Radiation Detectors Group
RDG
IMB-CNM, Barcelona

RDG, IMB-CNM (CSIC)
Barcelona, Spain

Centro Nacional de Microelectrónica IMB

CSIC
Consejo Superior de Investigaciones Científicas

Introducing IMB-CNM, CSIC

- *Instituto de Microelectrónica de Barcelona, Centro Nacional de Microelectrónica*
  National Microelectronics Center
- Belongs to CSIC: Spanish National Research Council
- Located in Bellaterra, Barcelona
- Dedicated to Nano- & Micro-electronics
- Micro- y Nano- Fabrication Facility "Clean Room"

- Departments
  - Micro and Nano Systems
    - Silicon sensors and Actuators
    - Nanotecnology
  - Systems Integration
    - Power Devices and Systems
    - Circuit and System Design
    - Biomedial Applications

IMB-CNM Research Facilities

- Clean room
  - 1.500 m^2, class 100 to 10.000
  - Technologies for Micro y nano fabrication
  - Areas:
    - CMOS (high purity, no contaminants)
    - MNC (Noble Metals – contaminants for Si)
    - Nanotecnology
  - Processes
    - 4'' complete
    - 6'' partial
  - Technologies:
    - CMOS, Bi-CMOS, MCM-D, MEMS/NEMS, power devices, radiation detectors
- Silicon Micromachining
- Microelectronic Packaging Area
  - 200 m^2, class 100
  - Wafer cutting, wire-bonding, bump-bonding

- Laboratories
  - Test and characterization
    - Automatic wafer probing
    - DC y RF (up to 8 GHz)
    - Thermography
  - Reverse engineering
  - Simulation
  - CAD
  - Mechanical workshop
  - Chemical sensors
  - Bio-sensors
  - Radiation sensors
  - Optical sensors

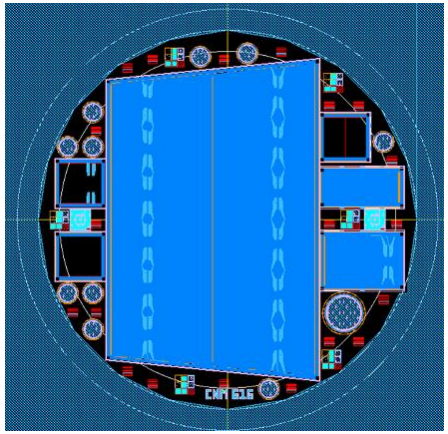
Radiation Detectors Group (RDG)

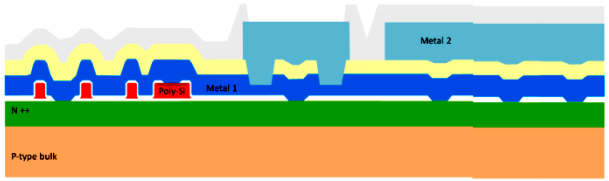
- Personnel
  - 8 permanent researchers (PhD)
  - 4 experienced researchers (PhD)
  - 5 PhD students
  - 1 technician

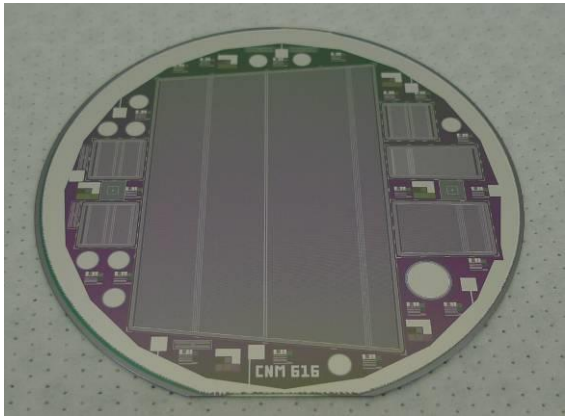
- Statting activities in 1996
- Experiments
  - ATLAS, CMS, LHCb
  - Founder members of RD50
  - ASTROMED
- Colaborations
  - IFAE, IFIC, IFCA (Spain)
  - BNL, SCIPP-Santa Cruz (US)
  - INFN (It)
  - Glasgow, Liverpool (UK)
  - DESY, Freiburg, Karlsruhe (Ger)
  - Medical applications: Roberts Proton Therapy Center (Univ. Pennsylvania, US), Orsay (Fr), Univ. Wollongong (Aus)

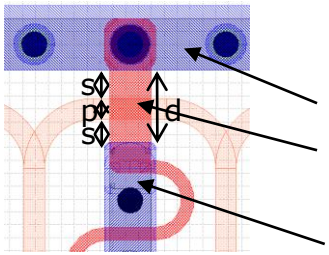
Radiation Detectors R&D at CNM

- Design, fabrication and optimization
  - Design and fabrication of full ATLAS-like sensors
  - Fabrication of sensors for the ATLAS Upgrade End Cap prototypes
  - Fabrication of sensors for the RD50 Collaboration







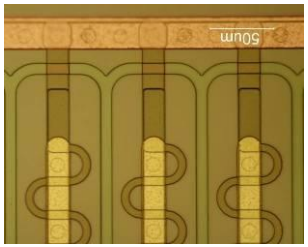


Bias rail

Polysilicon "bridge/gate"

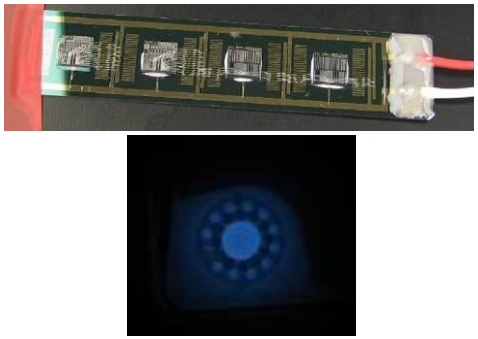
Implant

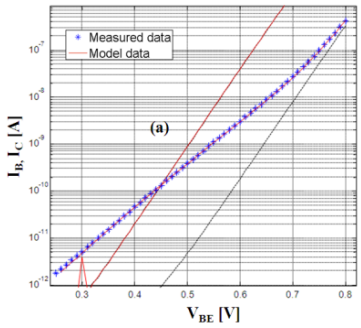
Optimization

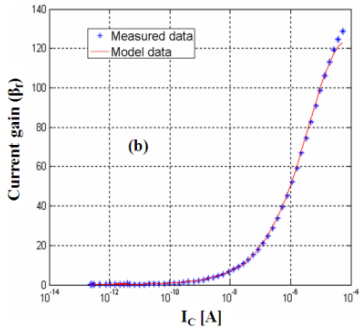


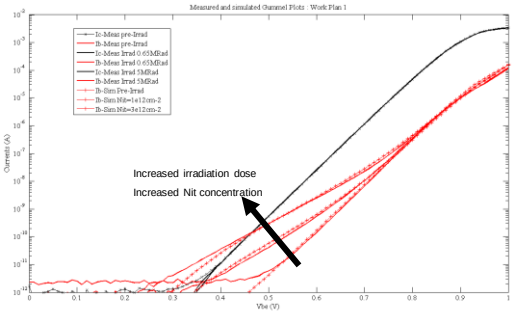
Radiation Effects Studies

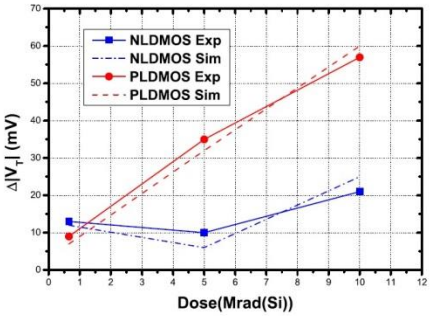
- Characterization of microelectronic devices degradation with radiation
- Simulation of radiation effects in microelectronic devices
  - TID, displacement, SEE
- Modeling radiation degradation







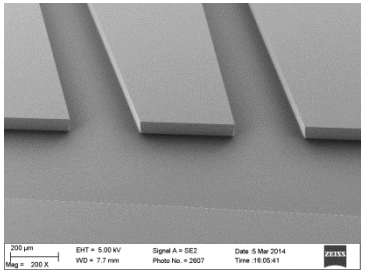


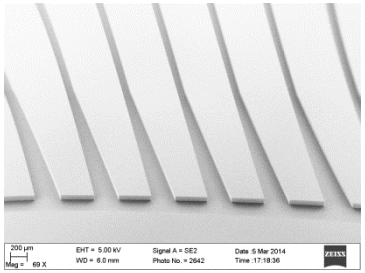


- Radiation hardening
- Development of rad-hard technologies

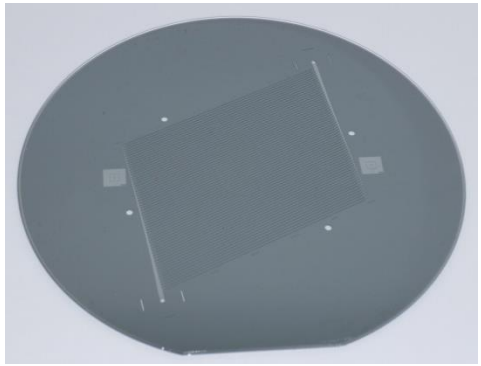
Micro-Channel Cooling (with DESY)

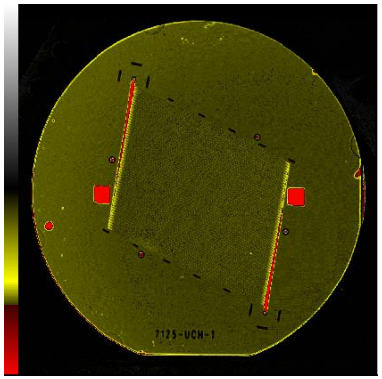
- Objective:
  - ✓ Reduce the mass of the cooling systems
  - ✓ Cool only the detectors increases efficiency



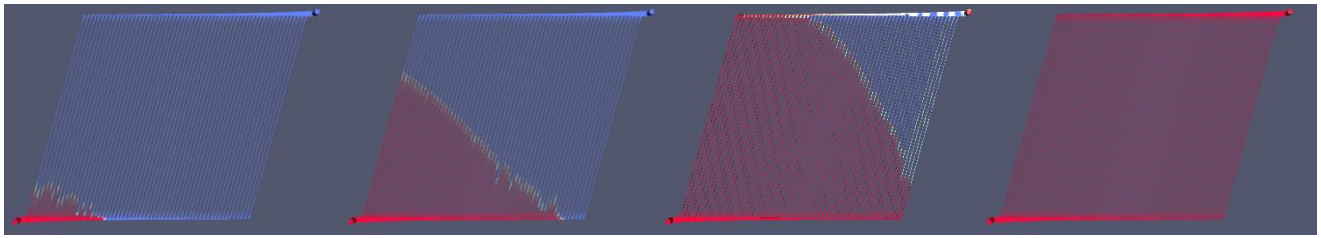


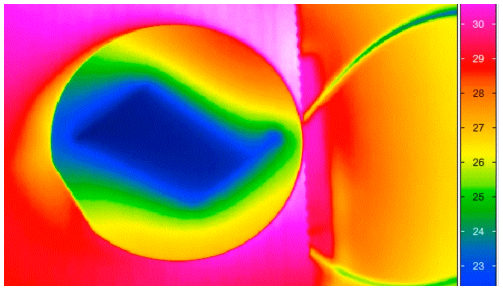
- Technology being developed:
  - ✓ Micro-channel generation
    - ➢ Deep Reactive Ion Etching (DRIE)
  - ✓ Wafer bonding
    - ➢ Anodic bonding (Si-SiO_2)
    - ➢ Fusion bonding (Si-Si)
    - ➢ Eutectic bonding (Metal-Metal)





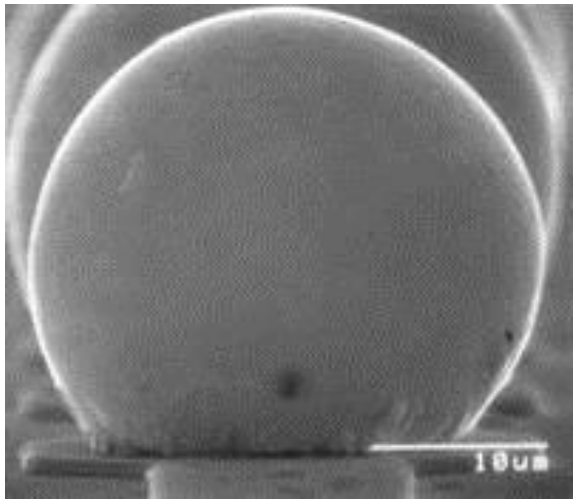
- Fluidics
- Cooling Power

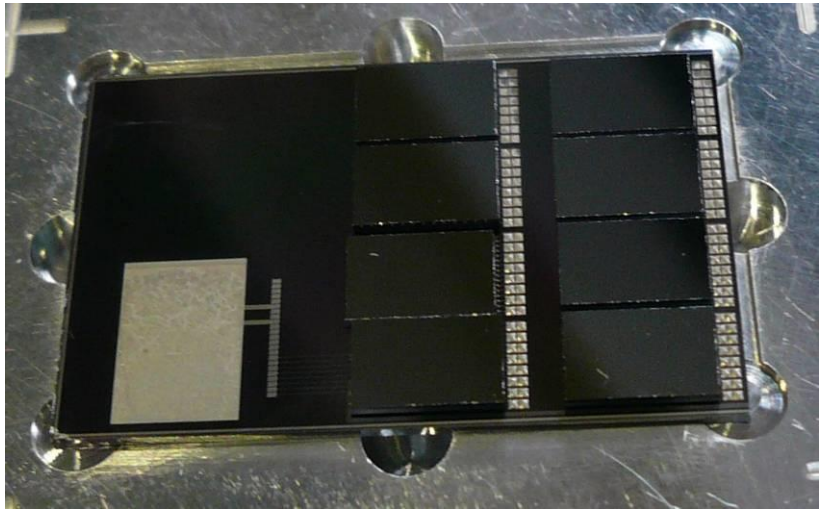


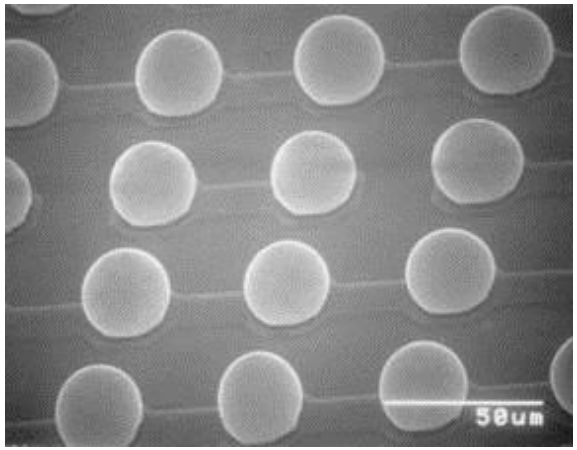


Flipchip Packaging

- Sn/Ag and Sn/Pb bump electroplating
- TiW/Cu electroplated UBM
- Ni/Au electroless UBM
- SET FC150 Pick&Place
- 1 micron placing accuracy
- Reflow in formic acid

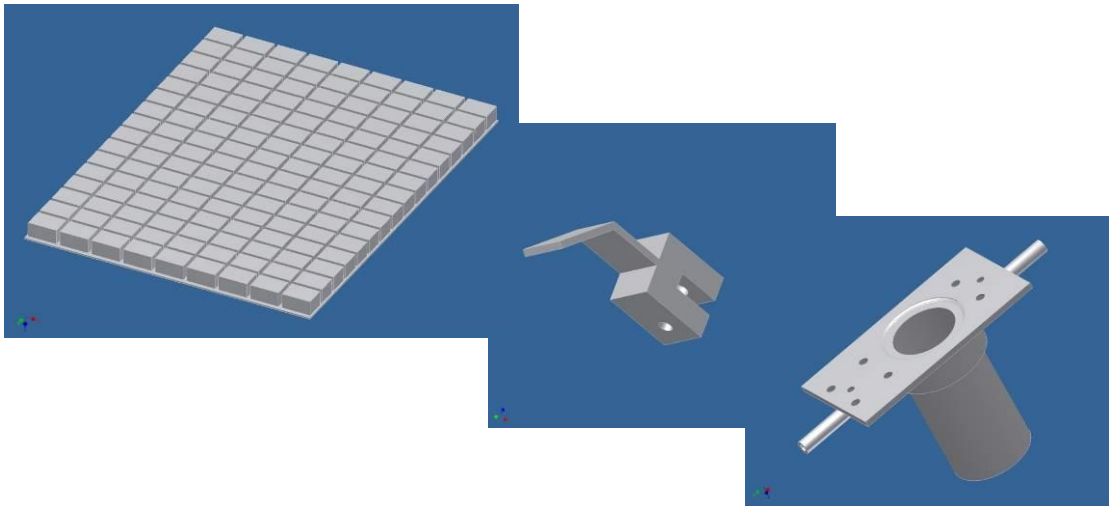






3D Rapid Manufacturing

- Polyamide Laser-sintering system
- EOS FORMIGA P 100
- From CAD to piece in few hours
  - Effective building volume:
    20 cm x 25 cm x 33 cm
  - Resolution ~0.1 mm (vertical)



New technological line: Printed Electronics

- **Inkjet type printer**
- **Many different inks available**
  - conductor
  - Insulator
  - Semiconductor
  - sensing elements
  - LEDs
- **Many groups working in the development of new types of inks**
  - Mostly based on nanoparticles

Ceradrop Ceraprinter X-Series
Accuracy 1.5µm
Print resolution 5µm
Print surface 30cm×30cm

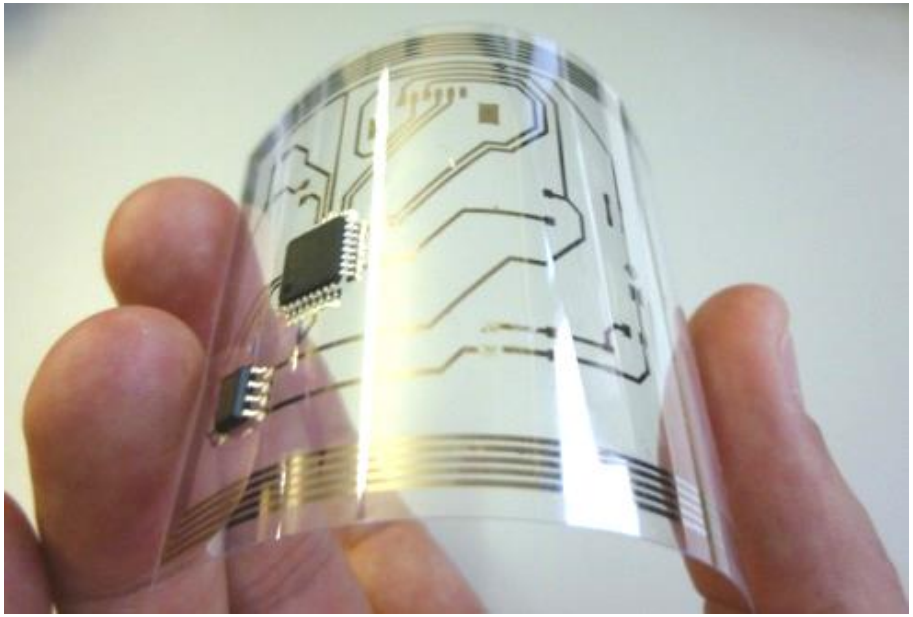
Electronics design

Potential applications

- **HF Antenna**
- **RFID**
- **OPV**
- **OLED**
- **Interconnection**
- **Printed memories**
- **Photodetectors**
- **Lens**
- **Semiconductor**
- **Biology**
- **Ceramic thick films**
- **LTCC**
- **Multilayer Ceramic Capacitor**
- **Magnetic components**
- **Temperature sensors**
- **Piezoelectric actuators**
- **Sol gel selective deposition**
- **Photocatalytic elements**
- **Fuel cells**
- **Solar cells front contacts**

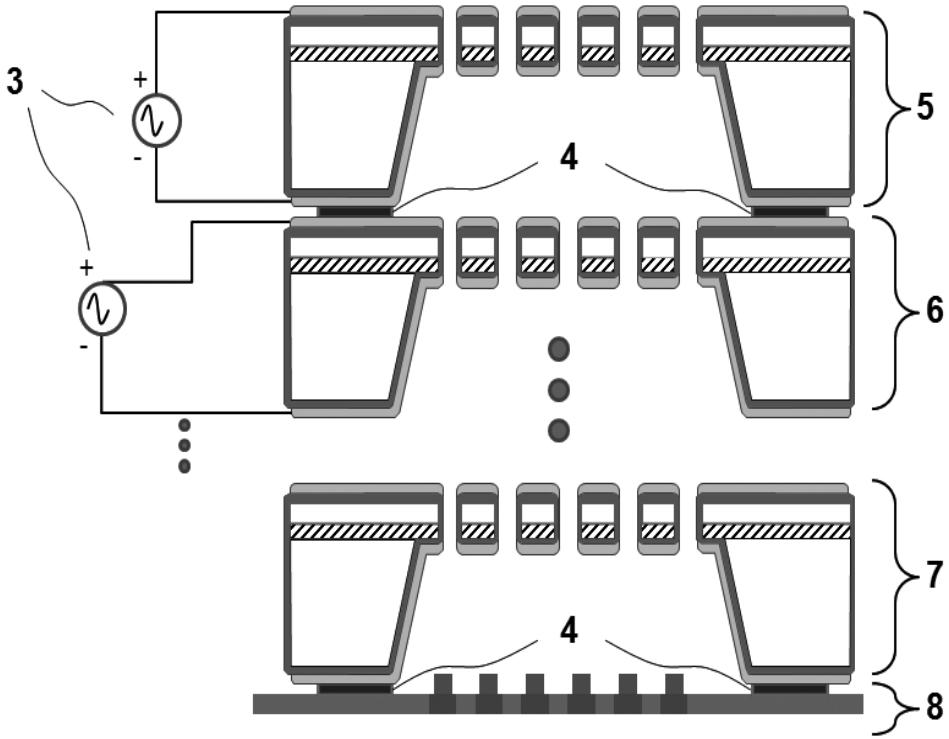
Example made at CNM:

- **Silver nanoparticles conductive ink**
- **SU8 insulator**

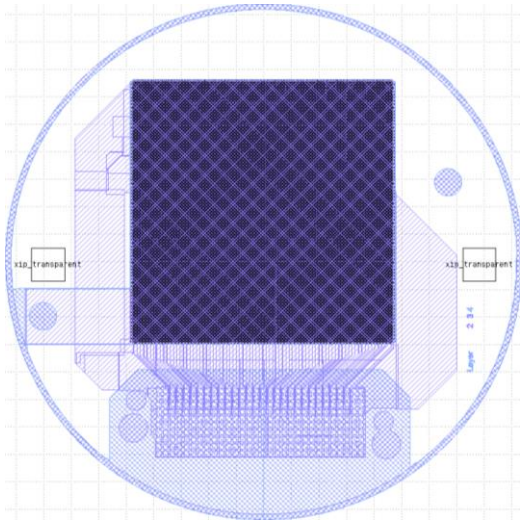


Si-GEMS Nanomigas Project Objectives

- There are two main approaches to Gaseous Detectors: The **GEM** (Gas Electron Multiplier), which is a thin metal coated insulator foil, perforated by a high density of holes and the **MicroMegas**, a similar layout, but in a multiple stage configuration.
- **CNM** is developing a **gaseous detector** using **Silicon** instead of the foil. This is a development following **CNM's patent** on a **pilable detector** made out of several individual Si-GEMs.

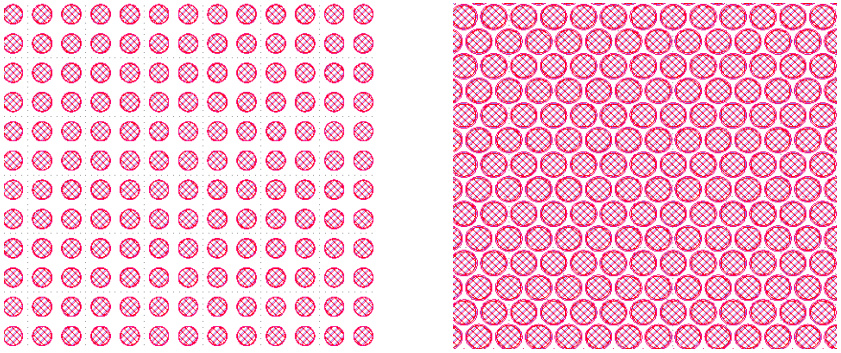


Side objective: SU-8 GEM together with UniZar (not included in original application)



Experiments

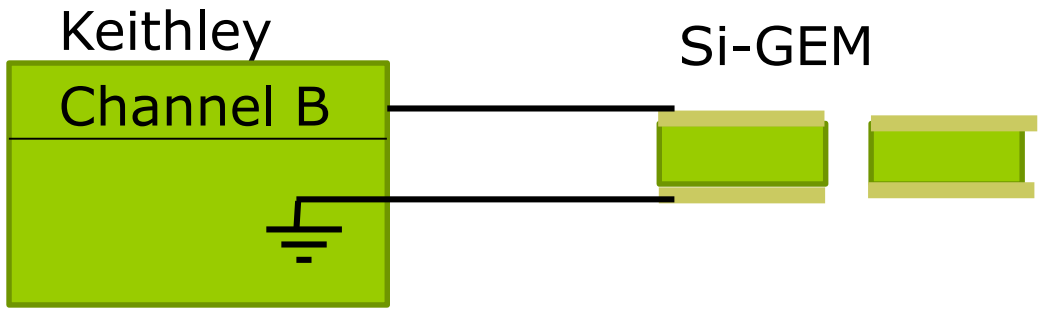
- Trials with micromachined silicon wafer



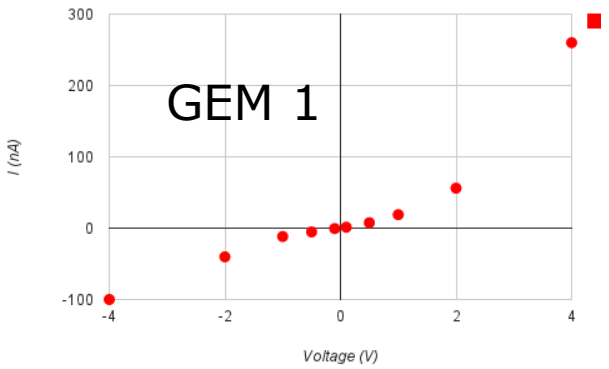
- 2 designs: squared and rhombohedral-shape distributed
- Hole diametre 80μm.
- Pitch 110 (double medipix pitch)

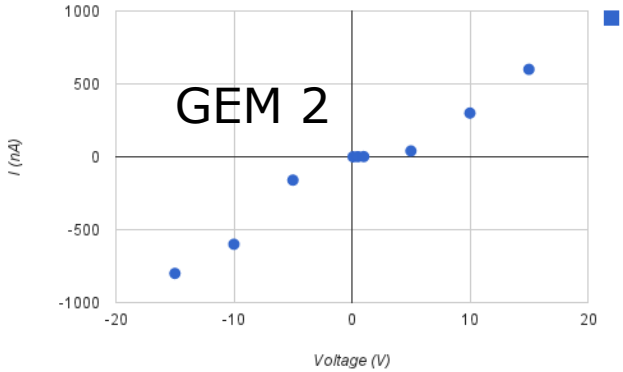
Resistance Measurement

- first the GEMs were tested with a Multimeter and for some R>2 GOhm were found
- afterwards measurements with Keithley



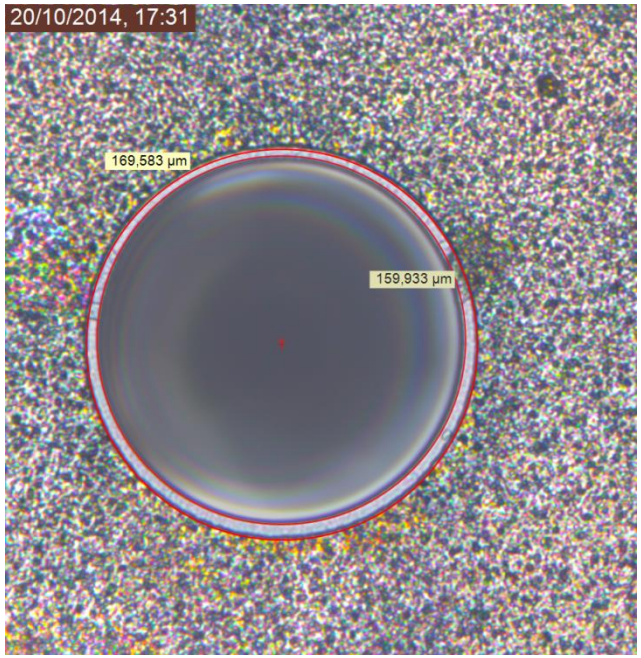
- Results: Several hundred nA at low voltages, not symmetric in respect of polarity



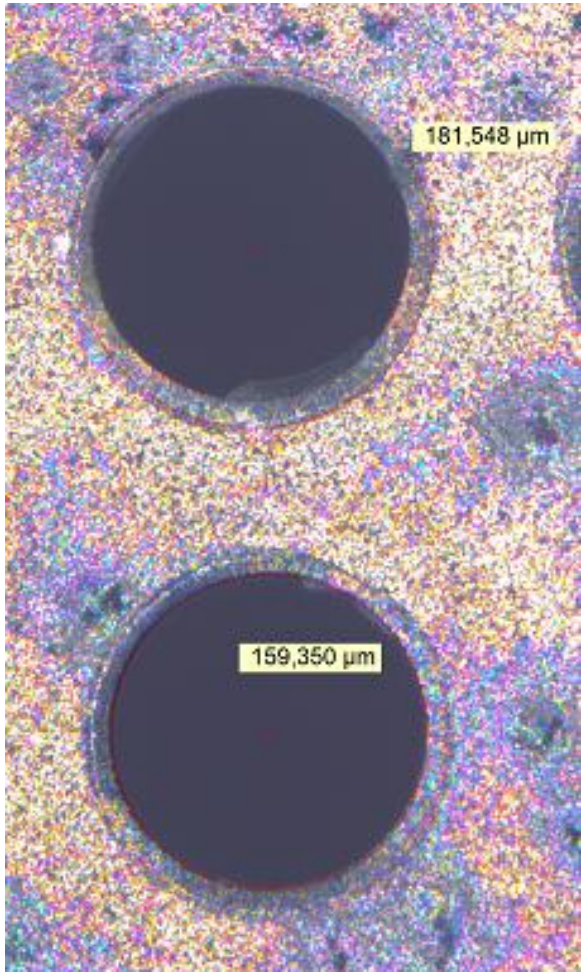


CNM758: Visual Inspection

One side looks good:
Rim is visible and of right size

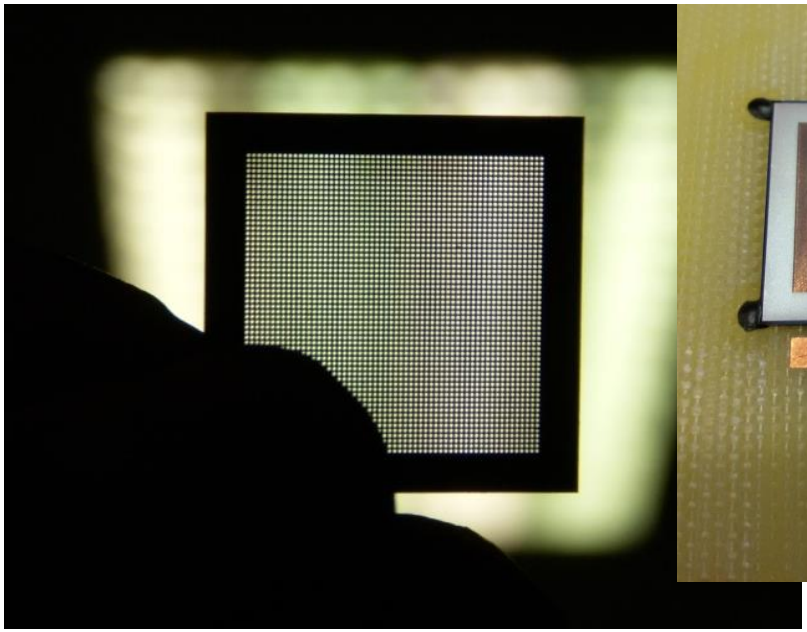


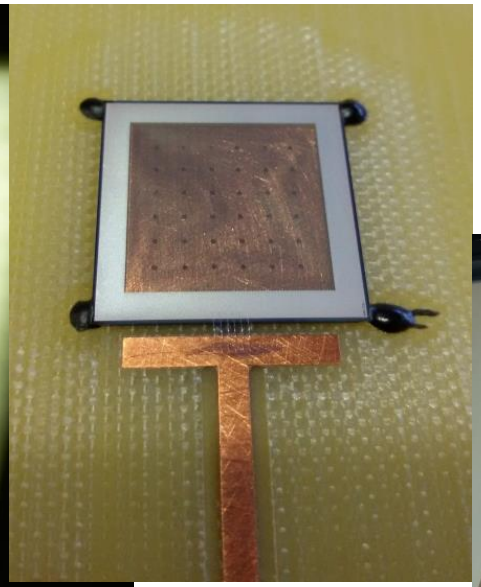
The other side not …
- No rim
- Al hole diameter smaller than Si hole diameter
- SiO_2 hanging in the hole (EXRS study at CNM)

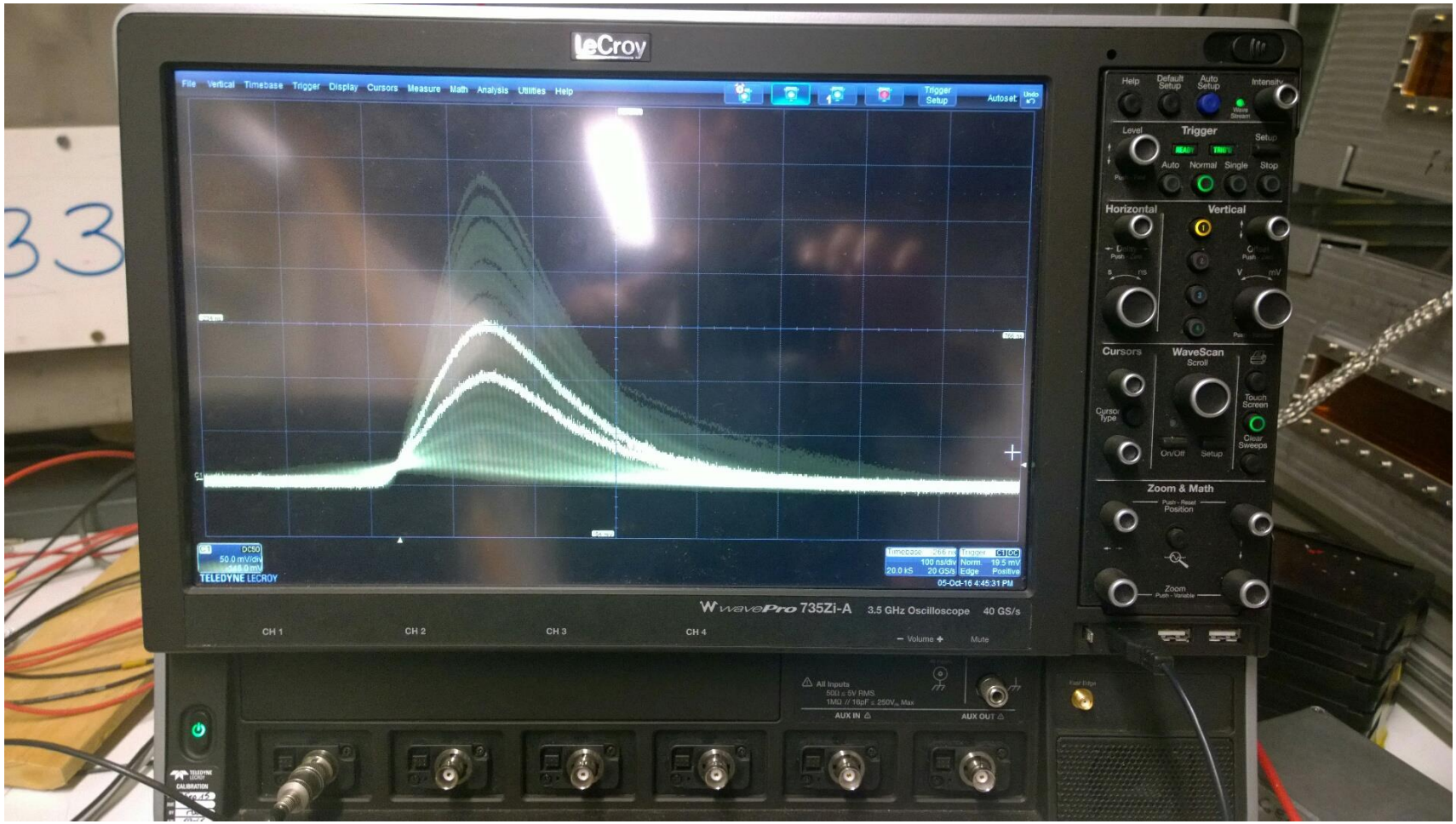


Results

- First Si-GEMs showed a too high leakage current
- Improvement with 2μm-thick SiO_2
- A final Si-GEM was build and is being tested





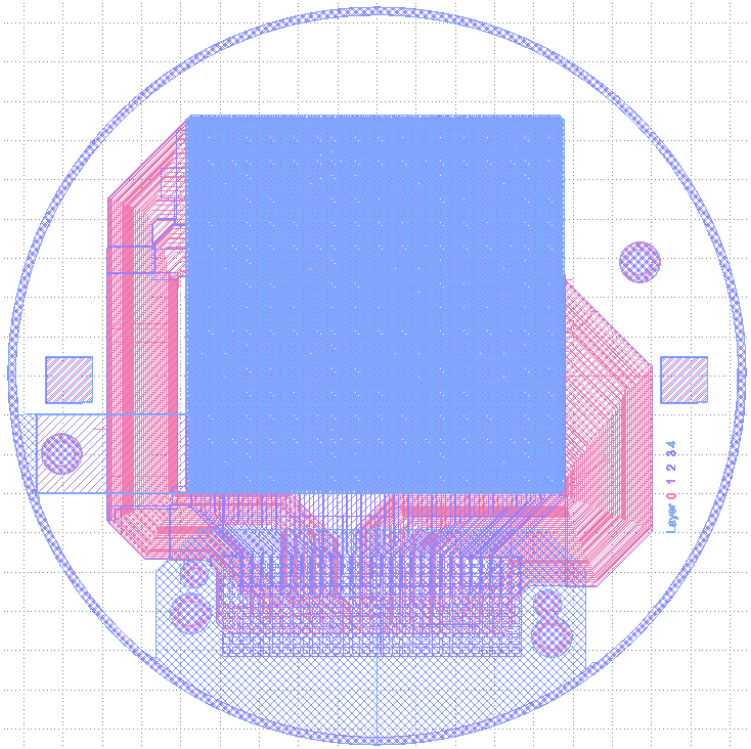


55Fe source. Stable after 2 hours operation. No sparks

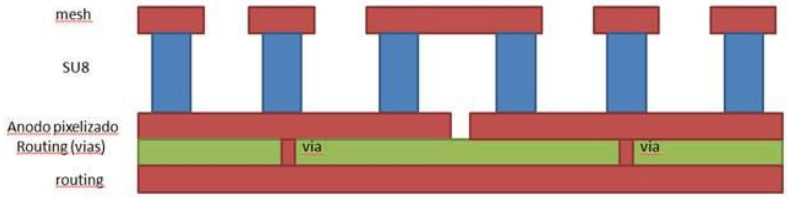
Conclusions on Si-GEMs

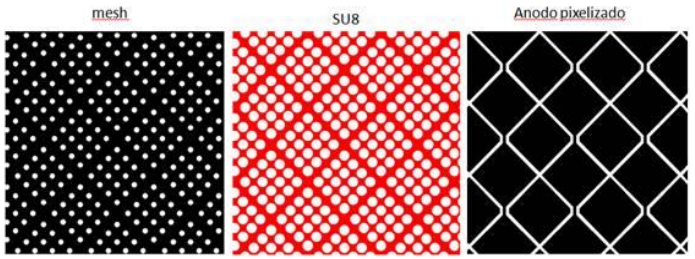
- First Si-GEMs showed strange V-I curves (e.g. not symmetric to 0V)
- Obvious problem with hole etching -> problem identified and currently being fixed. Thicker oxide + ONO
- Si-GEM with thicker SiO_2 layer showed better results.
- Promissing results, but further development needed.

ATOMGEM: Preliminary tests

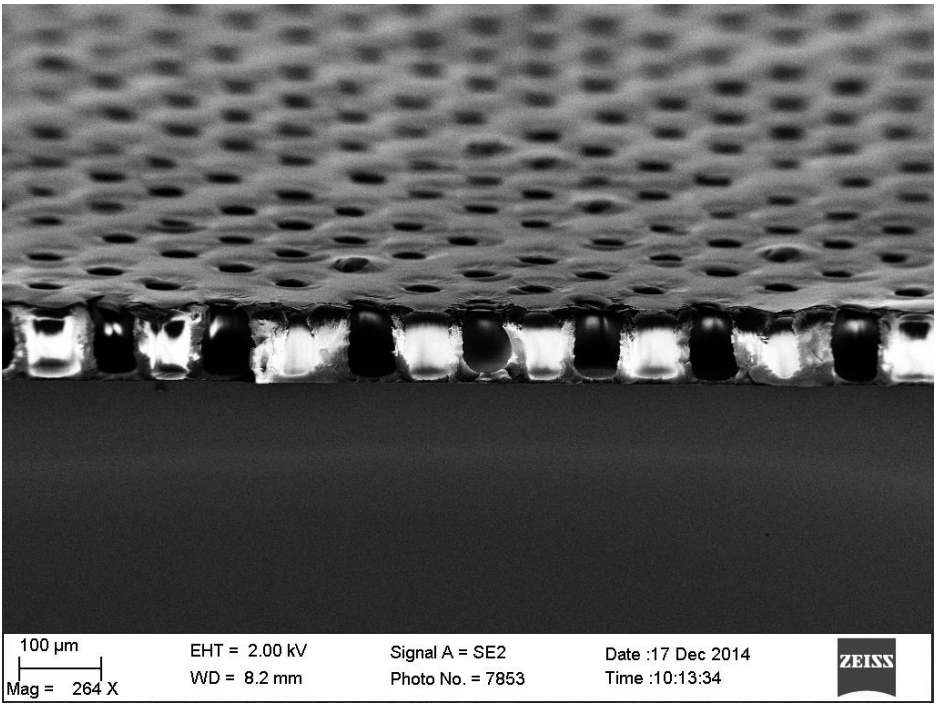


- Two mask sets CNM759 & CNM811
- SU-8 polimer 50µm-thick
- Technical problems encountered
- Solution will be found within ATOMGEM





SU8: Results



ATOMEGAS: Spanish project to develop this technology starting next January