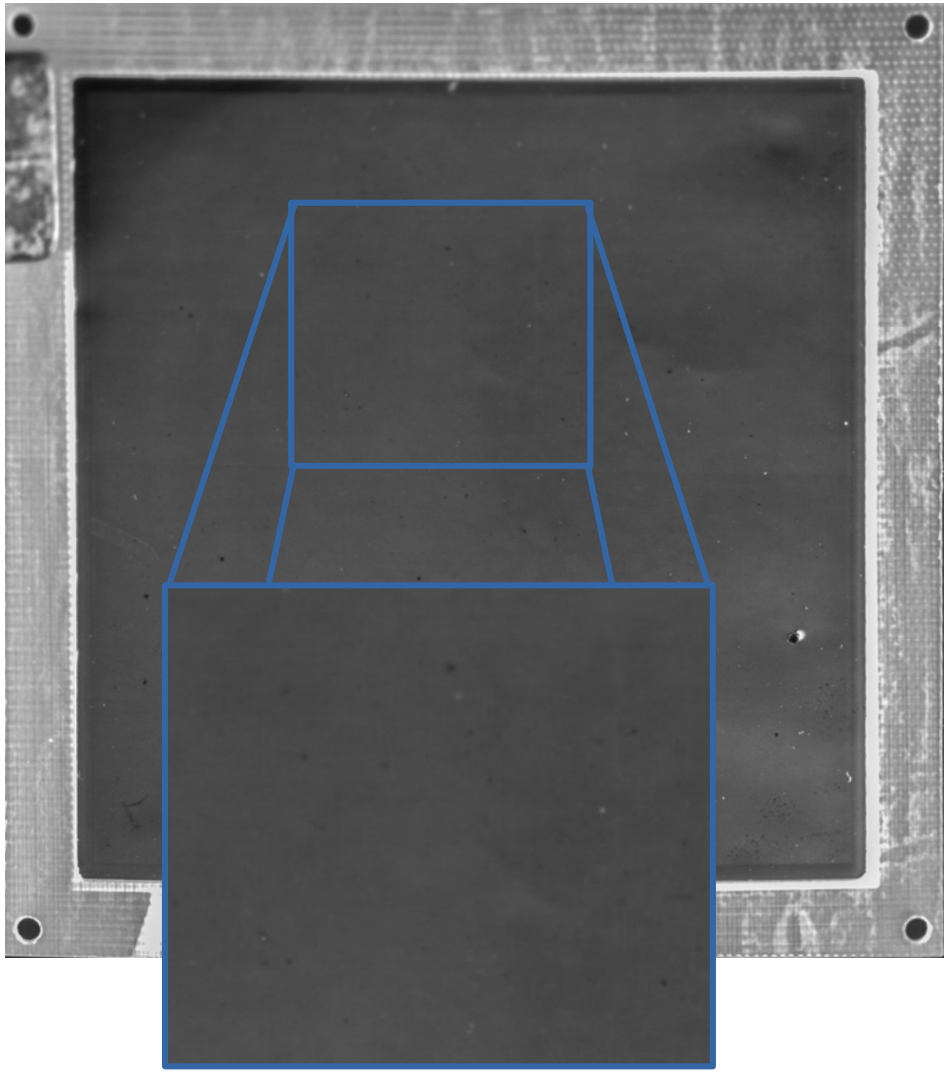

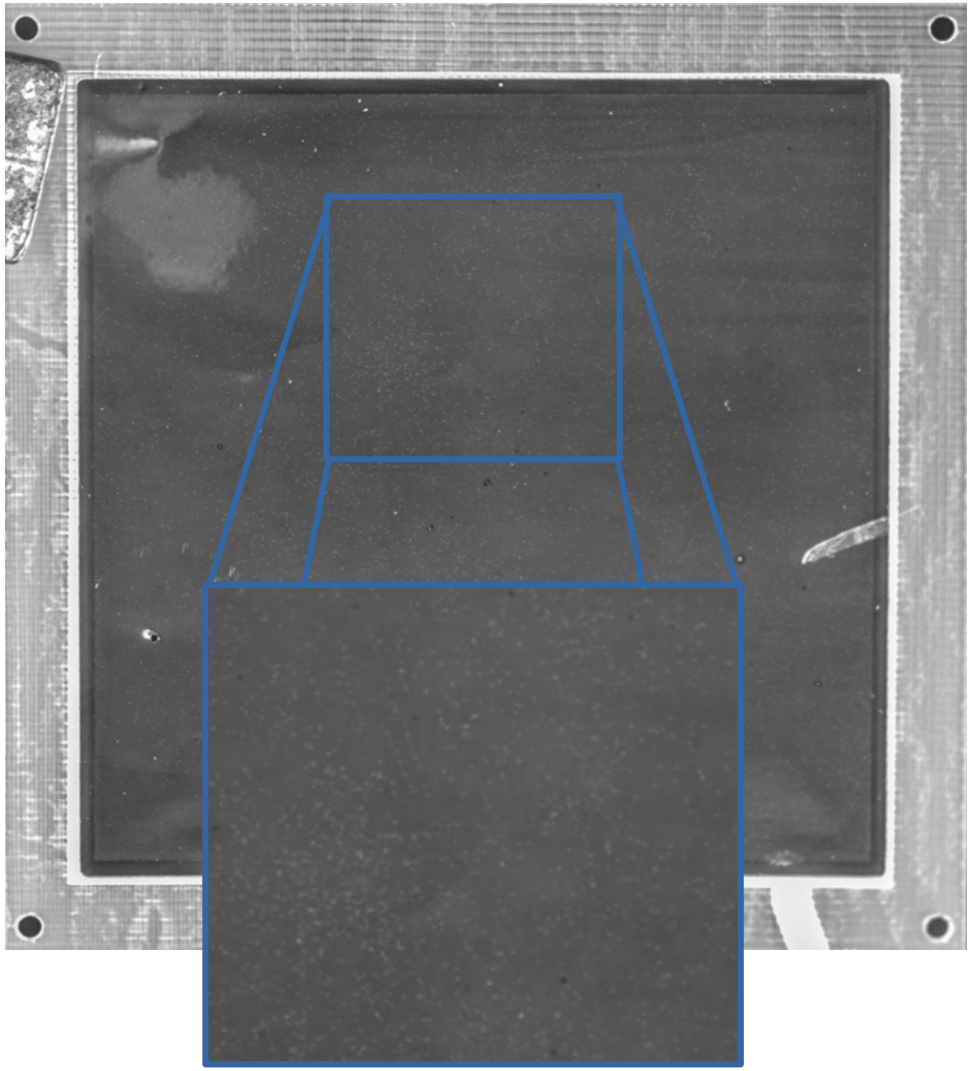

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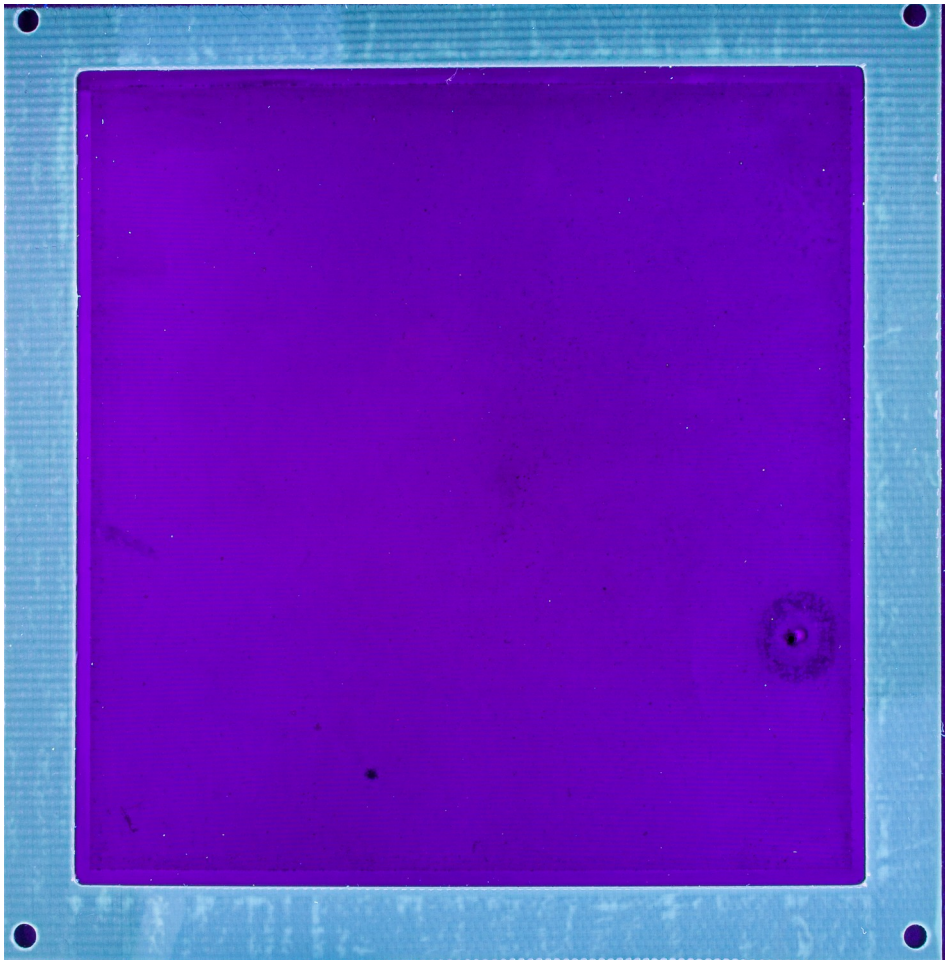
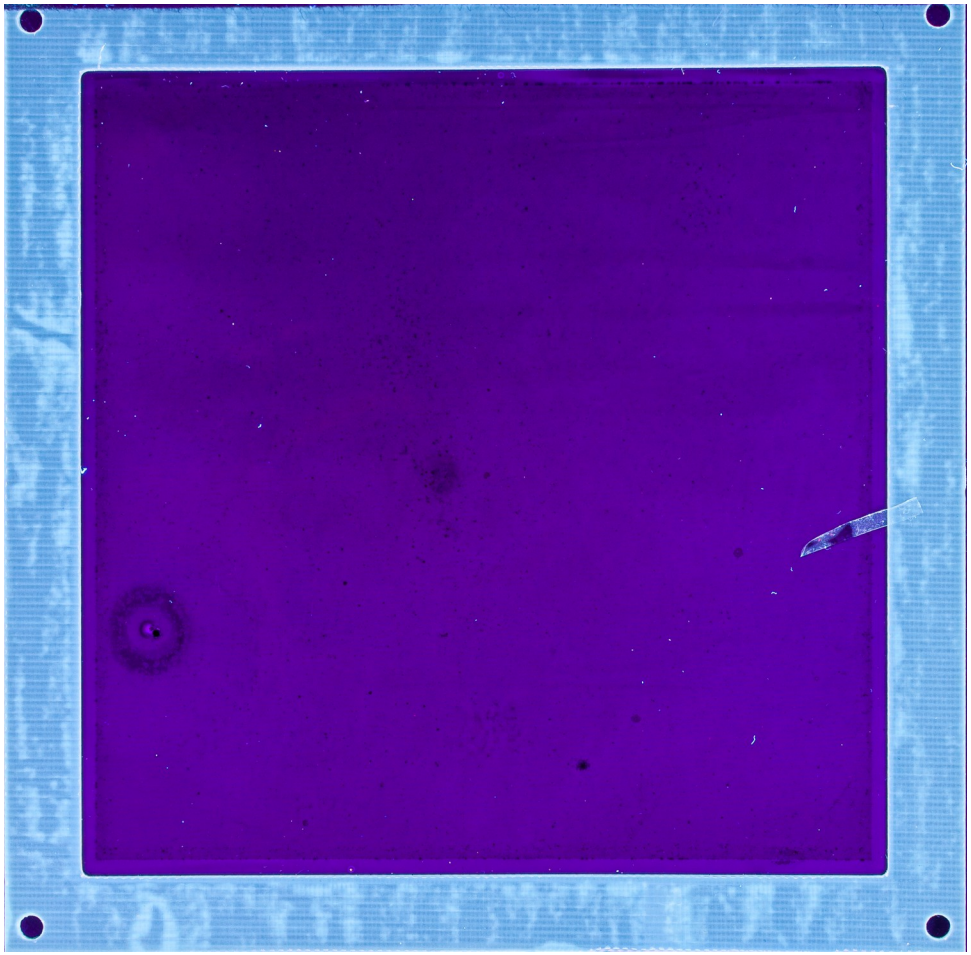
UV images of used GEMs





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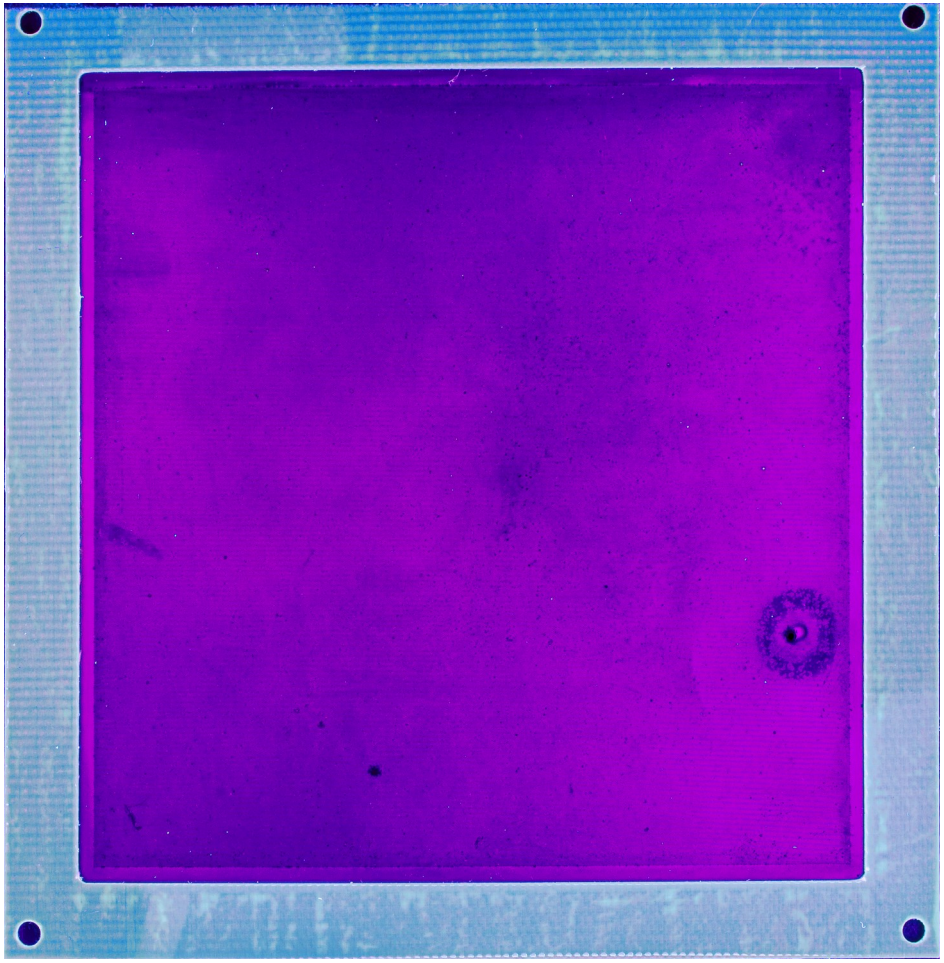
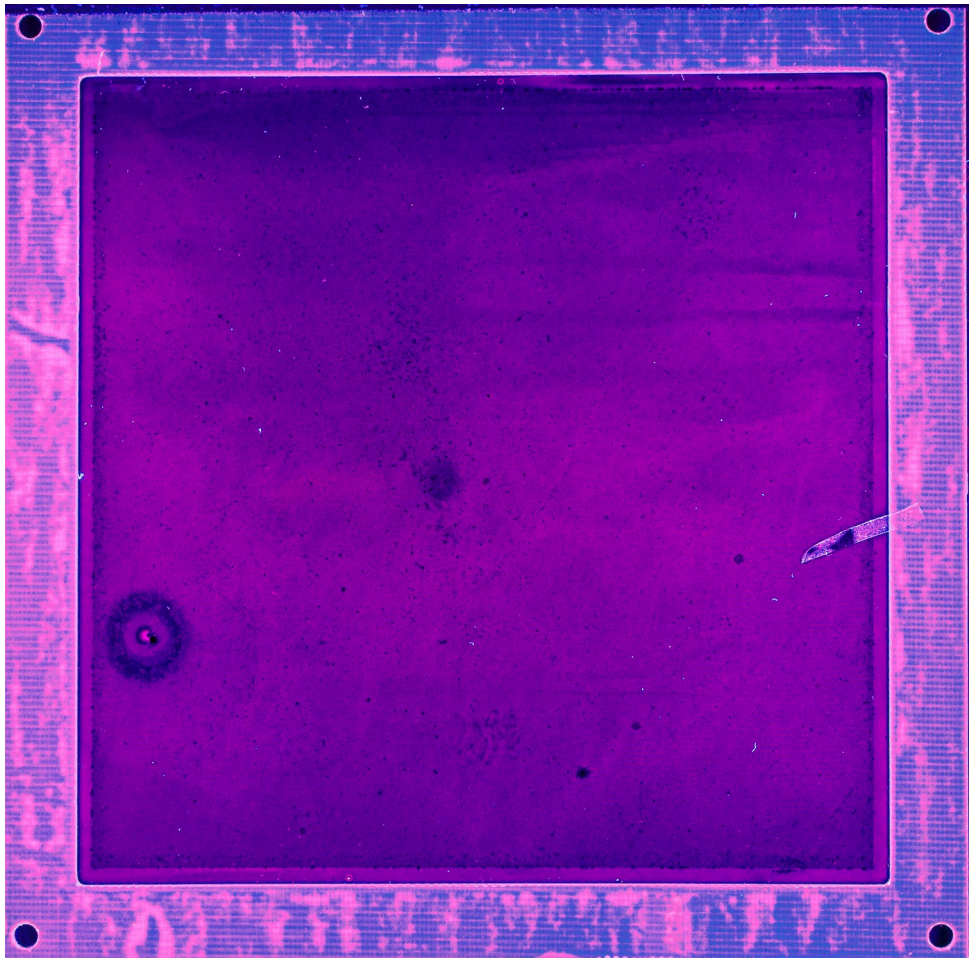
UV images of used GEMs





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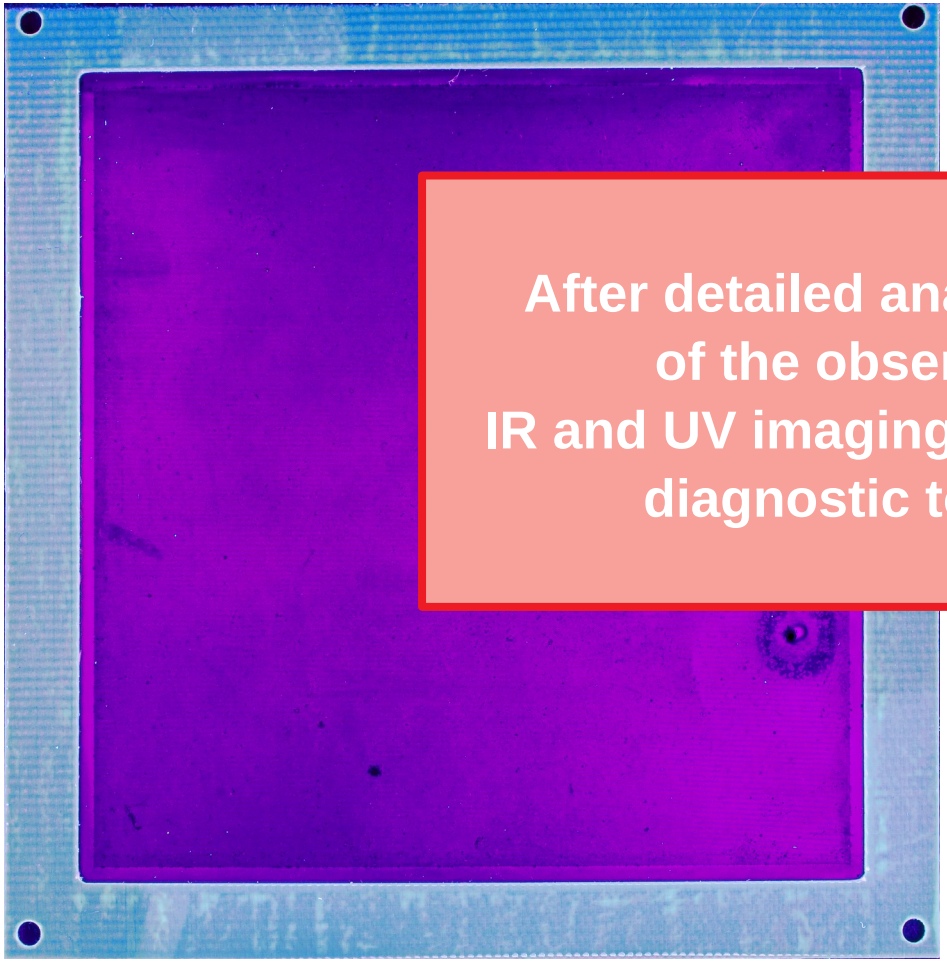
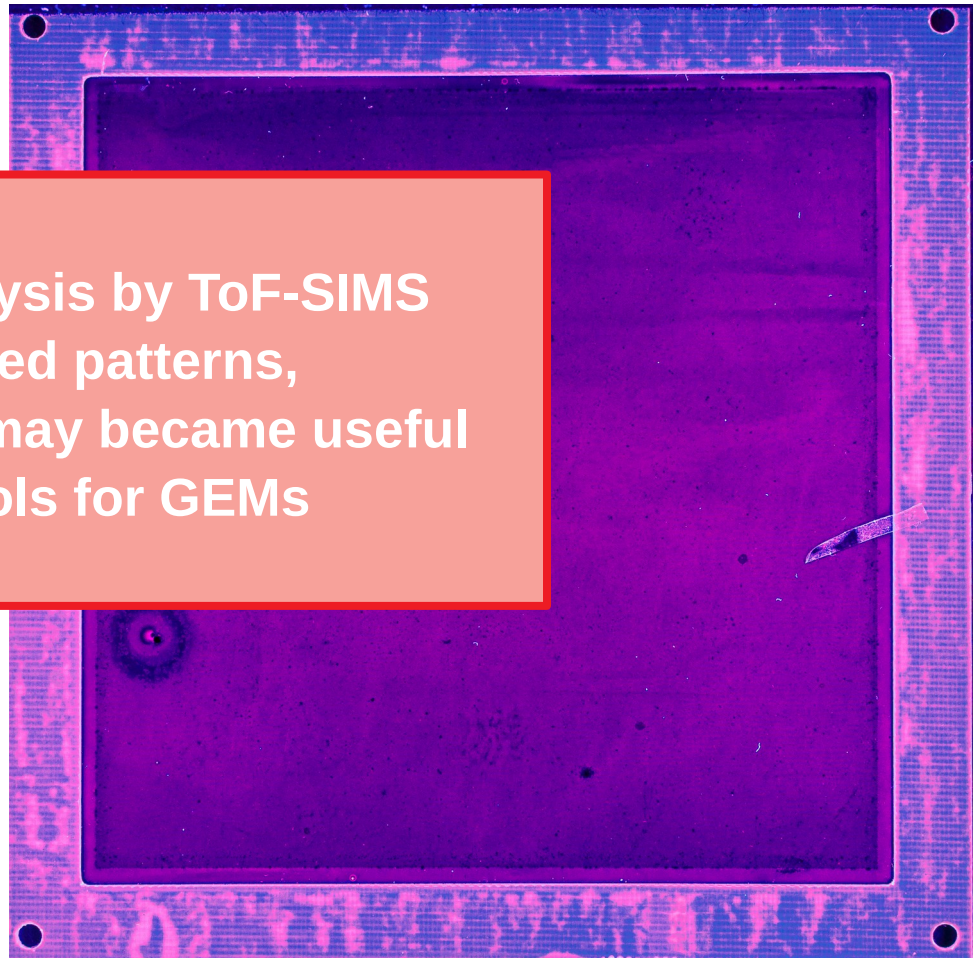




After detailed analysis by ToF-SIMS of the observed patterns, IR and UV imaging may became useful diagnostic tools for GEMs

Conclusions

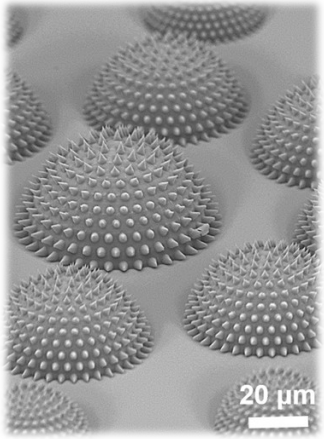
- **Surface chemistry** is an important topic to understand degradation and aging processes
- **ToF-SIMS is a promising tool** to improve our model for degradation
- On this studies, the **history of the GEM foils is important** (gas mixture, orientation, type of radiation, typical count rates, etc)
- We are directing some efforts on **finding diagnostic tools** and protocols that may be useful either for research or for assessment of **health status of GEMs**
- **We are willing to collaborate on other projects** offering systematic measurements and data interpretation

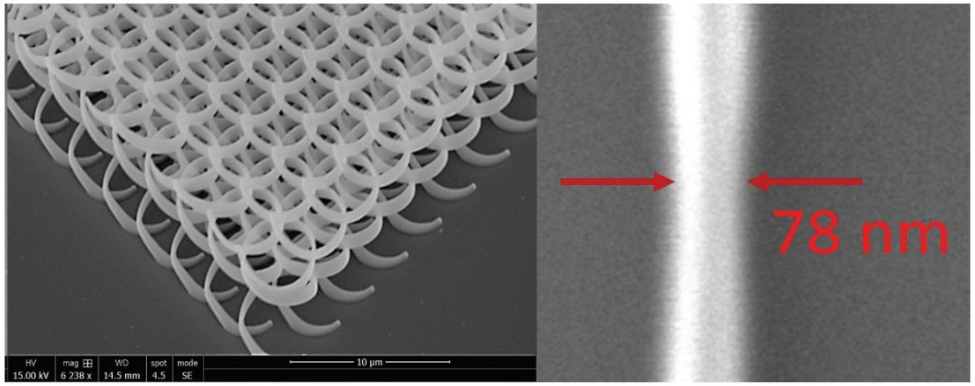
New routes of fabrication

Advanced features and micro-fabrication

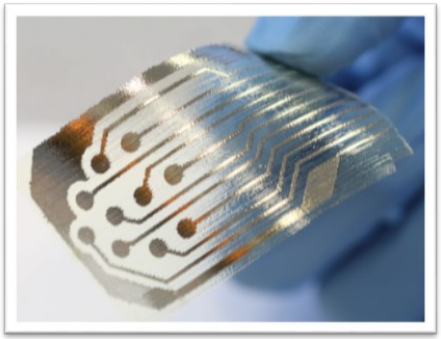
- Collaboration with the **Centre for Additive Manufacturing** of the **University of Nottingham**
- **Goal**: Production of GEMs from scratch (3D printing)
  - **Insertion of micro-structures aiming for sensor adaptability and optimizations**
  - Take advantage of very high resolution with multi-material 3D printing

Project submitted in the call for proposals to UoN-UoB-FAPESP collaborations.





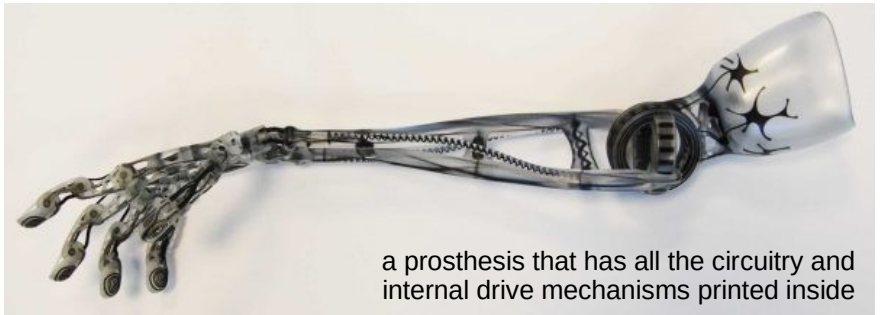
multi-photon stereolithography technique



Flexible electronics

themanufacturer.com

Experimental multimaterial 3D printing of silver electronic circuity



a prosthesis that has all the circuitry and internal drive mechanisms printed inside

Reactive Inkjet Printing
Polyurethane/Polyurea/
PDMS/Polyimide

New routes of fabrication

Advanced features and micro-fabrication

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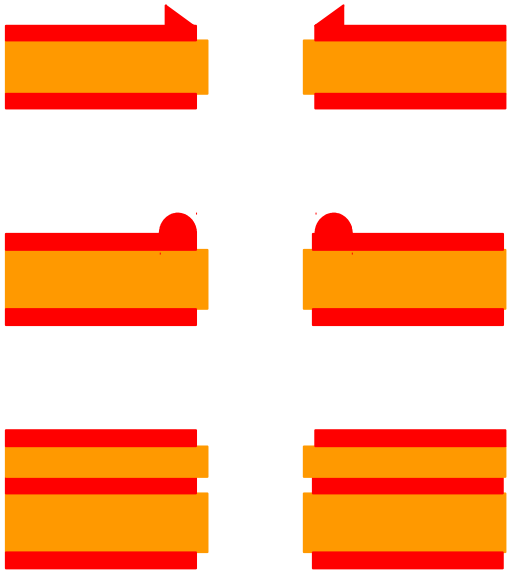
- **Goal**: Production of GEMs from scratch (3D printing)
  - **Insertion of micro-structures aiming for sensor adaptability and optimizations**
  - Take advantage of very high resolution with multi-material 3D printing

Possible geometries:
(to be confirmed by simulation!)



Goal 1: finding in simulations, what are the **decorations that can change the electric field configuration** that results in a **quicker dissipation of positive ions**.

Goal 2: finding ways to **print a GEM foil with these decorations** and **test the performance**.

Acknowledgments

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- **Acknowledgments for the support from:**

IFUSP
Instituto de Física da USP

FAPESP

CNPq

CAPES

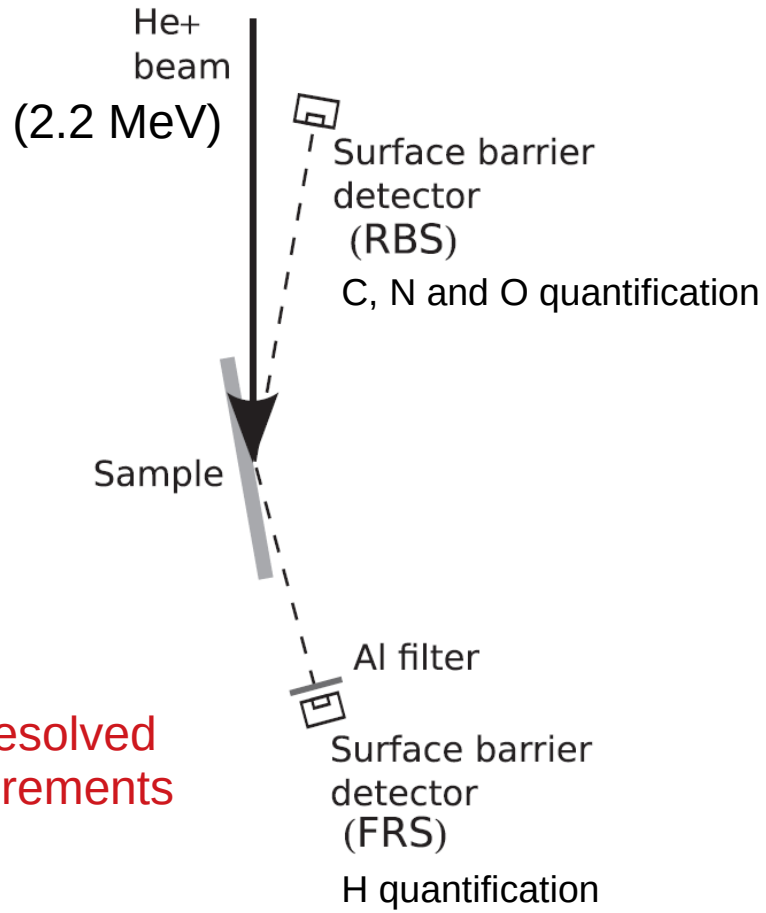
INCT-FNA
INSTITUTO NACIONAL DE CIÊNCIA E TECNOLOGIA
FÍSICA NUCLEAR E APLICAÇÕES

#SomosTodosCNPq

Backup slide

Search for a conceptual model of degradation

- How the kapton degradation experiment was performed?



Time resolved measurements

Why 2.2 MeV He beam?

- The process of energy deposition is the same as for highly energetic particles
- Rate of energy transfer is higher
- Particle flux also higher