Institute of Microelectronics of Barcelona (IMB-CNM, CSIC)

Integration Technologies and Prospects at CNM

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Centro Nacional de Microelectrónica IMB | EXCELENCIA MARÍA DE MAEZTU | CSIC

MICRO nano FABS Red Española de Salas Blancas de Micro y Nano Fabricación

www.imb-cnm.csic.es

Outline

- The Institute (IMB-CNM, CSIC)
- Facilities and capabilities
- Technologies
- Integration developments
- Prospects and future developments

Institute of Microelectronics of Barcelona (IMB-CNM, CSIC)

- **Public research organism** that belongs to the **Spanish Council for Scientific Research** (CSIC)
- Located in Bellaterra, close to **Barcelona** (Spain) at **Autonomous University of Barcelona** (UAB) Campus
- Devoted to **nano-** and **micro-technologies** and **electronics**
- Micro-Nano **Fabrication Facility** (**Clean Room**) apt to R+D+I and small series

Our mission is to improve the knowledge in micro- and nano-systems and to contribute to solve societal challenges through the implementation of solutions based in these technologies in new products.

KEY FIGURES

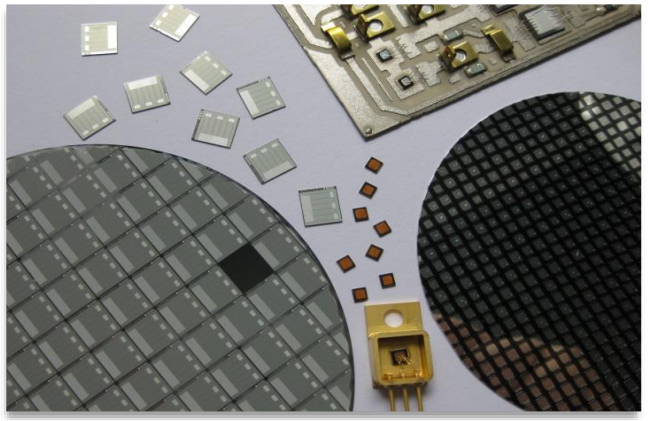
207	35,3%	71	2612	84	21	59
People	Women	Research staff	Papers published since 1996	H-index	European projects since 2018	National projects since 2018

2023

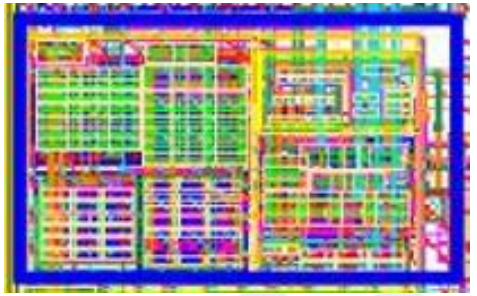
https://www.imb-cnm.csic.es/en/highlights/imb-cnm-figures

Institute of Microelectronics of Barcelona (IMB-CNM, CSIC)

Leveraging role in the semiconductor ecosystem



- **Trajectory of 40 years (2025)**
- **Proven experience in fabrication and design (analog & digital)**



- **Transversal and enabling activity (public-private) in Spain**
- **International Representativity**

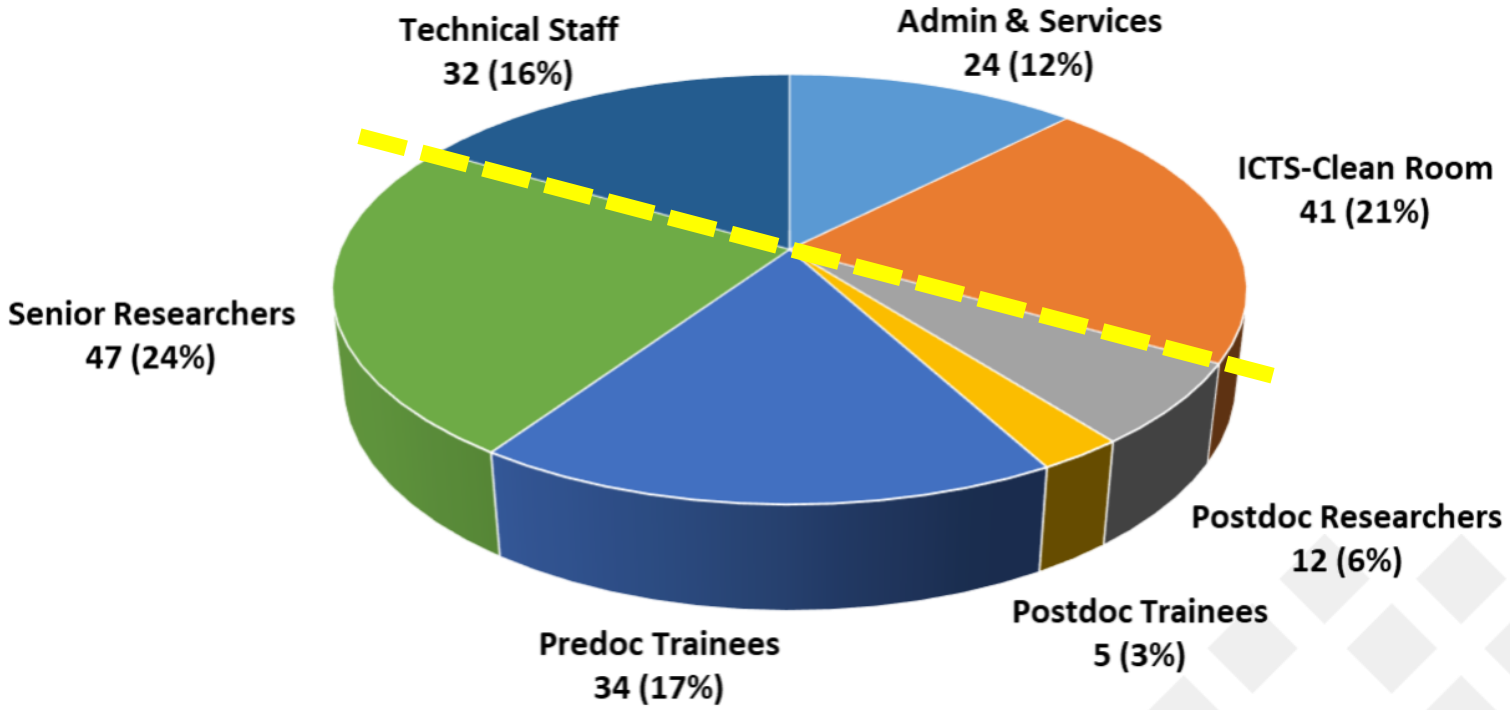
- **Versatile, flexible 1500 m² Clean Room unique in Spain**

KEY FIGURES

KEY FIGURES

≈ 250

STAFF



KEY FIGURES

KEY FIGURES

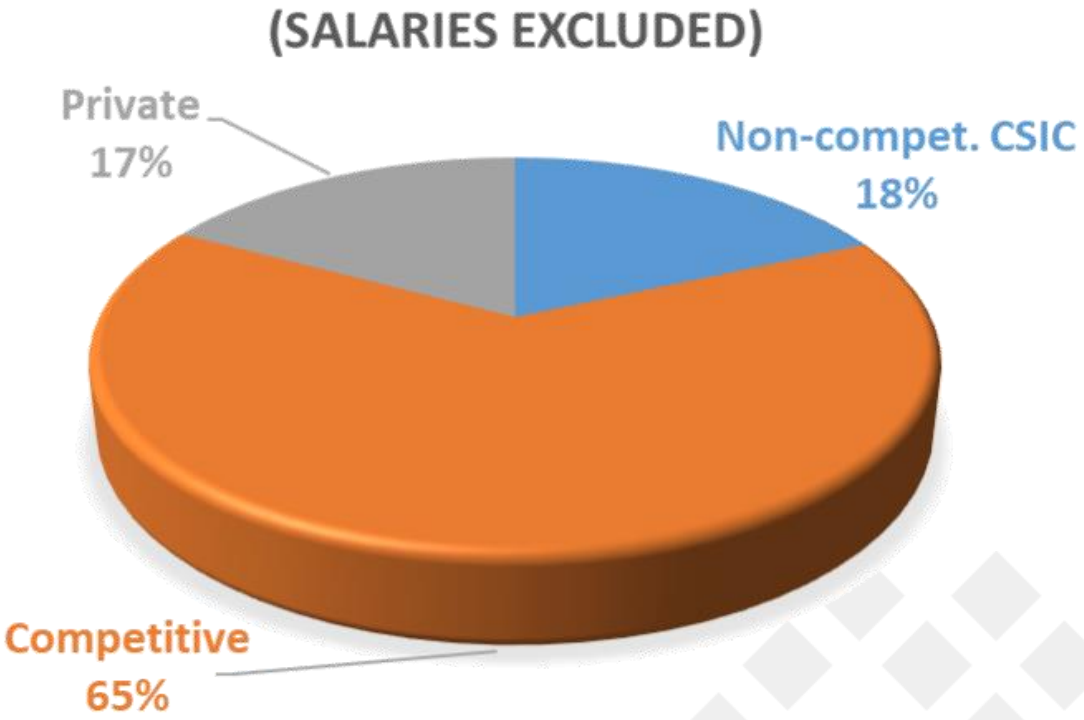
≈13

million euros of budget

45% competitive projects & contracts

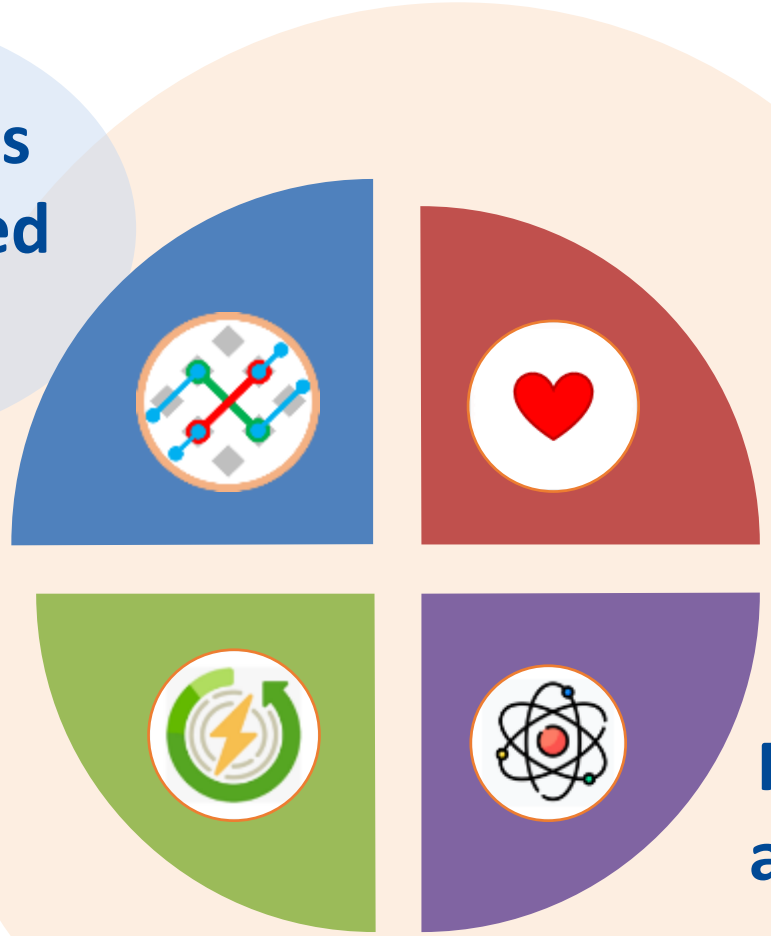
40% of them international

BUDGET



Micro-Nano (physical-digital) systems for…

Technologies and Advanced Processes



Health and Environment

Energy and Mobility

Physics Frontiers and Civil Security

3
Thematic axes

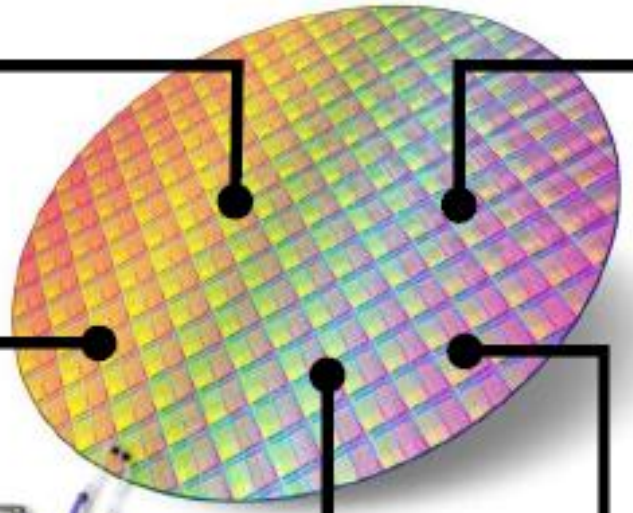
1
Technology Unit

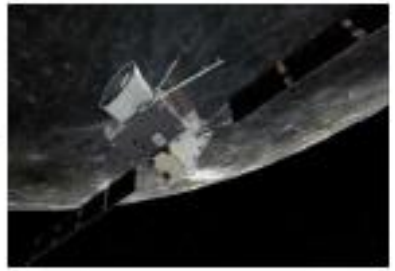
Research at IMB-CNM, CSIC Organization

Physics Frontiers & Civil Security

Detectors for advanced instruments in harsh environments

- Particle physics & astrophysics.
- Nuclear physics & accelerator/ synchrotron facilities.





μ/η Devices & Systems in Space

- Crewed and Uncrewed Mission Support Systems
- Sensors and ICs Customized for Space
- Packaging and Systems Integration in Space Environment

Cybersecurity

- ICs design with enhanced security performance.
- Advanced techniques for chip analysis for fighting crime and terrorism.

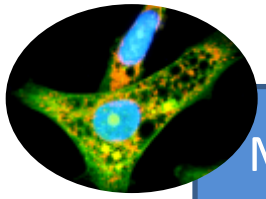
Debugging, reliability & ruggedness in extreme environments

- Qualification and Accelerated Life Tests
- Local Functional Characterization and Failure/ Forensic Analysis
- Right-at-first and Long Lifetime Design Techniques

Disaster-Resilient Societies

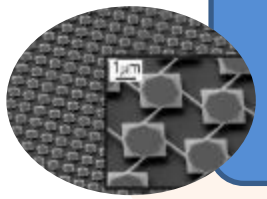
- Sensors for Radiological and Nuclear Incidents.
- CBRN Systems and Networks Integration

Research at IMB-CNM, CSIC Organization



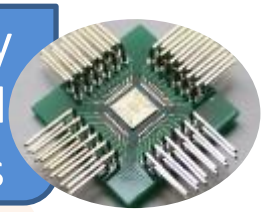
Micro Nano Tools

Chemical Transducers

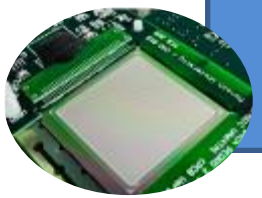


NanoNEMS

Microenergy Sources and Gas Sensors

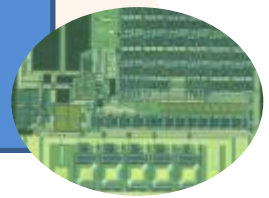


8 Research Groups



Radiation Detectors

Integrated Circuits and Systems



Biomedical Applications

Power Devices and Systems

https://www.imb-cnm.csic.es/en/research

+ Clean Room Facility

Research at IMB-CNM, CSIC Organization

Technologies & Advanced Processes for Micro & Nanosystems

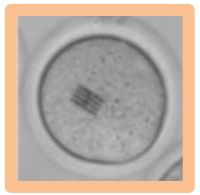
- Microfabrication
- Microintegration functional materials
- Nanofabrication

- Silicon (incl. photonics, quantum, neuromorphic)
- Wide band gap semiconductors
- 2D materials (Graphene, …)
- Polymers / Paper

- Design
- Characterization

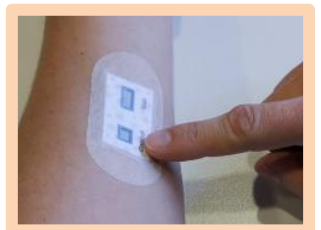
→ Devices
→ Systems

→
- Health and Environment Axis
- Energy and Mobility Axis
- Physics Frontiers and Security Axis



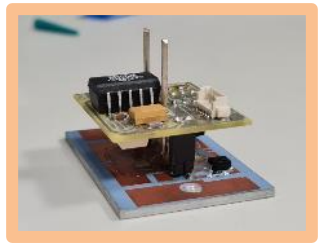
Intracell Si chips

Graphene neural probes



Sweat patches

Covid test platforms



Smart power modules

Si radiation sensors

SiC diodes onboard space missions

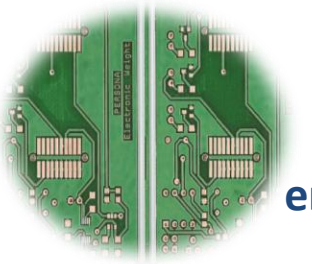
Cleanroom & ICTS facilities at IMB-CNM

Associated laboratories

Electrical characterization

Packaging

Printed electronics



Electronics systems

\+ Reverse engineering

Key figures

100-10,000 Class	21±1ºC	45±5% Rel. Humidity	8:00-20:00 Open hours

Integrated cleanroom: 1500m²

Services: 3x600m²

Packaging: 40+35m²

IMB-CNM cleanroom capacities

KEY FIGURES										
>150	13	45	1130	315	13117	5289	2342	4582	106
Process tool	Process areas	Staff	Runs & Mini-runs	For third parties (28%)	Single steps	Processed wafers	External access	Hours	Individual users

IN 2024

Areas

Thermal processes and CVD
Ion implantation
PVD
Photolithography
Cleaning and wet etching
Dry etching (RIE)
Microsystems
Nano-fabrication
On-line characterization
Electrical characterization
Packaging
Reverse engineering
Printed electronics

Compatible processes	Wafer & dies	Work orders
CMOS Not-CMOS	150 mm 100 mm	Self-service Per assignment

Thermal processes and deposition

Thermal process and CVD

- Oxidation, annealing y RTP
  - 8 tubes + 3 RTP
- B and P diffusion (doping)
- LPCVD
  - 5 tubes: polySi & a-Si, Si_3N_4, SiO_2
- PECVD
  - 3 tools: Si_3N_4, SiO_2, BSG
- ALD
  - 2 reactors: Al_2O_3, HfO_2, TiO_2, SiO_2
- Pyrolysis chamber: parylene

PVD

- 5 sputtering tools
  - Al, Al/Cu, Ti, W, Si, AlN, TiN, Si3N4, SiO2, Ta, TaSi2, Ni, Au
- 2 evaporation tools (E-beam, Joule)
  - Ag, Al, Al2O3, Au, B, C, Cr, Cu, Fe, ITO, Mo, Nb, Ni, Pd, Pt, Sn, Ta, Ti, W, ZnO, Zr…

Ion implantation

- 1 ion implanter
  - B, P, As, N, Ar, Al, Si, Mg, O, He…

& more (micro-systems)

- Electroplating & electroless
  - Materials: Ni, Cu, Au…
- Anodic & eutectic bonding

Cleaning and etching

Cleaning

- 7 wet benches:
  - Piranha, HF, RCA…
- 1 spray etcher
- 2 resist ashers
- Rinser&dryers

Wet etching

- 16 wet benches:
  - Si, SiO2, Si3N4, AlN, HfO2, Al, Ti, Ni, Cr, W, Au, …
  - Anisotropic etching of Si
- Bulk & surface micro-machining
- Critical point dryer

Lift-off

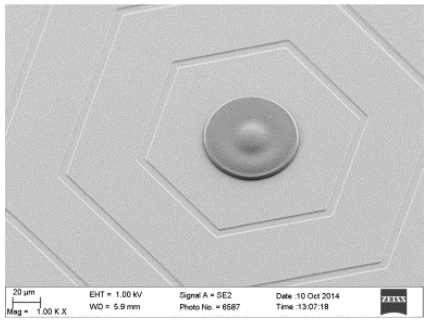
Dry etching

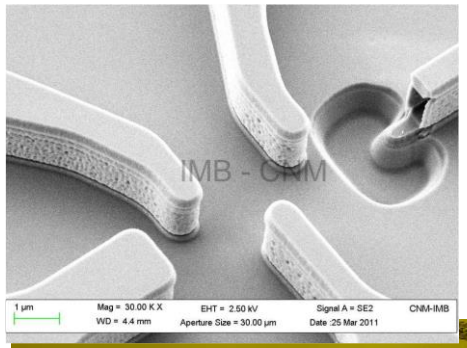
- 8 RIE tools:
  - Chemistry: F, Cl, Bosch process…
  - Materials: Si, polySi, SiO2, Si3N4, Al, ...

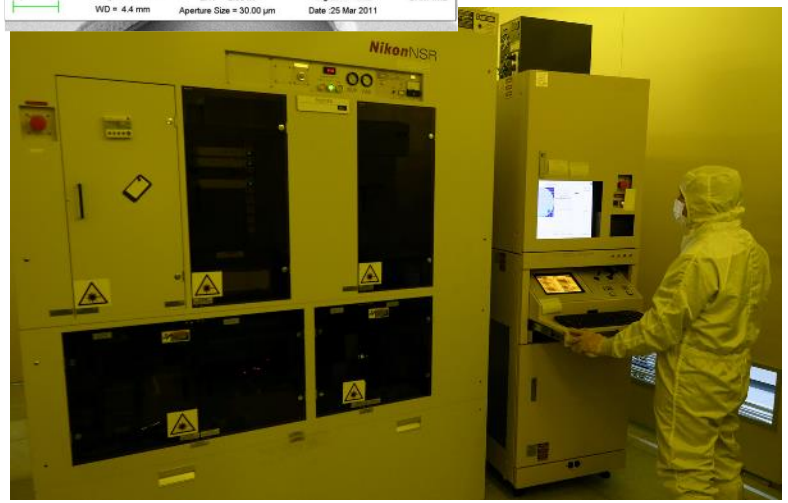
Lithography

Photolithography

- 3 mask aligners
  - Contact and double-side mask aligners
- 1 (maskless) direct write laser
- 1 automatic coater-developer tool
  - Resolution > 1,5µm





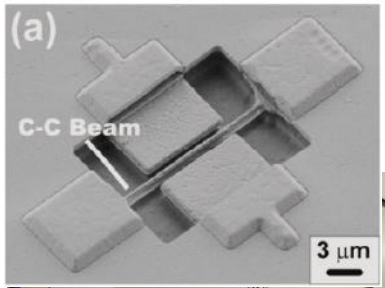


Stepper

- 1 i-line stepper
  - Resolution ~ 0,5µm

Nanolithography

- 1 Electron-beam lithography tool
  - Resolution < 50nm
- Block copolymers technology
- Nanopatterning by AFM



Characterization and Packaging

Characterization

In-line characterization

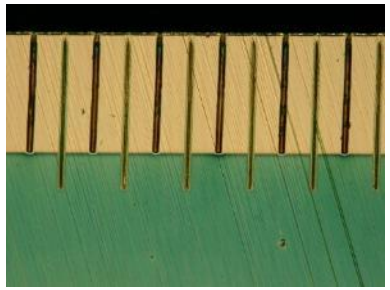
Optical microscopy
Scanning Electron Microscopy
Confocal microscopy
Interferometry
Ellipsometry
FTIR
Raman
Sheet resistance
Wafer thickness & bow
Lifetime measurement
Profilemeter
Atomic Force Microscope

Semiconductor characterization

I(V), C(V), …

Post-process analysis

Reverse engineering, FIB

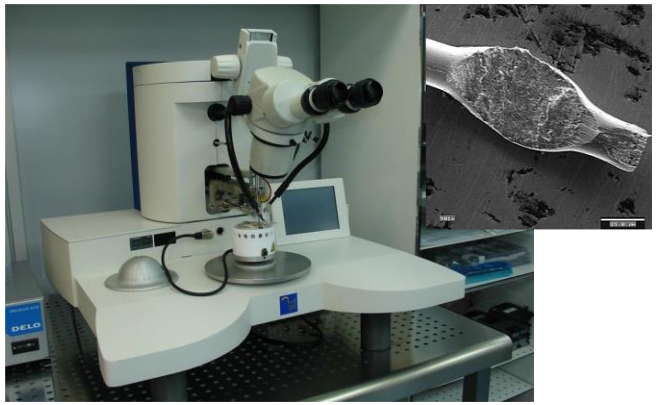


+ Laboratories of IMB-CNM research groups

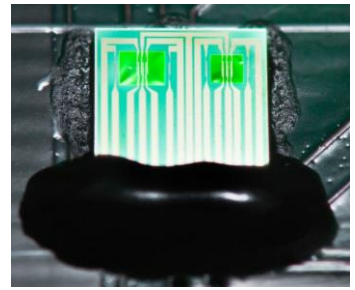
Packaging

From dicing, die attach, wire bonding, to final encapsulation

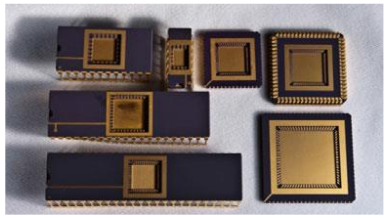
3 dicing saws & several associated tools

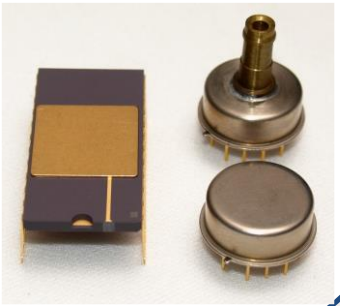


7 bonders & Test



Cleaving



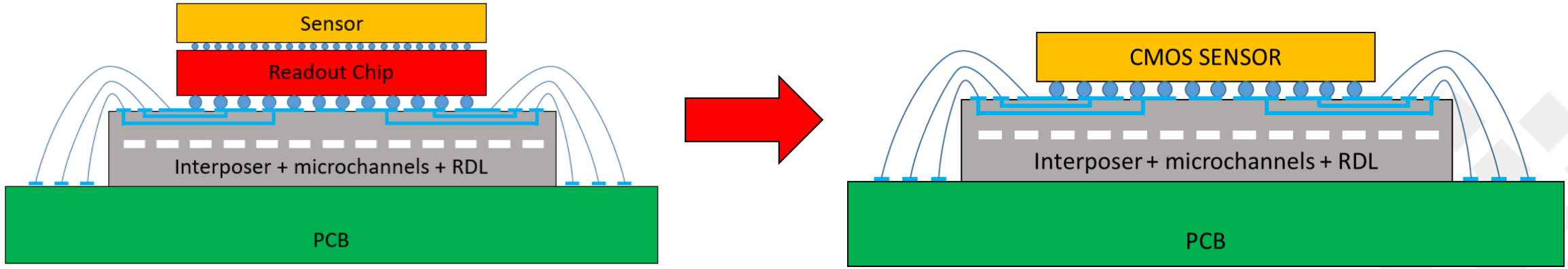


Technologies

CMOS-compatible technologies	▪ CMOS
	▪ Radiation sensors
	▪ Power devices
	▪ ISFETs
	▪ Memristors
	▪ Integrated photonics
	▪ Semiconductor quantum devices
MEMS technologies	▪ Micro-fluidics
	▪ Gas sensors
	▪ Harvesters
	▪ Micro/nano mechanics
	▪ Graphene-based materials on thin films
2D functional materials	
Printed electronics	

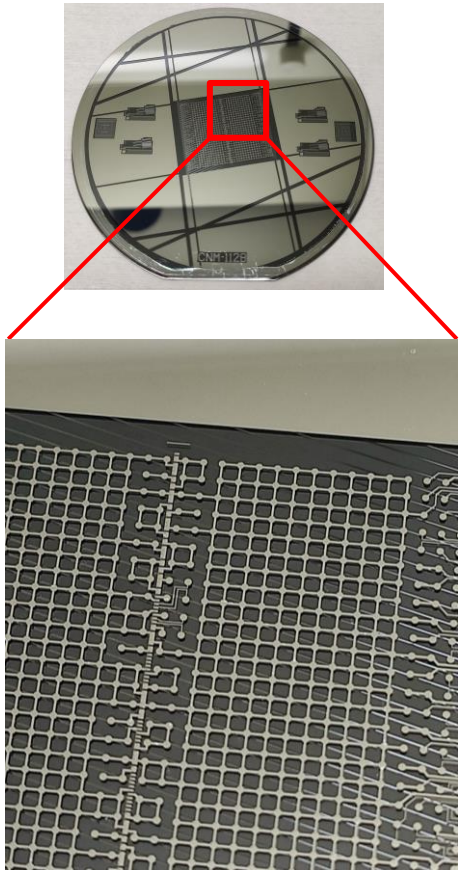
Heterogeneous integration

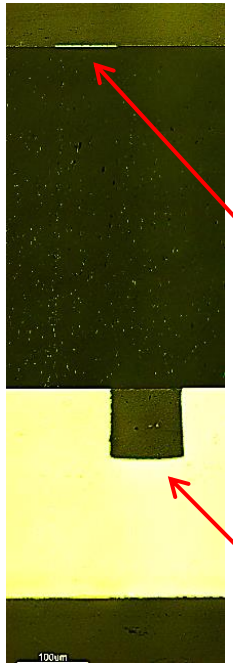
- Microchannels embedded in functional silicon interposers with integrated signal and power routing
  - Combining the cooling capabilities with the electrical connection of the CMOS detector
    - For signal and power routing → Redistribution Layer (RDL)

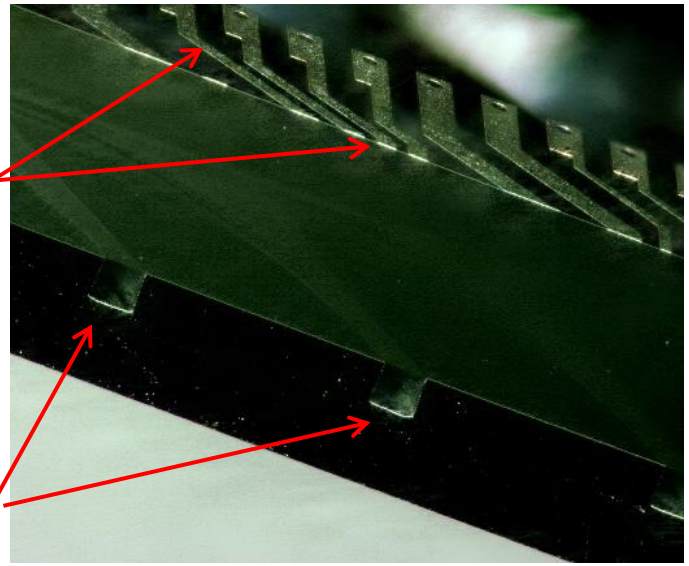


Active Silicon Interposers

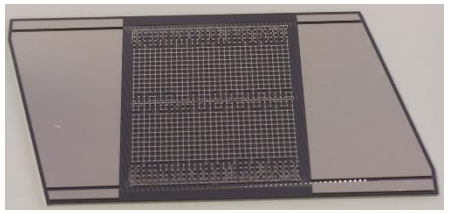
- Successful integration of microchannels in silicon plates with integrated signal and power routing by “**Pre-processing**”
  - M. Ullán, et al. NIMA, 169490, 2024. https://doi.org/10.1016/j.nima.2024.169490







Silicon Interposer

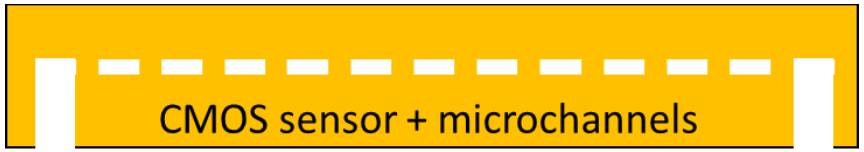


Front

Back

“Monolithic” integration

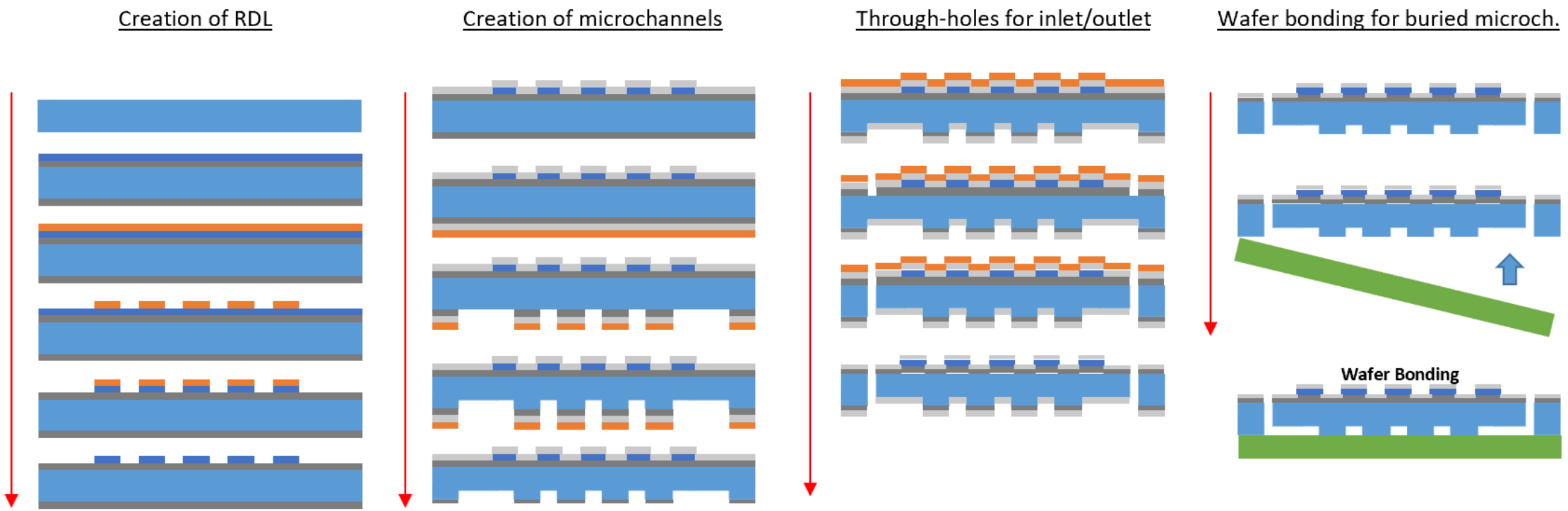
- Micro-channel cooling technology fully compatible with (CMOS) sensors in the same substrate (monolithic integration)
  - Fabricate micro-channels in the same substrate as silicon sensors



  - Full integration of “*external*” CMOS process with microchannels
    - ☞ Technological compatibility
  - “**Post-processing**”
    - Develop a technological process for CMOS-compatible “post-processing”
  - Main challenge: Back-End-Of-Line (BEOL) layers

Post-processing Technology

- Technological process for CMOS-compatible post-processing
  - Good metal results in blanket wafers
  - Full assemblies with structured metal (signal and power tracks) on-going
  - Critical step for CMOS integration process

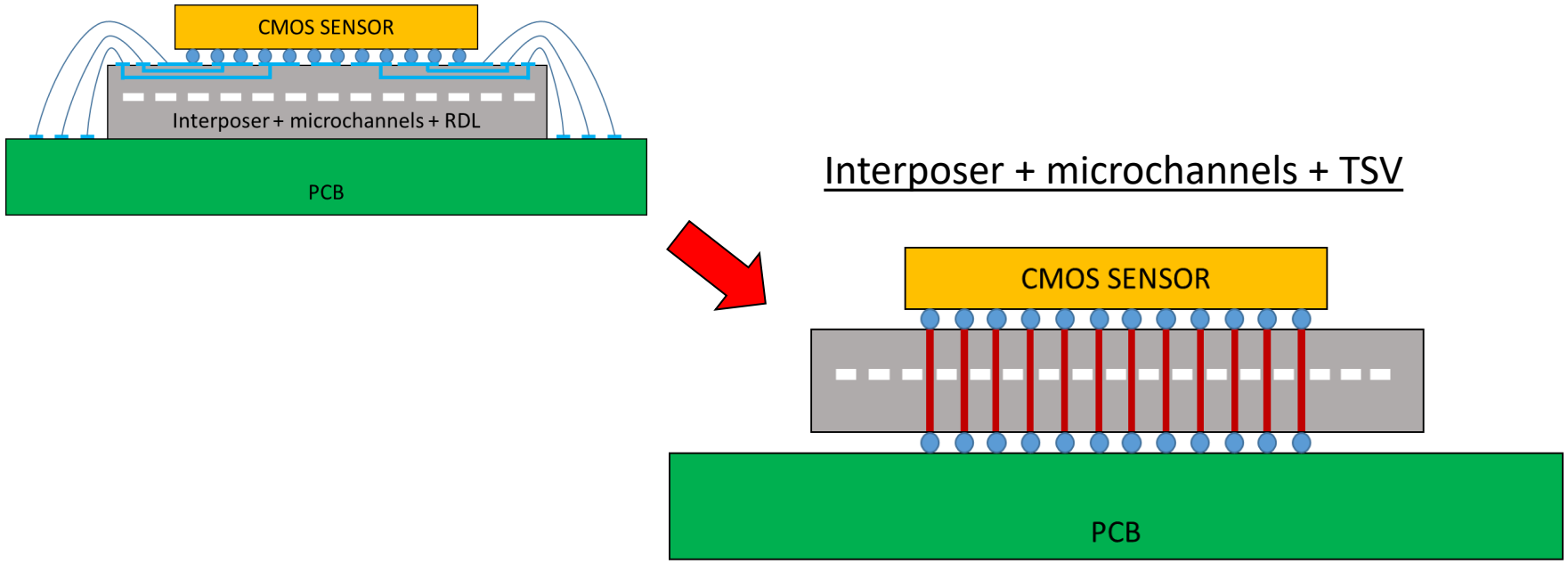


Prospects: Improving technological capabilities

- We are expecting funding from Spanish Ministry to procure some new equipment to increase 3D integration capabilities
  - Automatic Precision Surface Grinder
    - Planarization, wafer thinning, multi-tier metals, TSV
  - Advanced Manual Electrochemical Deposition
    - Cu deposition, TSV

Prospects: future developments

- Improved RDL
  - Multi-tier metal layers, additional metals (Cu), higher density
- Interposers with TSV
  - TSV development
  - Developing interposers with Through Silicon Vias in order to improve the interconnection with the detectors



Centro Nacional de Microelectrónica IMB

CSIC
Consejo Superior de Investigaciones Científicas

Thanks for your attention

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Barcelona · Spain

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Backup

ISO 9001

Organization: IMB-CNM, D+T & SBCNM

Scope: Design development and production of devices based on micro and nanoelectronics technologies

Validity: 28/04/2023 – 28/04/2026

IQNET

Building trust together.

Certificate

AENOR has issued an IQNET recognized certificate that the organization:

AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

INSTITUTO DE MICROELECTRÓNICA DE BARCELONA (IMB-CNM).
INSTITUTO DE MICROELECTRÓNICA DE BARCELONA (IMB-CNM). CL DELS TIL·LERS
CAMPUS UAB
08193 - BELLATERRA
(BARCELONA

has implemented and maintains a/an
Quality Management System

for the following scope:
Design development and production of devices based on micro and nanoelectronics technologies.

which fulfils the requirements of the following standard

ISO 9001:2015

Linked to the certificate ES-1026/2023

Registration Number: ES-1026/2023 - 001/00

First issued on: 2023-04-28 Validity date: 2026-04-28

Alex Stoichitoiu
President of IQNET

Rafael GARCIA MEIRO
CEO

AENOR

This attestation is directly linked to the IQNET Member's original certificate and shall not be used as a stand-alone document.

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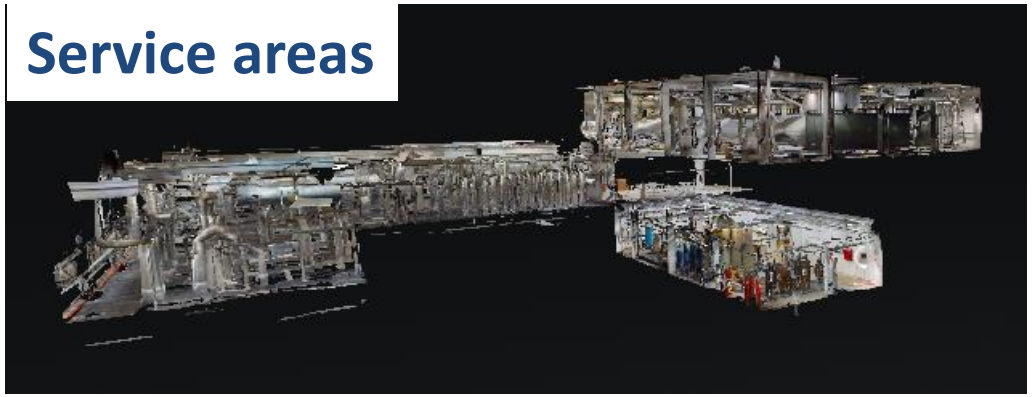
* The list of IQNET Members is valid at the time of issue of this certificate. Updated information is available under www.iqnet-certification.com

Virtual tour

Clean room

Service areas



Virtual tour of the clean room

Visit us!

https://www.imb-cnm.csic.es/en/micro-and-nanofabrication-clean-room/clean-room-virtual-tour