Open session PiezoMAT - LETI

Experience of LETI in microsystems technologies applied to PiezoMAT project

Heterogeneous integration of nano-objects

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PiezoMAT – Eurosensors 2016

September 7th 2016

SEVENTH FRAMEWORK PROGRAMME

EU Project No. 611019

OUTLINE

- LETI : presentation and mission
- Microsystems activities in LETI
- LETI's contribution in PiezoMAT project

LETI WITHIN CEA

- 16 000 collaborators
  - 10 % PhD and post-doc
- 10 research centres



Nuclear Energy Division

Defence and Security Division

Technological Research Division

leti Electronic and information technologies

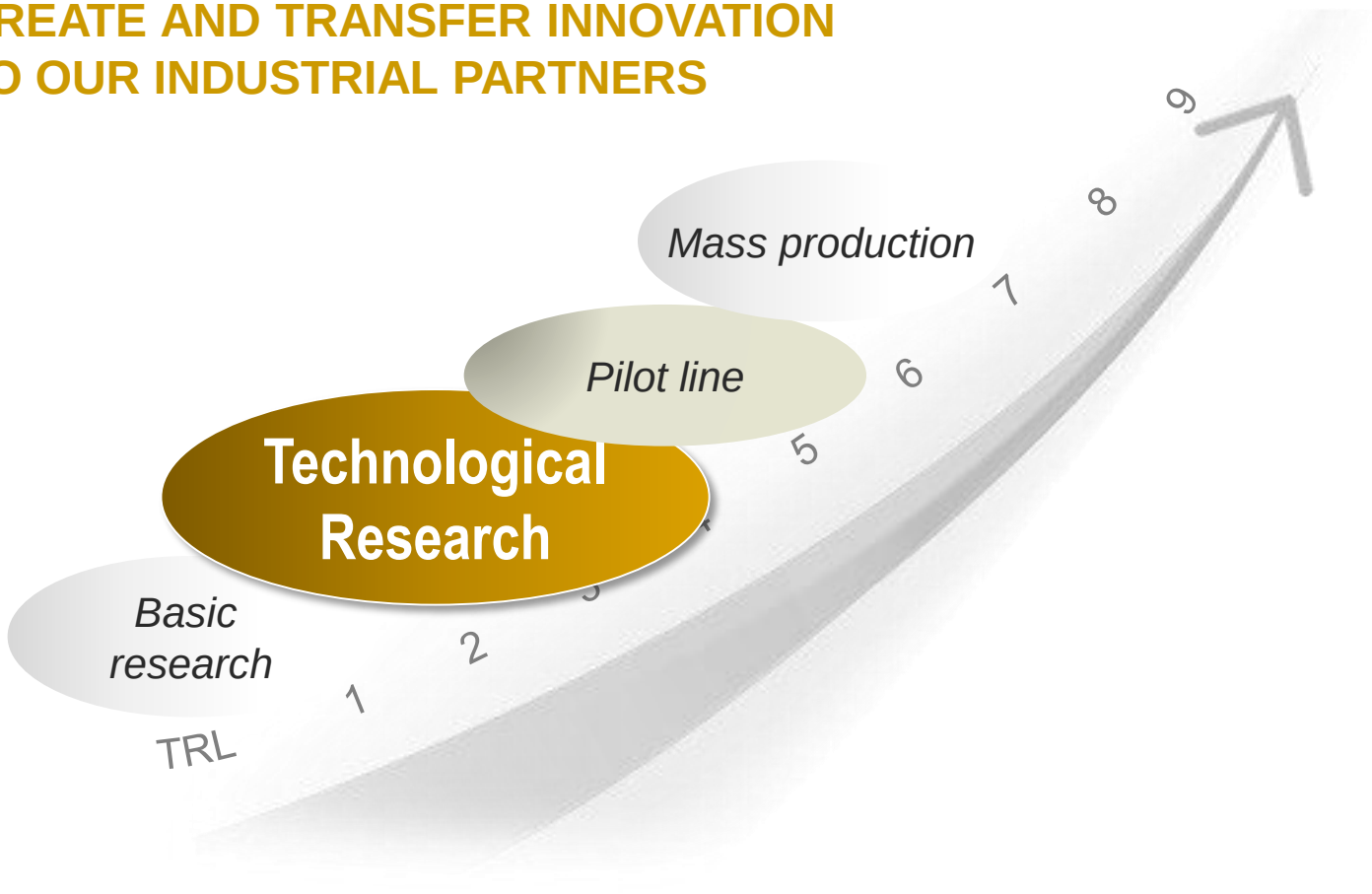
liten New Energies

List Software

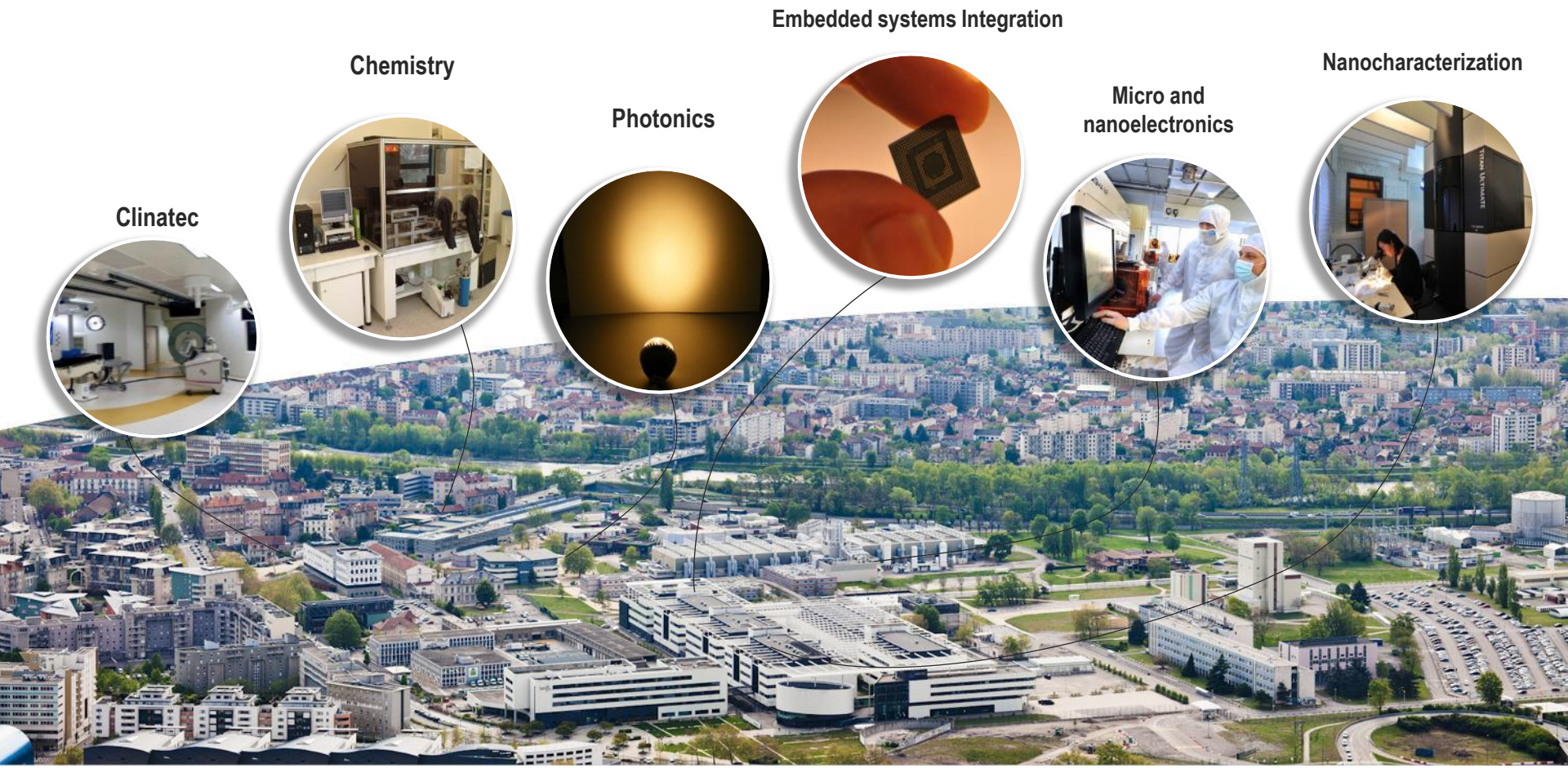
Basic Research Division (Life sciences and Physical sciences)

A BUSINESS MODEL

CREATE AND TRANSFER INNOVATION TO OUR INDUSTRIAL PARTNERS



RESEARCH PLATFORMS IN GRENOBLE



ELECTRONICS WITHIN SOLUTIONS

Consumer

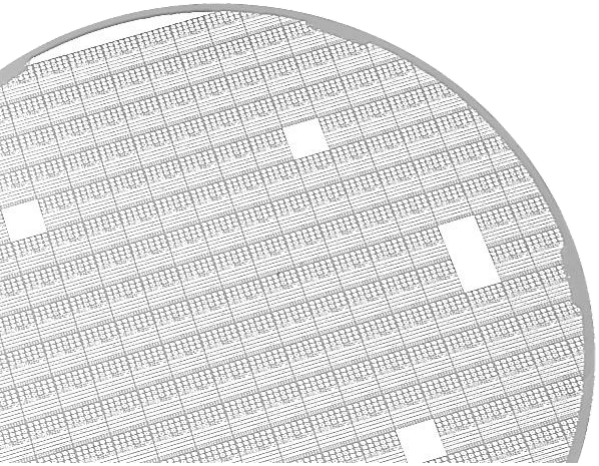
IoT & Smart objects

Space

Manufacturing

Energy and environment

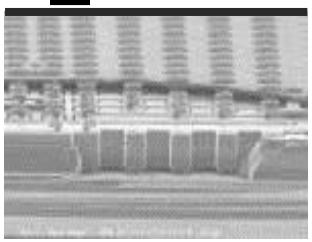
Biology and health



Transport

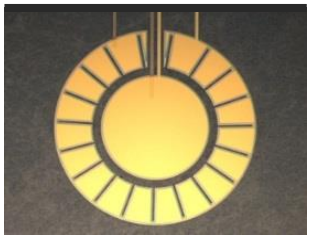
Safety and Security

MICROSYSTEMS SECTION



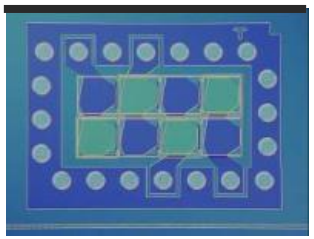
LCMC Lab.

Sensors
Components



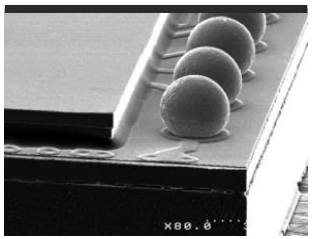
LCMA Lab.

Actuators
Components



LCRF Lab.

RF Components



LPI Lab.

Packaging &
Interposer

LCFC Lab.

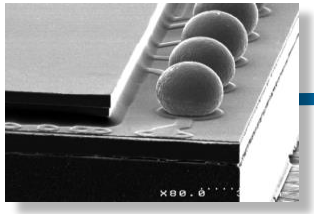
Characterization
& Reliability

TECHNOLOGICAL PLATFORM

- MEMS 200mm (1000 m²) + FE 200mm (3000 m²) Cleanrooms
- Specific MEMS equipment : DRIE, HF-vapor, bonder…
- 5 shifts working: 7days/week – 24h/days

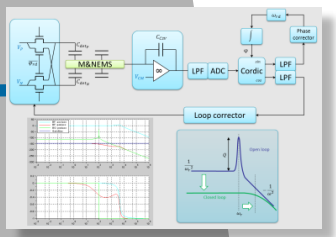
FROM MEMS DESIGN TO SYSTEM INTEGRATION

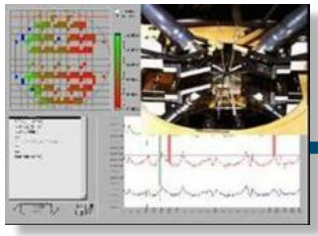
Prototyping



3D assembly

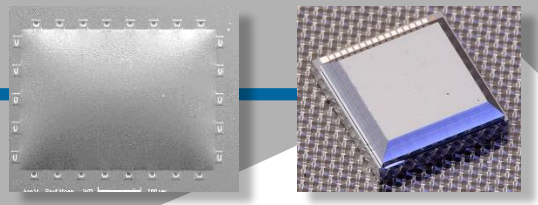
Electronic design



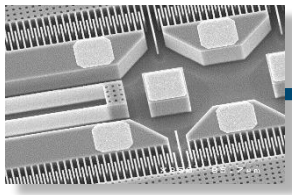


Characterizations

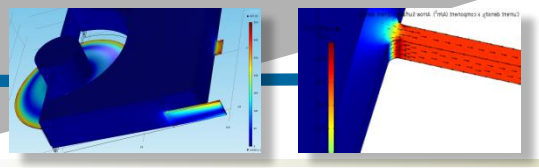
WLP & TFP Packaging



MEMS Technology



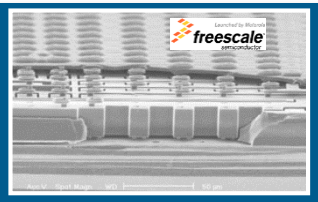
MEMS Design



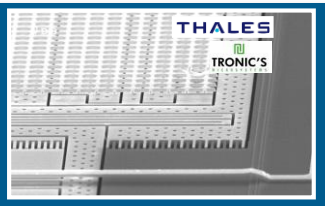
Leti covers the whole chain of development

MEMS BACKGROUND

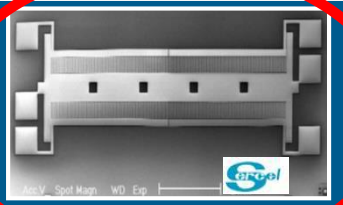
Inertial Sensor



3-axis Accelerometer



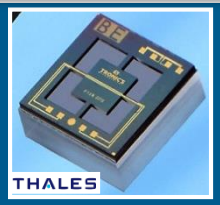
3-axis Gyroscope



Geophone

Pressure sensor

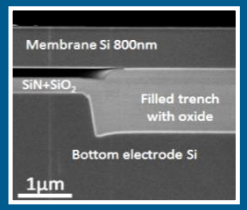
Capacitive pressure sensor



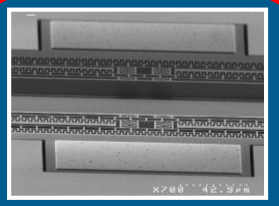
Piezoresistive pressure sensor

3-axis force sensor

Acoustic sensor

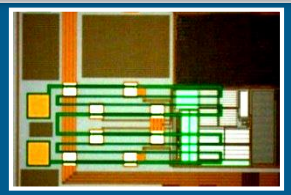


cMUT

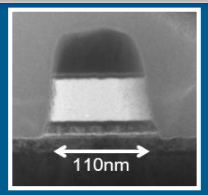


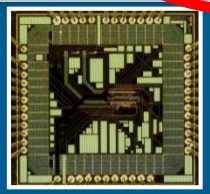
Microphone

Magnetic sensor

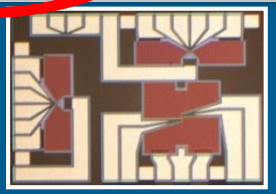


Above-IC GMR sensor





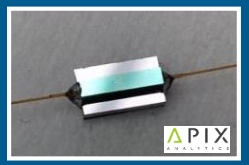
TMR sensor and MRAM

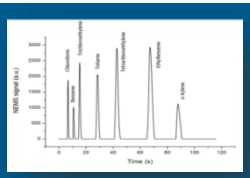


3-axis Compass

MEMS BACKGROUND

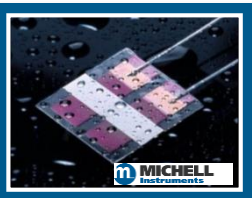
Gas sensor





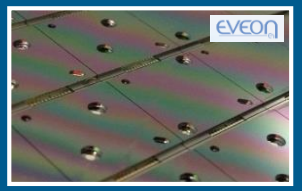
NEMS-based + µGC gas sensor

µ-TOF Mass-spec for NRBC



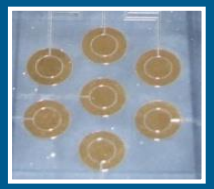
Humidity

MEMS Actuator



Implanted micro-valves

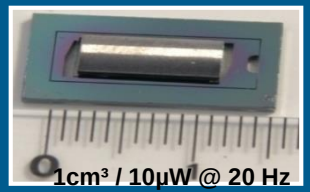
PZT-based Variable Lens



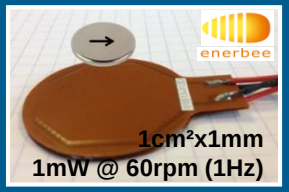
PZT ultrasonic transducers

Energy harvesting

Piezoelectric AlN harvester

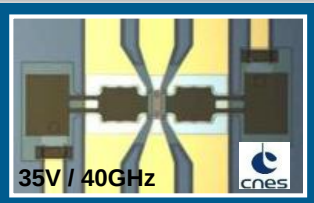


Electret-based harvester

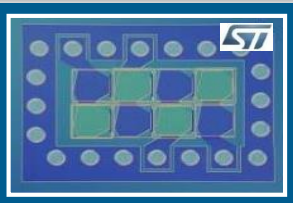


Breakthrough concept

RF-MEMS



Micro-switch

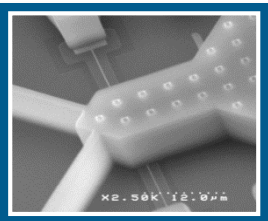


BAW filter

TECHNOLOGY BACKGROUND

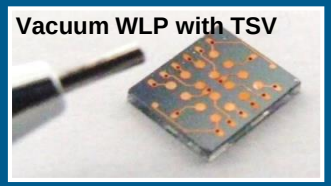
Nano-scale technologies

NEMS resonator

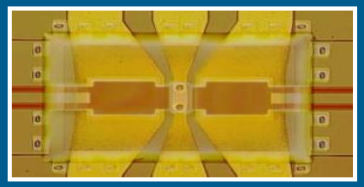


M&NEMS platform

Hermetic packaging

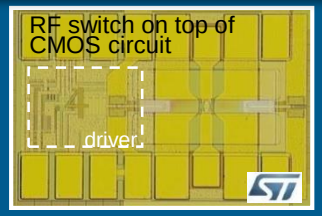


Vacuum Wafer-level packaging

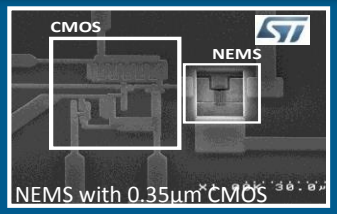


Thin-Film packaging

MEMS / CMOS Co-integration

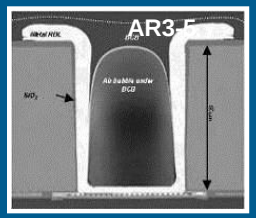


Above-IC co-integration

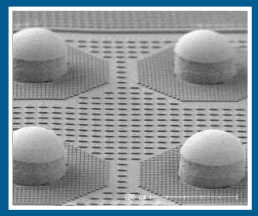


Pre-CMOS co-integration

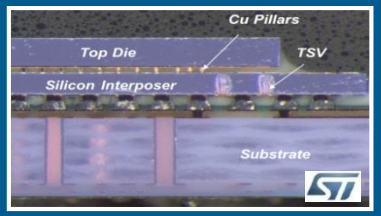
3D integration



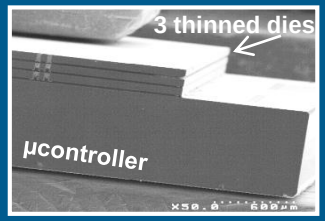
TSV last (Cu-liner)



Cu pillars (pitch 40µm)



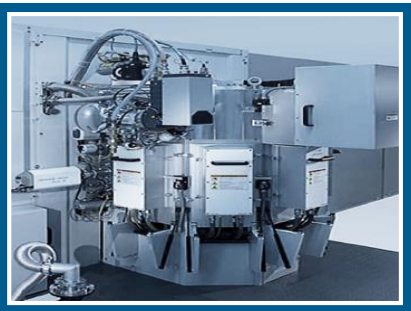
Silicon Interposer

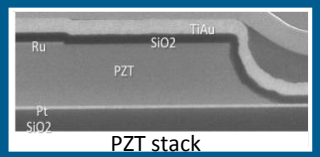


Multi-die stacking

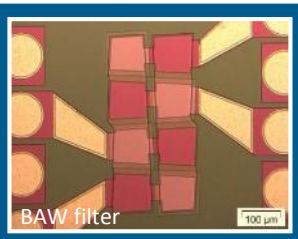
TECHNOLOGY BACKGROUND

Material Expertise

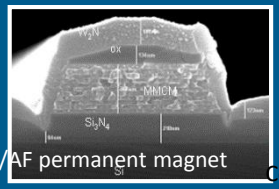


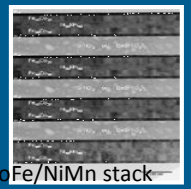


PZT stack



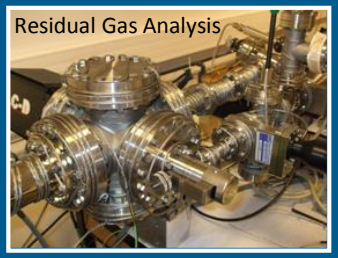
Piezoelectric material
(actionneur, RF, high k)





Magnetic material
GMR, TMR, high permeability mat. (RF inductor) and high permitivity and permeablity mat. (for antenna)

Characterization Expertise



Packaging reliability

MEMS device & Passive component reliability

LETI'S MISSION IN PIEZOMAT

Steps made at LETI

Process
Wafer level 200mm

dicing

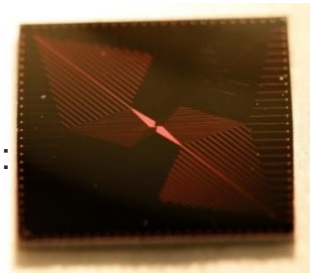
1.5x1.5 cm^2 dies

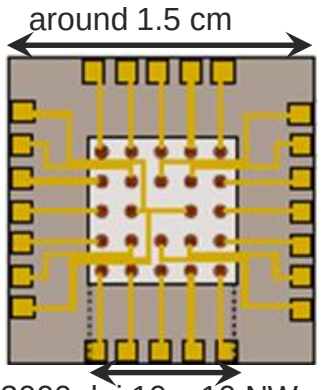
Project partners

- Nanowires growth
- Encapsulation
- Top electrode
- Bonding
- Testing

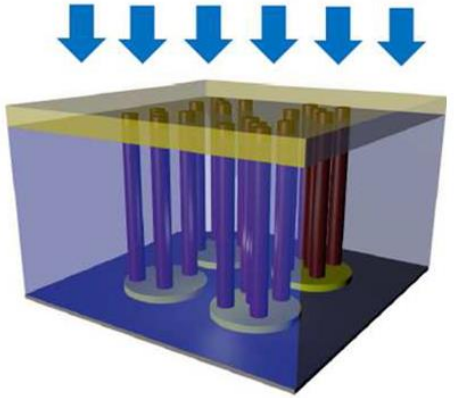
Specifications:

- Seed layer patterns for NW growth for 3000 dpi:
  - Ø2µm
  - matrix 10x10
  - pitch 8µm
- Bottom electrode connected to seed layer
- Electric lines
- Pads for bonding : 100 pads
- Dies around 1.5x1.5 cm^2





3000 dpi 10 x 10 NWs
active area 0.8 x 0.8 mm^2



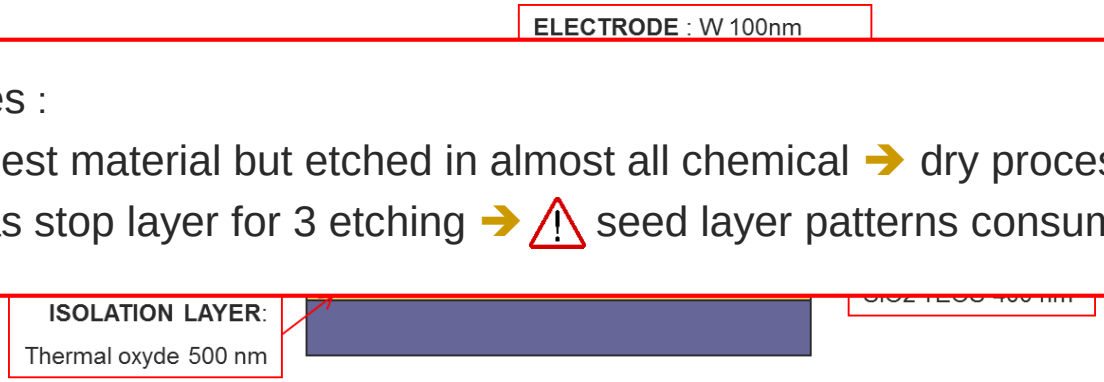
➔ **Challenges** :
High patterning density, choice of materials (in & out seed layer), integration

MATERIALS & TECHNOLOGICAL CHOICES

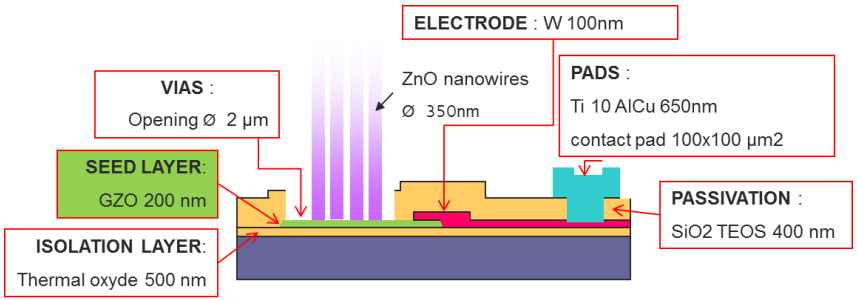
- Materials choice
  - Seed layer : GZO (8% doping) conductive layer allowing nanowires growth
  - Electrical lines : W thin patterning by dry etching without overetch
  - Thermal SiO2 : isolation from substrate
  - TEOS SiO2 : passivation & no NW growth out of seed layer patterns
- Technological choices
  - GZO deposition by pulsed CVD : high deposition rate
  - Dry etching & stripping only to preserve GZO : RIE or IBE, microwave plasma
  - Cleaning : Mechanical spray only (no chimical bath)

Challenges :

- GZO best material but etched in almost all chemical ➔ dry process only
- GZO as stop layer for 3 etching ➔ ⚠ seed layer patterns consumption



STACKING & PROCESS FLOW



Step I: GZO deposition and etching (seed layer patterns)

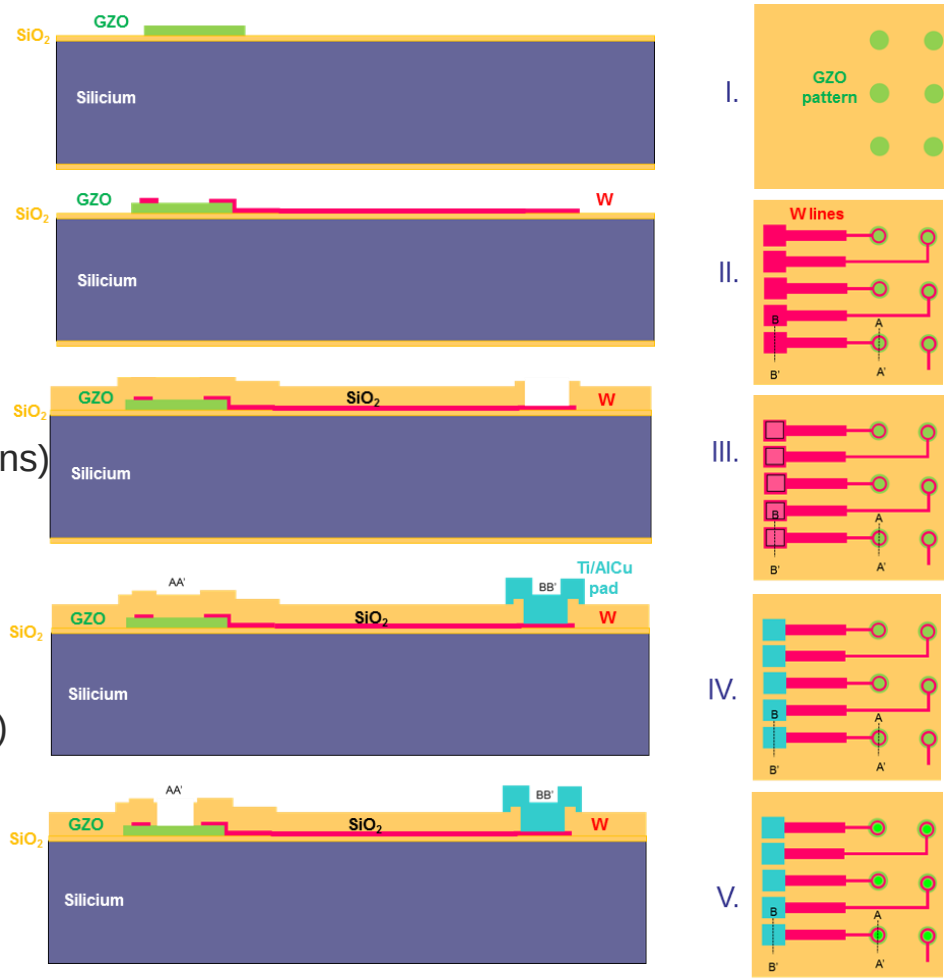
Step II: W deposition and etching (electric lines)

Step III: SiO_2 deposition and etching (pad location)

Step IV: Ti/AlCu deposition and etching (contact pads)

Step V: SiO_2 etching (future NW's location)

Step VI : Dicing

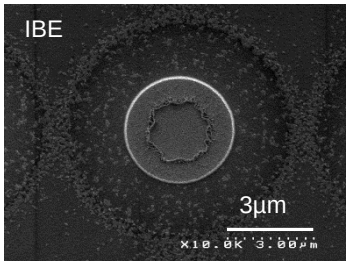


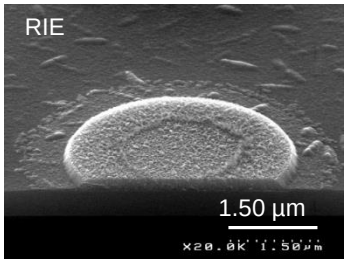
GZO ETCHING DEVELOPMENT

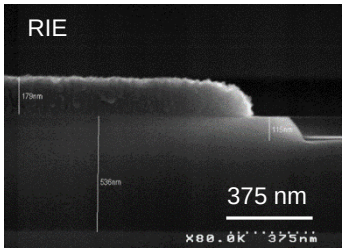
- GZO etching improvement
  - Many difficult points solved

	Improvement solutions	
	RIE etching	**IBE etching**
Homogeneity	Gaz change	ok
End point detection	Gaz change	Fixed time
Corrosion	Stripping in situ	ok
Vertical etching side	ok	Postbake resist
Polymere residues	Mechanical cleanning	Mechanical cleanning
Reproducibility	Steps sequences	Protective layer

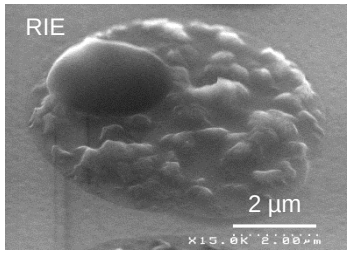
Polymere & GZO residues





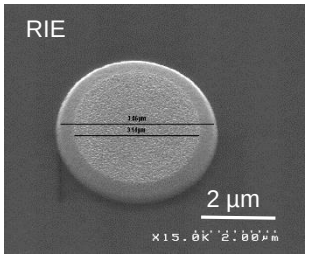


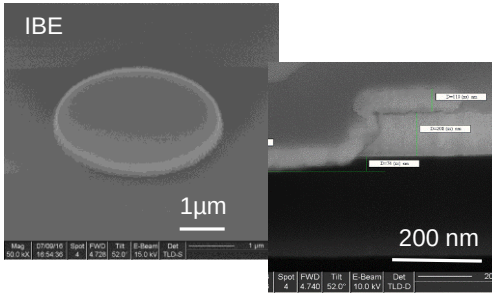
Overetch



Corrosion

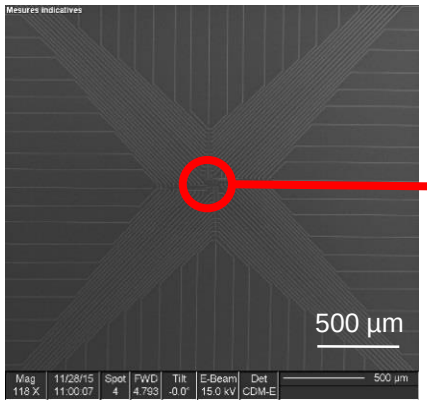
- Final results : 2 processes compliant with specifications
  - Reproducible
  - GZO & SiO2 : low non-desired consumption
  - Electrode W well shaped

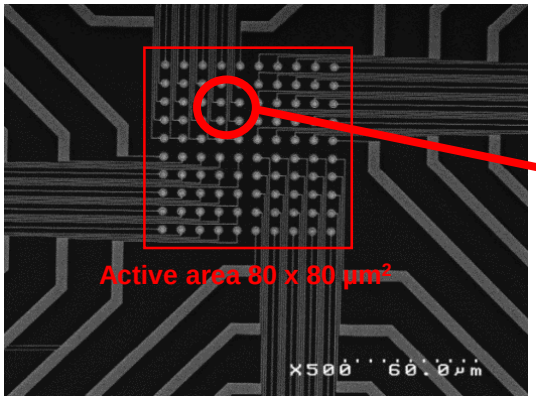


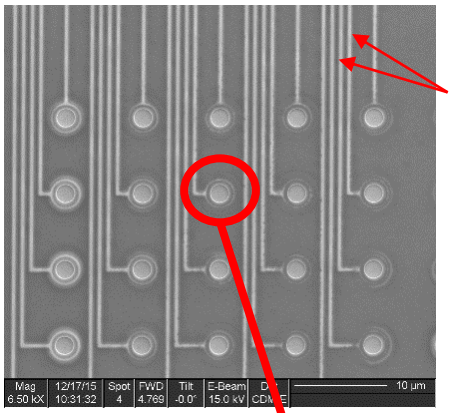


SEM VIEWS OF THE DEVICE

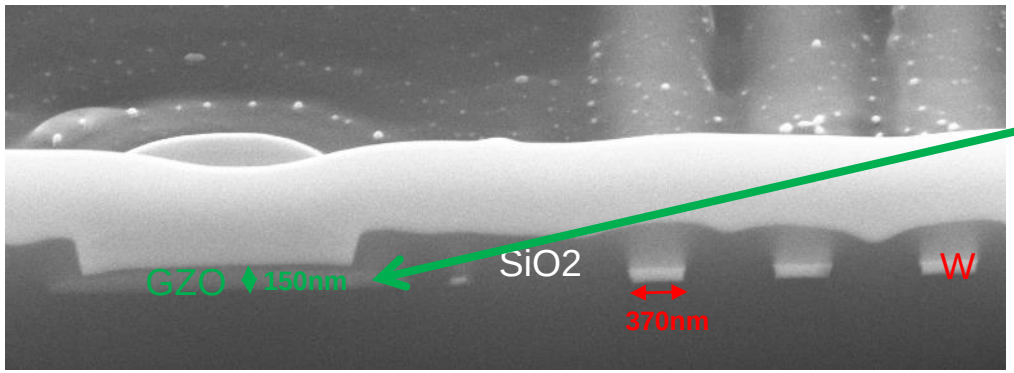
- High density patterning ➔ low critical dimensions CD_{min}=400nm



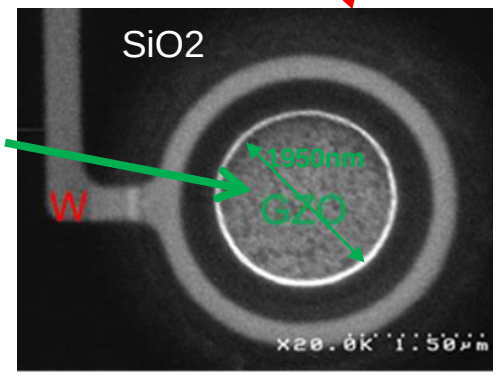




- Dies compliant with specifications : profile and CD ok

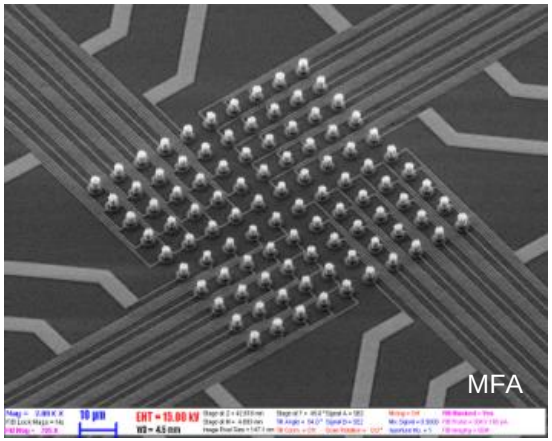


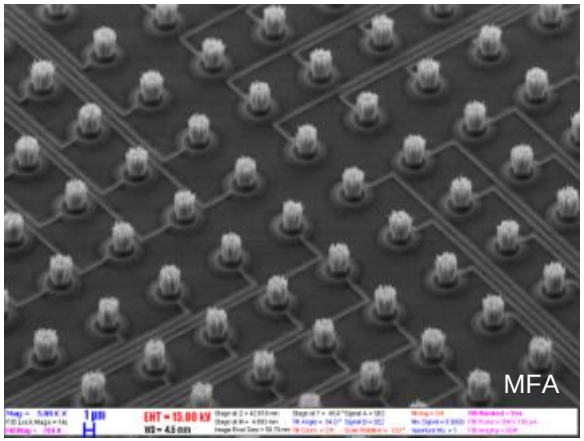
NW seed layer pattern Ø2µm

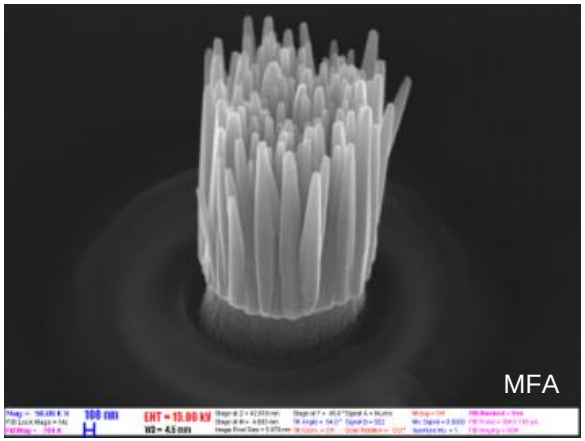


CONCLUSION

- Functional dies sent to project partners
  - Dies compliant with specifications : NW growth on seed patterns





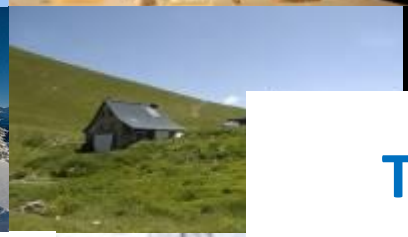


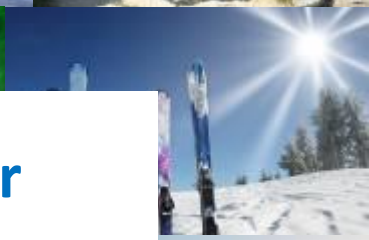
- Next step : demo dies with more pixels





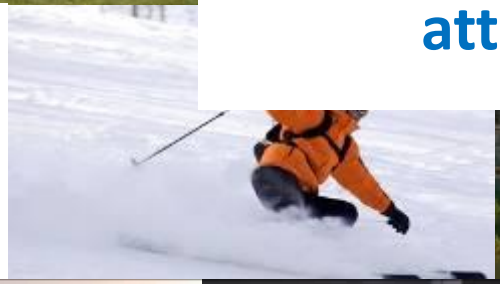
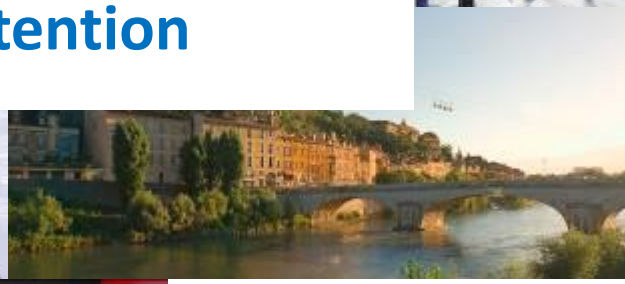
leti



Thanks for your attention

a strong partner for innovation development research from technologies to applications,



in a dynamic and global environment