leti
cea tech

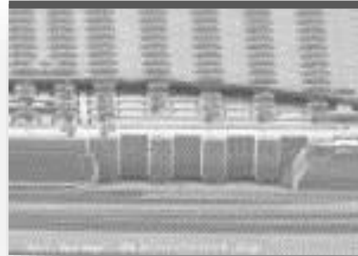
M&NEMS : A GENERIC PLATFORM FOR MEMS MANUFACTURING

Philippe ROBERT | July 2018

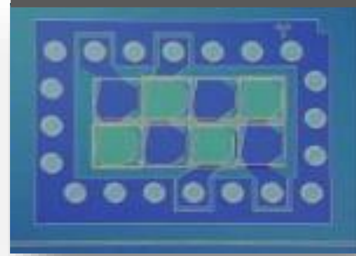
Introduction to LETI’s MEMS activities

MICROSYSTEMS SECTION

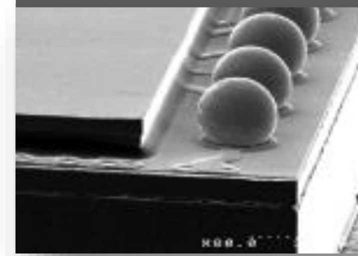
LCMA Lab.
Actuators Components



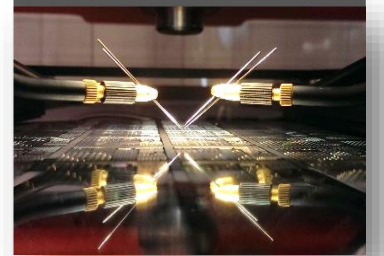
LCMC Lab.
Sensors Components



LCRF Lab.
RF Components

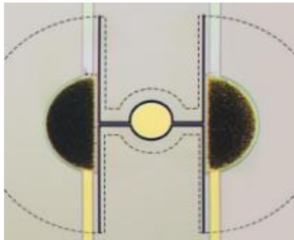


LP3D Lab.
Packaging & 3D



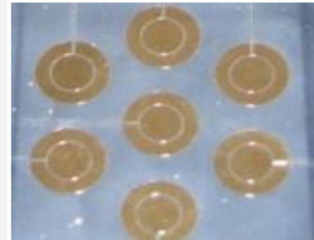
LCFC Lab.
Charact. & Reliability

Components



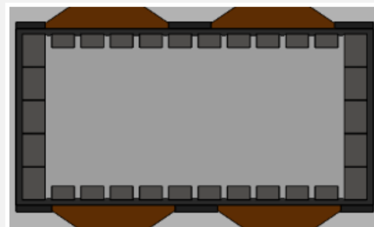
Optical Scanner

Variable focus lens



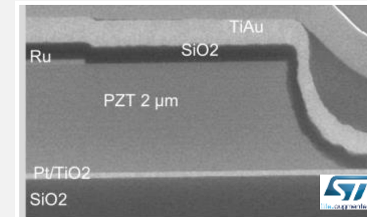
Loudspeaker

Micro-valve / Micro-pump



Haptics

Technologies background



PZT

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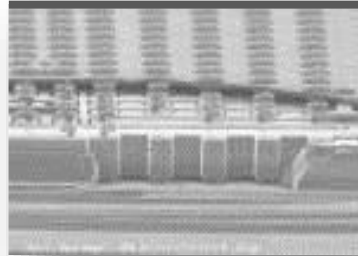
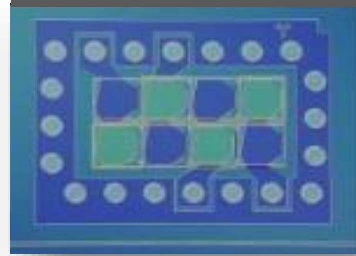
MICROSYSTEMS SECTION

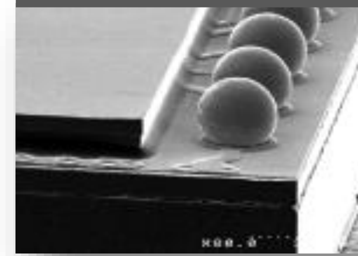
LCMA Lab.
Actuators Components



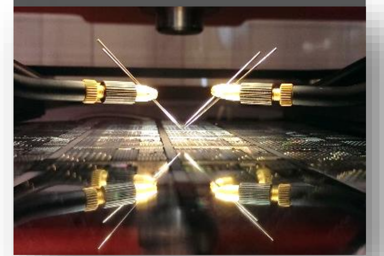
LCMC Lab.
Sensors Components



LCRF Lab.
RF Components

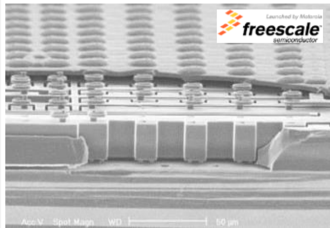


LP3D Lab.
Packaging & 3D



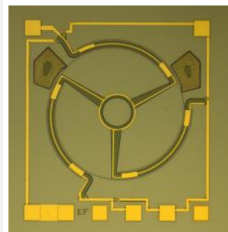
LCFC Lab.
Charact. & Reliability

Components

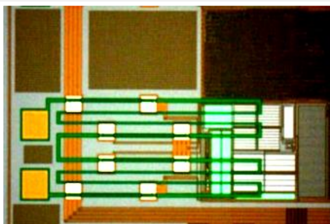


Inertial sensor

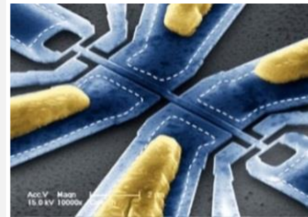
Pressure sensor


Acoustic sensor

Ultrasonic sensor (MUT)


Magnetic sensor (TMR)

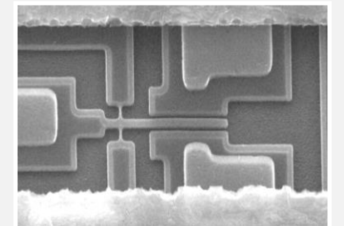
Gas sensor

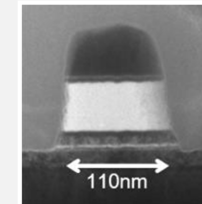

Bio sensor

Force sensor

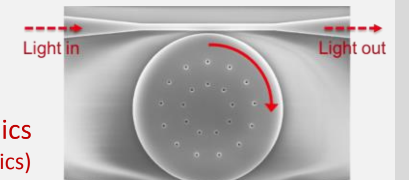
Technologies background

NEMS



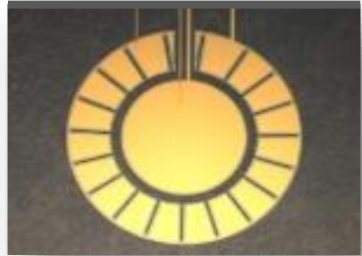


Spintronics

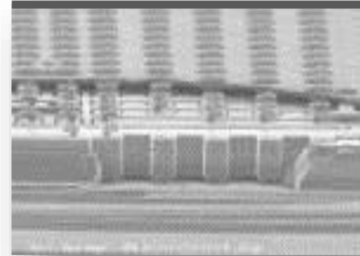


Optomechanics
(NEMS + Photonics)

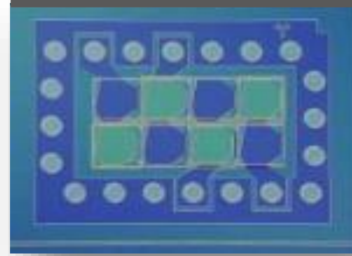
MICROSYSTEMS SECTION



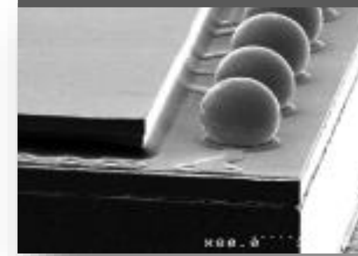
LCMA Lab.
Actuators Components



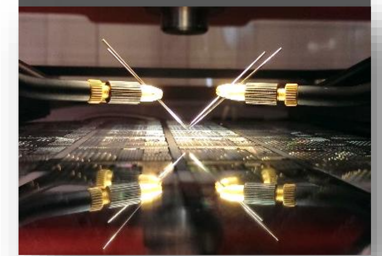
LCMC Lab.
Sensors Components



LCRF Lab.
RF Components

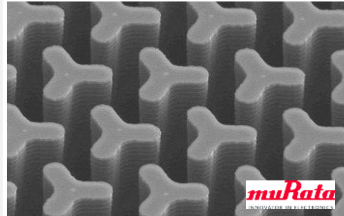


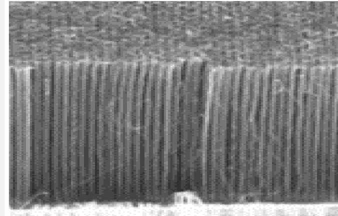
LP3D Lab.
Packaging & 3D



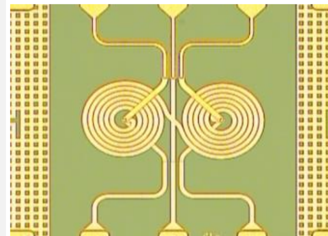
LCFC Lab.
Charact. & Reliability

Passive





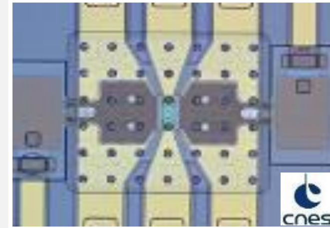
3D High density capacitor

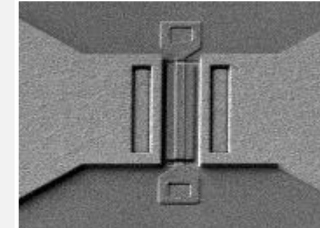


Magnetic inductor

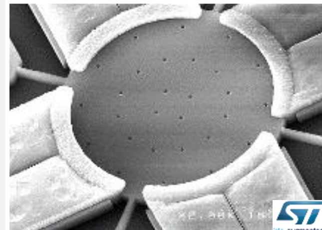
Electro-Magnetic Transformer

RF-MEMS

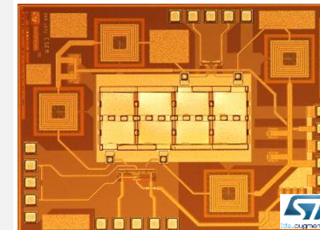




RF micro-switch

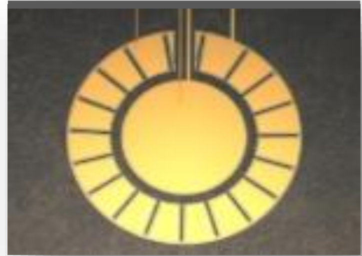


RF resonator



Acoustic Filter

MICROSYSTEMS SECTION



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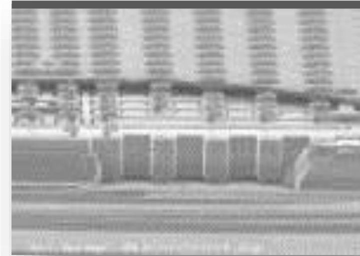
Actuators Components



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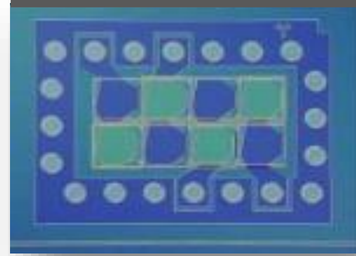
Sensors Components



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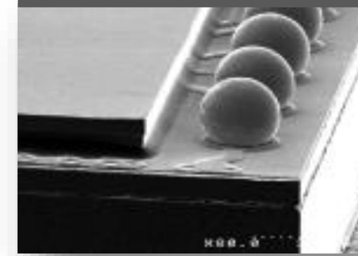
RF Components



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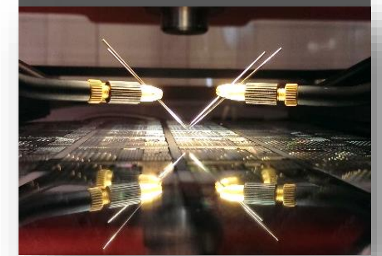
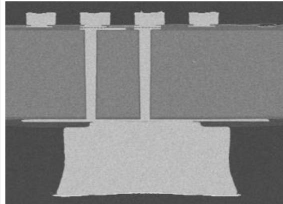


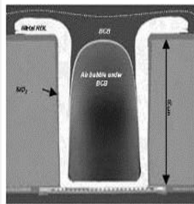
LCFC Lab.
Charact. & Reliability

3D Technology

TSV



TSV-Mid (Cu-filled)



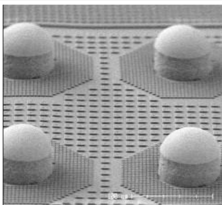
TSV last (Cu-liner)

Wafer process

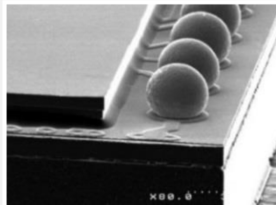
Wafer thinning

Overmolding

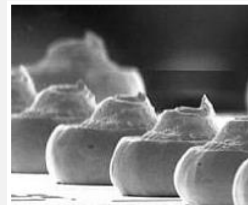
Connecting



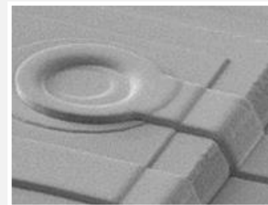
Cu pillars (pitch 40µm)



Bumping - Balling

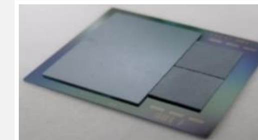


Au stud bumps

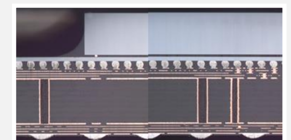


RDL + conformal routing

Si interposers

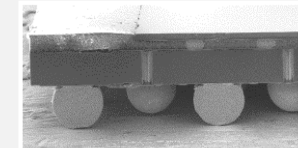


Large interposer



HD interposer

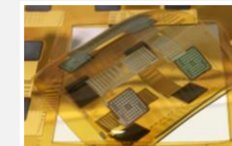
Rebuilt wafer



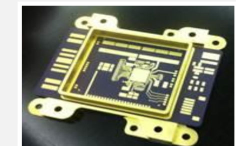
Rebuilt wafer

3D power module

Packaging



Integration in Flex



High temp. SiP

MICROSYSTEMS SECTION

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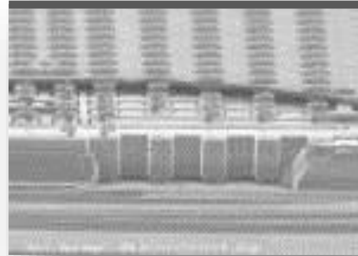

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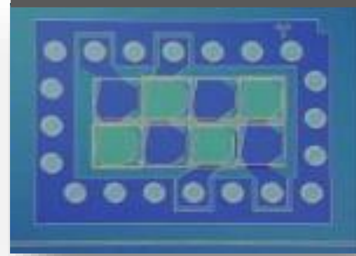

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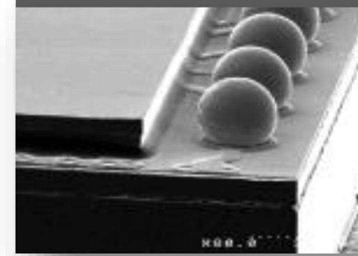

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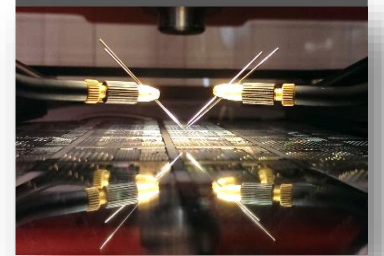


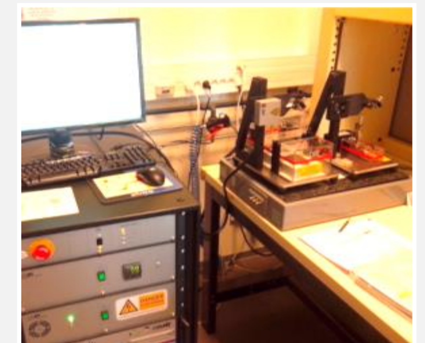
LCFC Lab.
Charact. & Reliability

Special MEMS Characterization tools

Residual Gas Analyzer

Laser vibrometer

200 mm semi-automated vacuum probe system

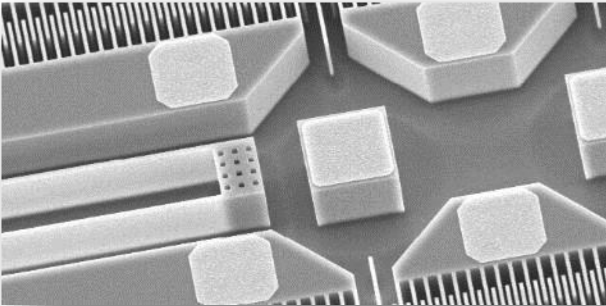


4-Point Bending system

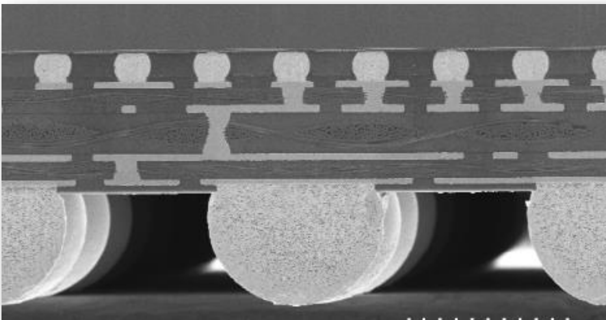
WORLDWIDE INDUSTRIAL MICROSYSTEMS PARTNERSHIPS

CEA-LETI
THE LEADING MEMS R&D LAB WORKING FOR INDUSTRY

- **30+** years experience on MEMS
- **200+** people: **World's Largest MEMS R&D Institute**
- **All 8" and 12"** MEMS technologies in-house



- **330** patents portfolio in the MEMS field
- **30** new patents and **65** publications/year



- **25** ongoing industrial collaborations
- **20+** industrial transfers
- **7** startups creation

OUTLINE

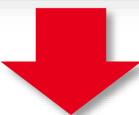
M&NEMS Multi-sensors Platform

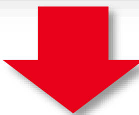
MAIN MARKET TRENDS FOR MEMS SENSORS

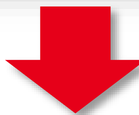
Smart automobile

Mobile

Industry 4.0

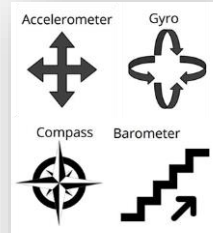






KEY MARKET DRIVERS

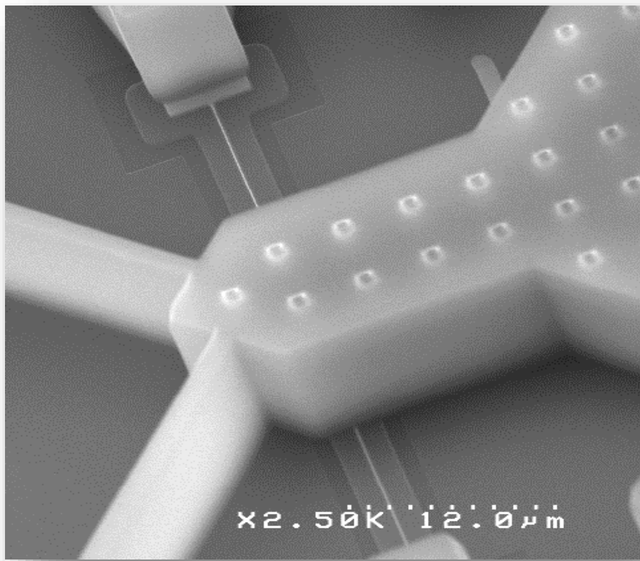
Cost | Performances | Miniaturization | Combo-sensor

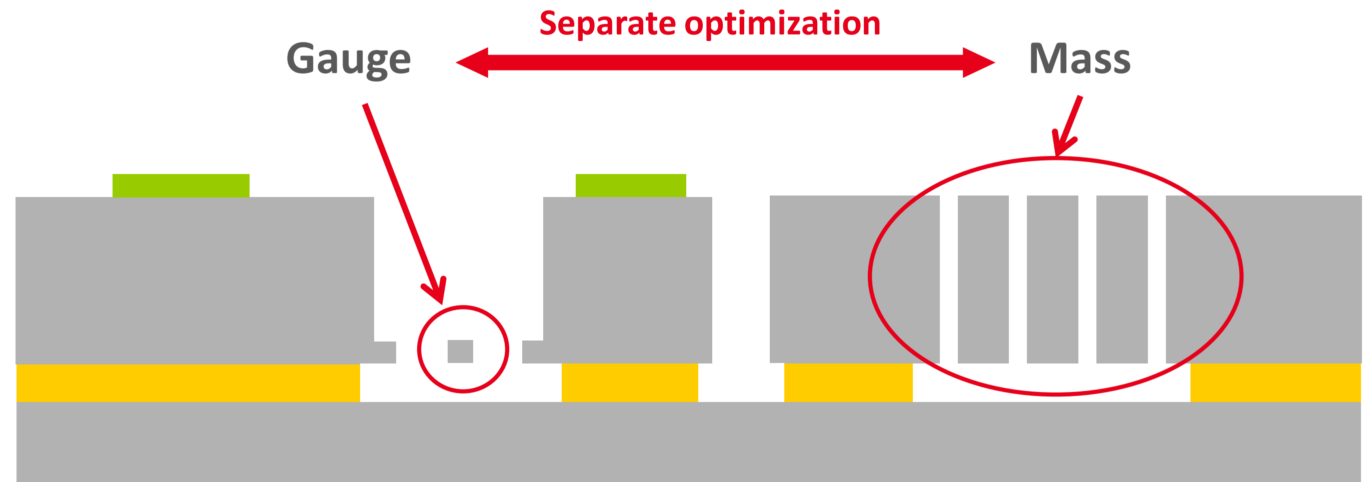


M&NEMS: WORLD-FIRST MULTI-SENSORS PLATFORM

MEMS size mechanical part

Nano-size piezoresistive gauge



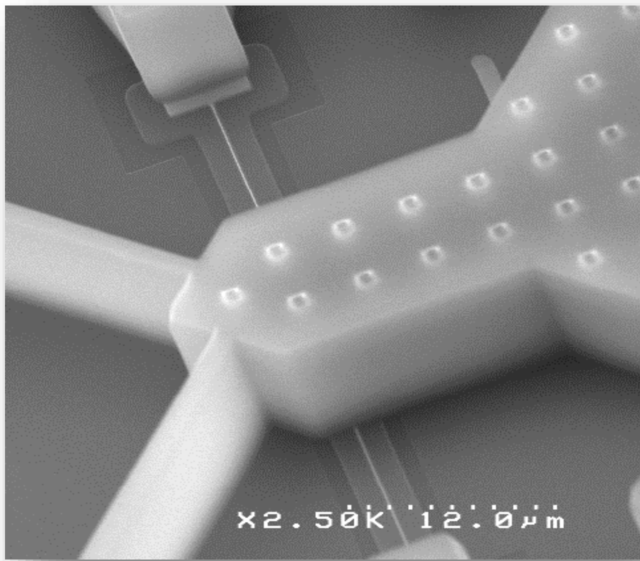


- Ultra-Miniaturized
- Combo sensors
- High performance
- Low power

M&NEMS: WORLD-FIRST MULTI-SENSORS PLATFORM

MEMS size mechanical part

Nano-size piezoresistive gauge



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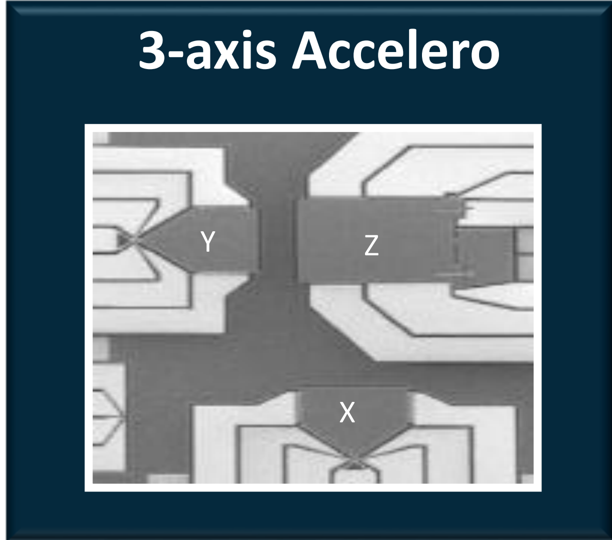
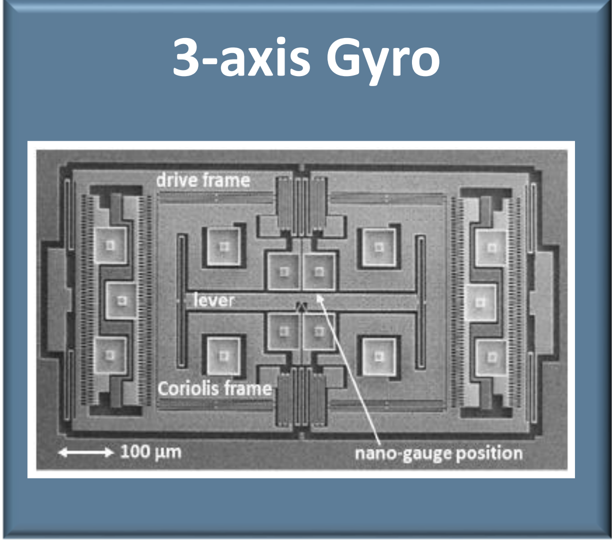
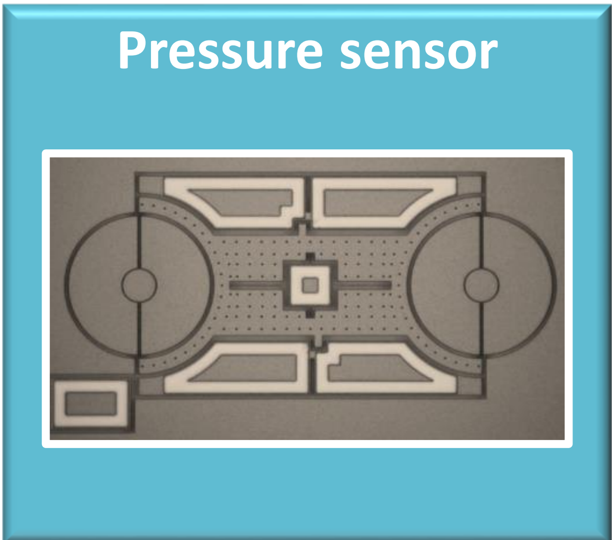
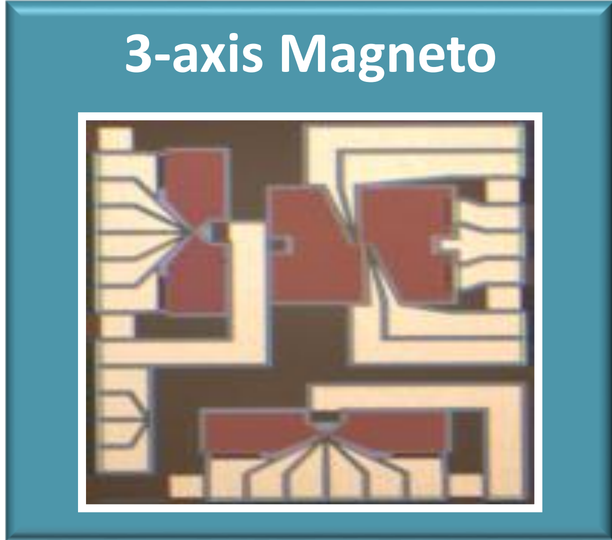






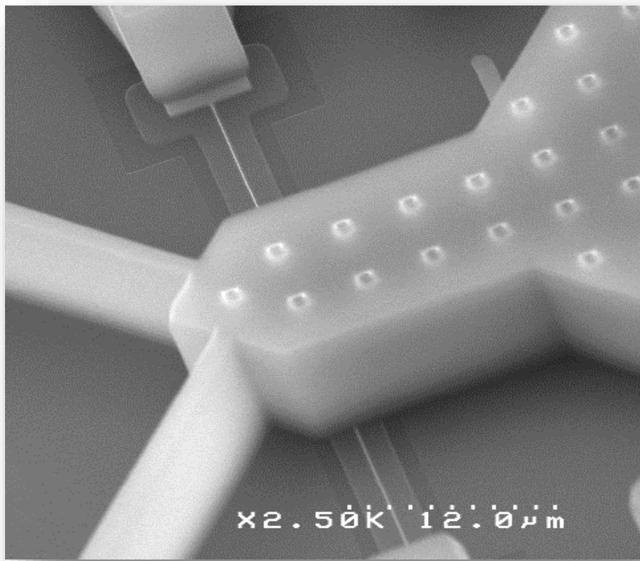


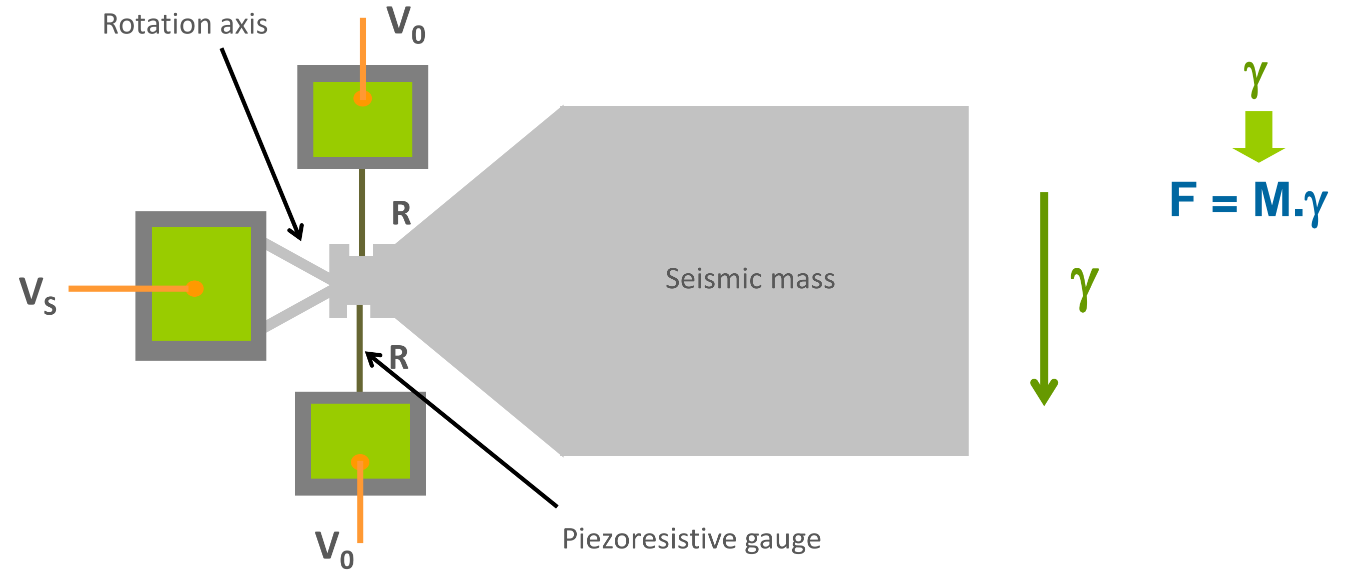
M&NEMS: WORKING PRINCIPLE

MEMS size mechanical part

Separate optimization

Nano-size piezoresistive gauge



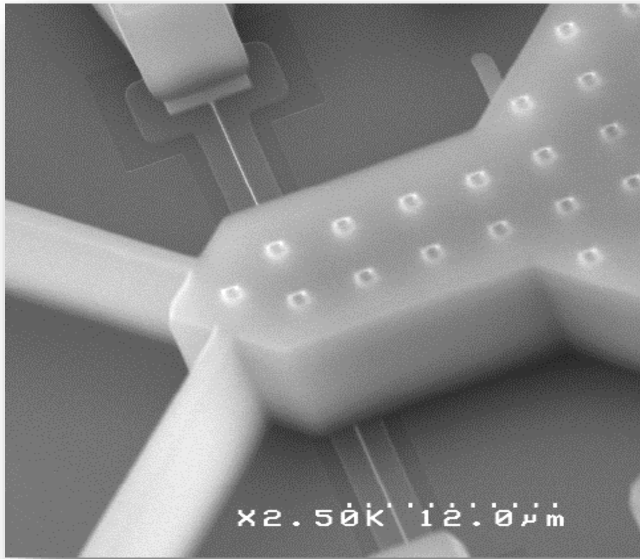


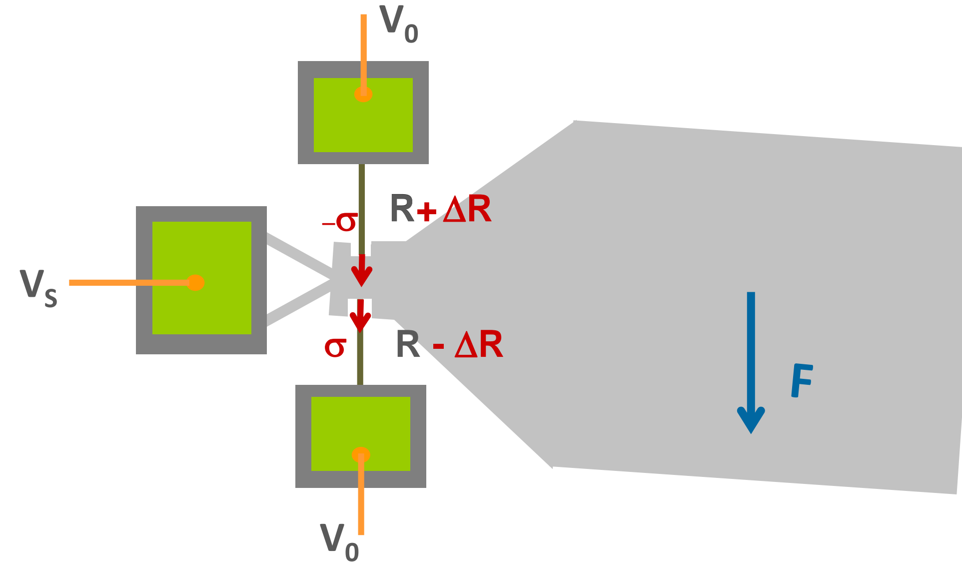
- Ultra-Miniaturized
- High performance
- Combo sensors
- Low power

M&NEMS: WORKING PRINCIPLE

MEMS size mechanical part

Nano-size piezoresistive gauge





γ

$F = M.\gamma$

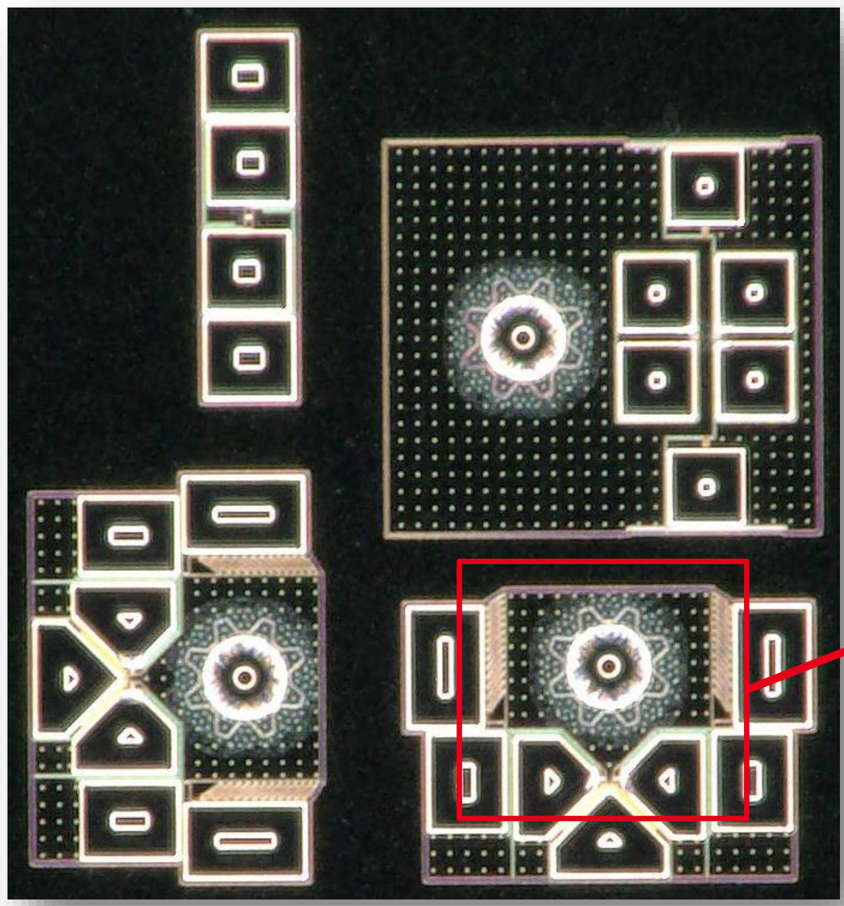
σ

$$\frac{\Delta R}{R} = \pi\sigma$$

- Ultra-Miniaturized
- Combo sensors
- High performance
- Low power

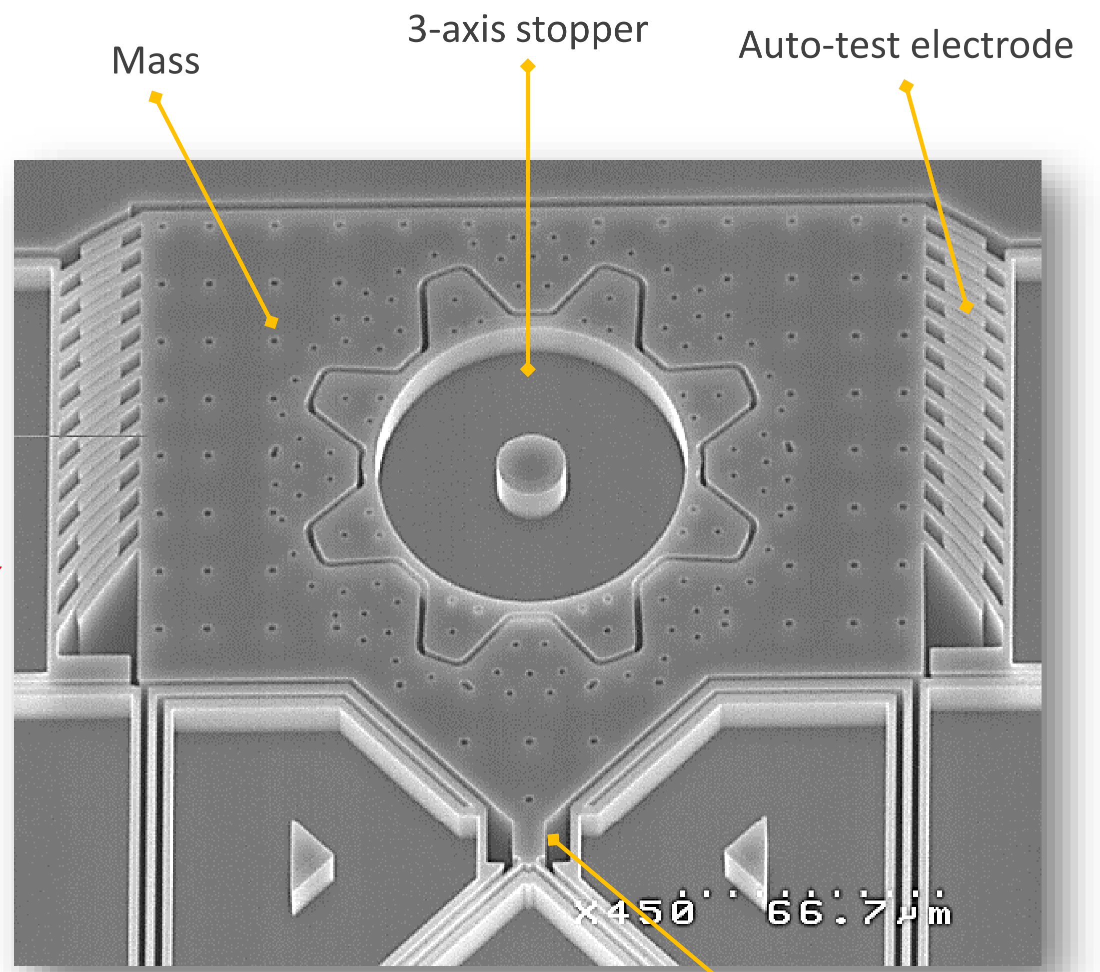
Stress magnification (sensitivity) induced by the use if nano-gauges **x100**

M&NEMS 3-AXIS ACCELEROMETER



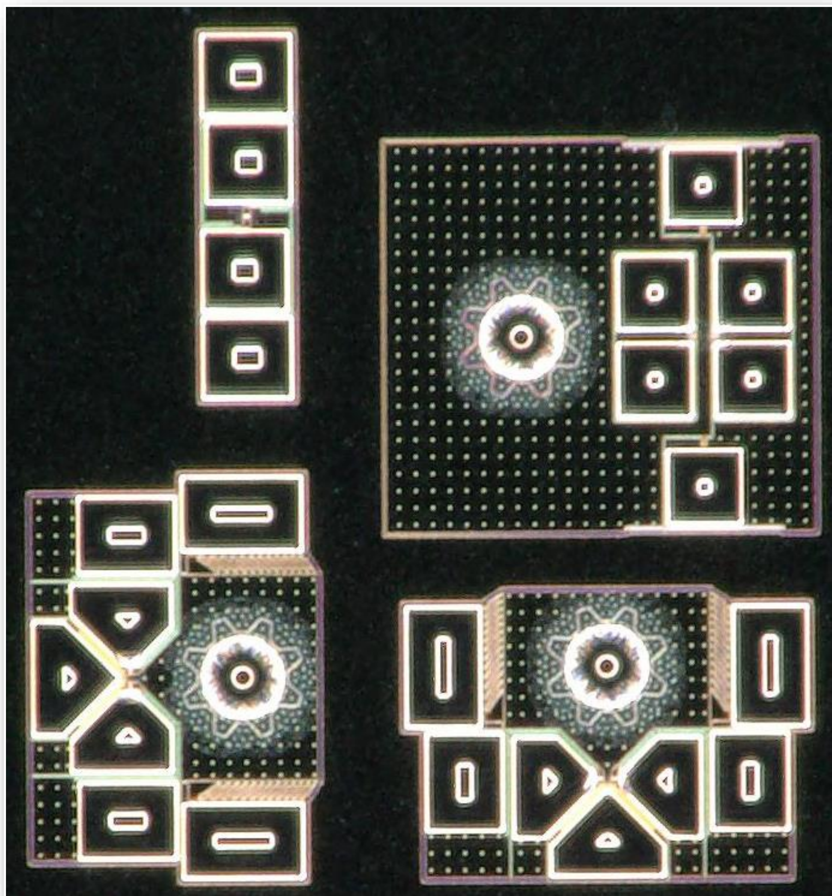
3-axis 20G Accelerometer

(optical microscope view)



(SEM view)

M&NEMS 3-AXIS ACCELEROMETER

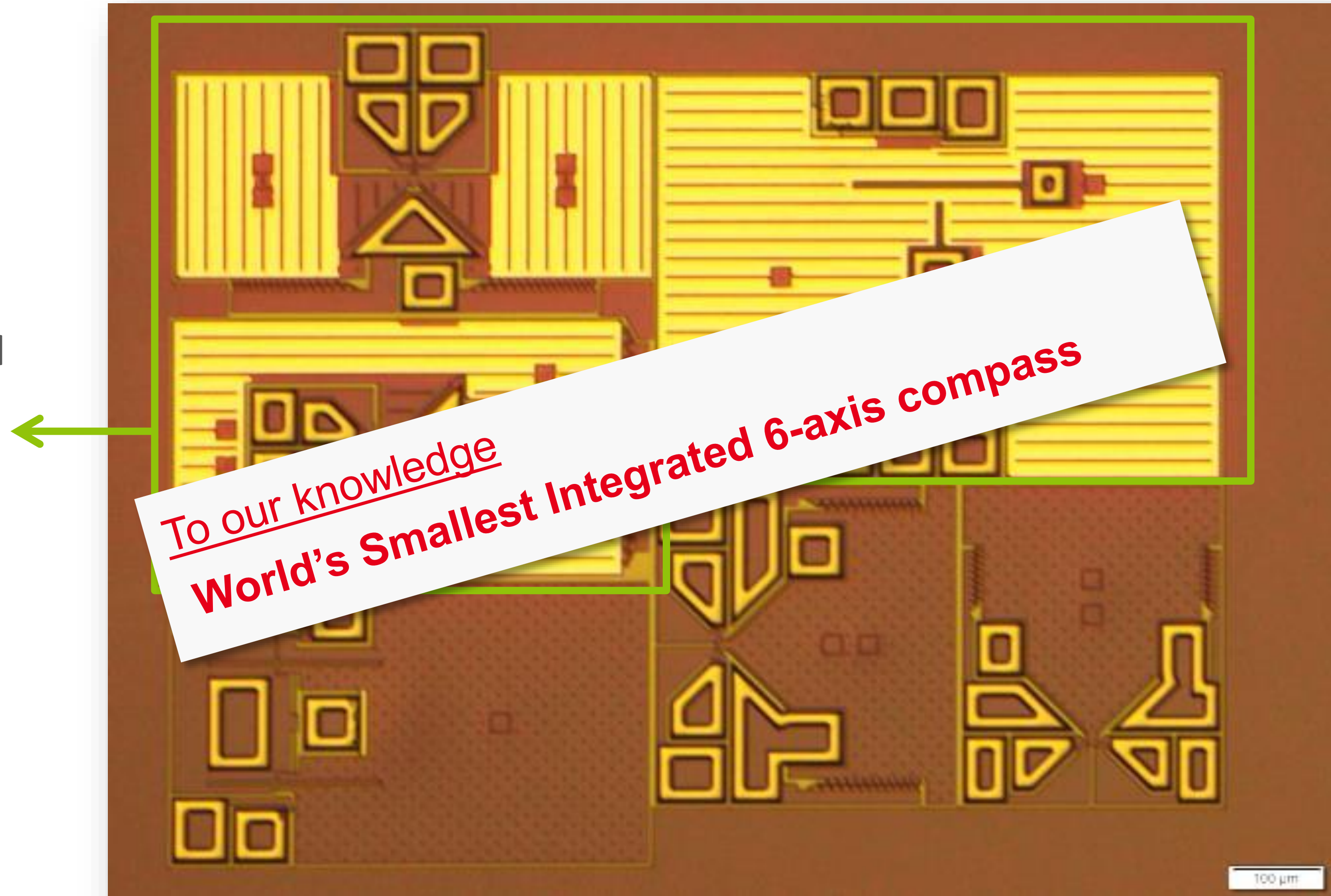


3-axis 20G Accelerometer
(optical microscope view)

- Sensitivity : **7 mV/mA/G**
- Offset variation before and after packaging **< 0.3% of the FS**

M&NEMS 6-AXIS COMPASS

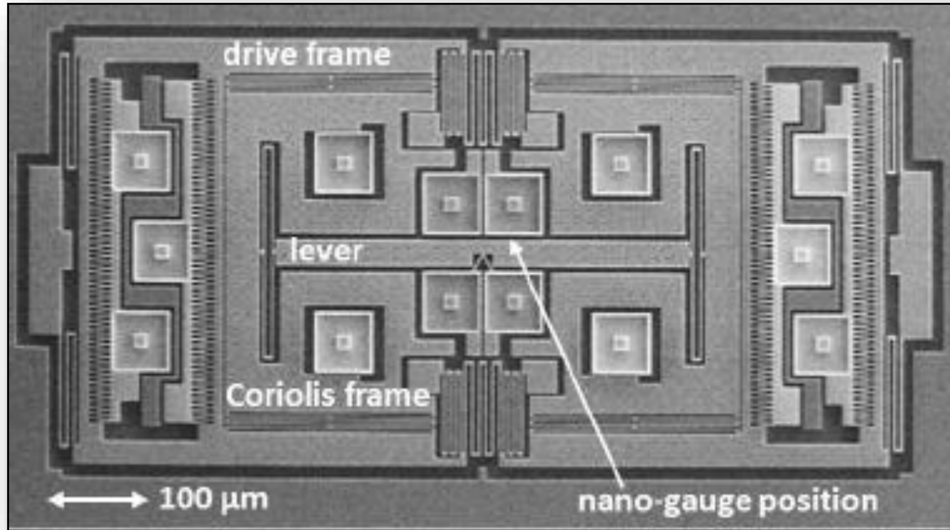
- **Robust to external field**
  (x10 compare to Hall, GMR, TMR)
- **Low power**
- Low noise
- High range



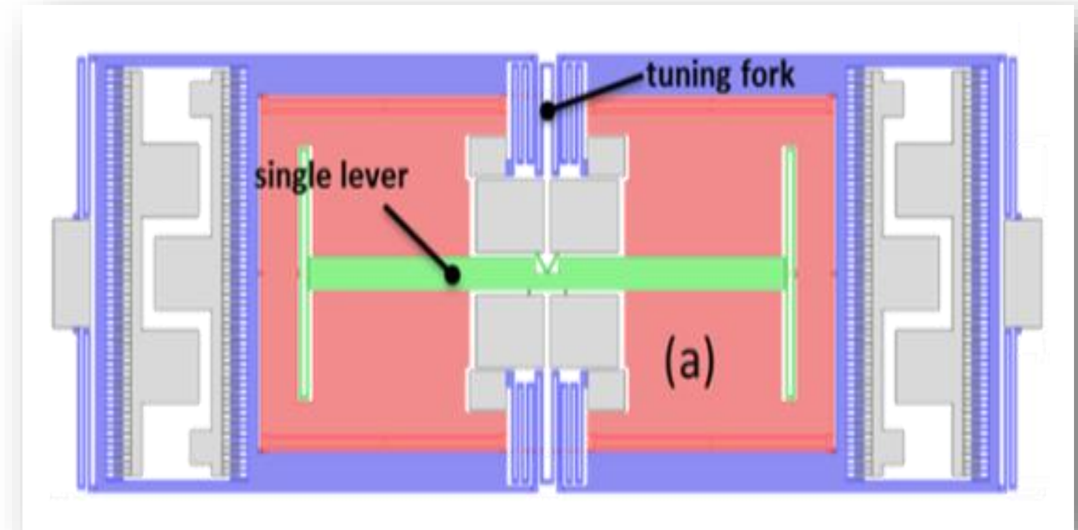
6-axis M&NEMS compass
(mechanical footprint≈1.1mm²)

TDK tronics microsystems

M&NEMS GYROSCOPE



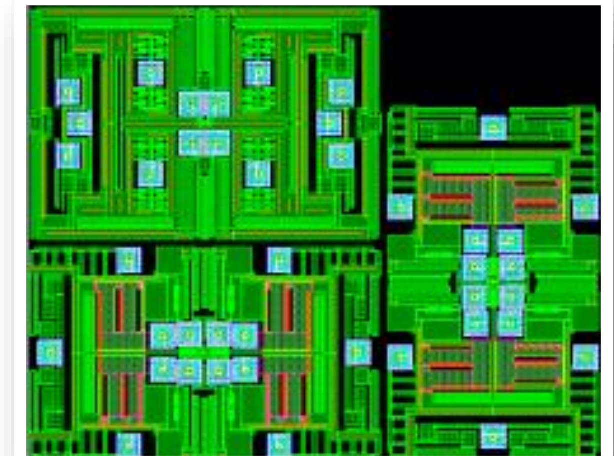
Device area: 800µm x 450µm (0.36mm²)



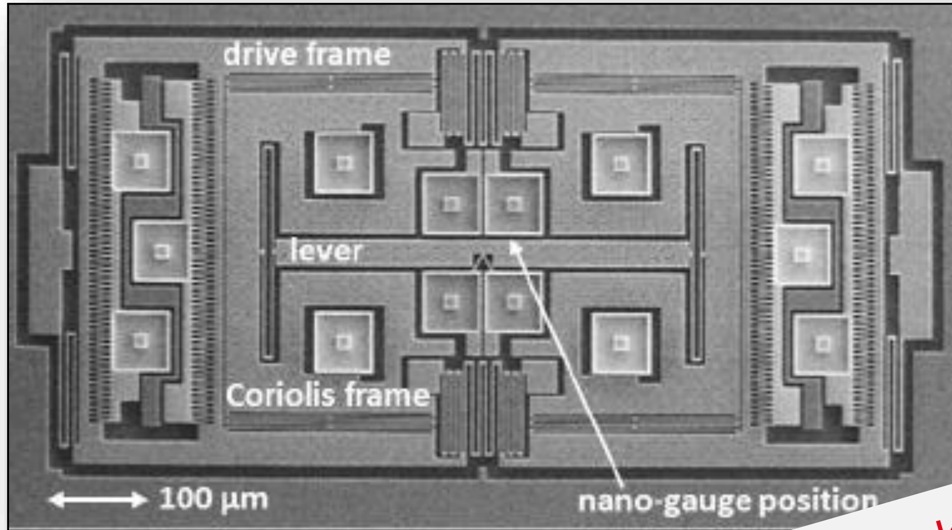
Nano-Gauge vs. Capacitive

- **Low impedance detection**
  - ⇒ No electrical coupling between drive and sense
  - ⇒ Not sensitive to parasitic capacitance
- **Force measurement vs. displacement**
  - ⇒ Well adapted for high frequency gyroscope
- **Linear detection**
  - ⇒ Less sensitive to vibration environment

3-axis consumer gyro overall area: 1.4 mm x 1.4 mm



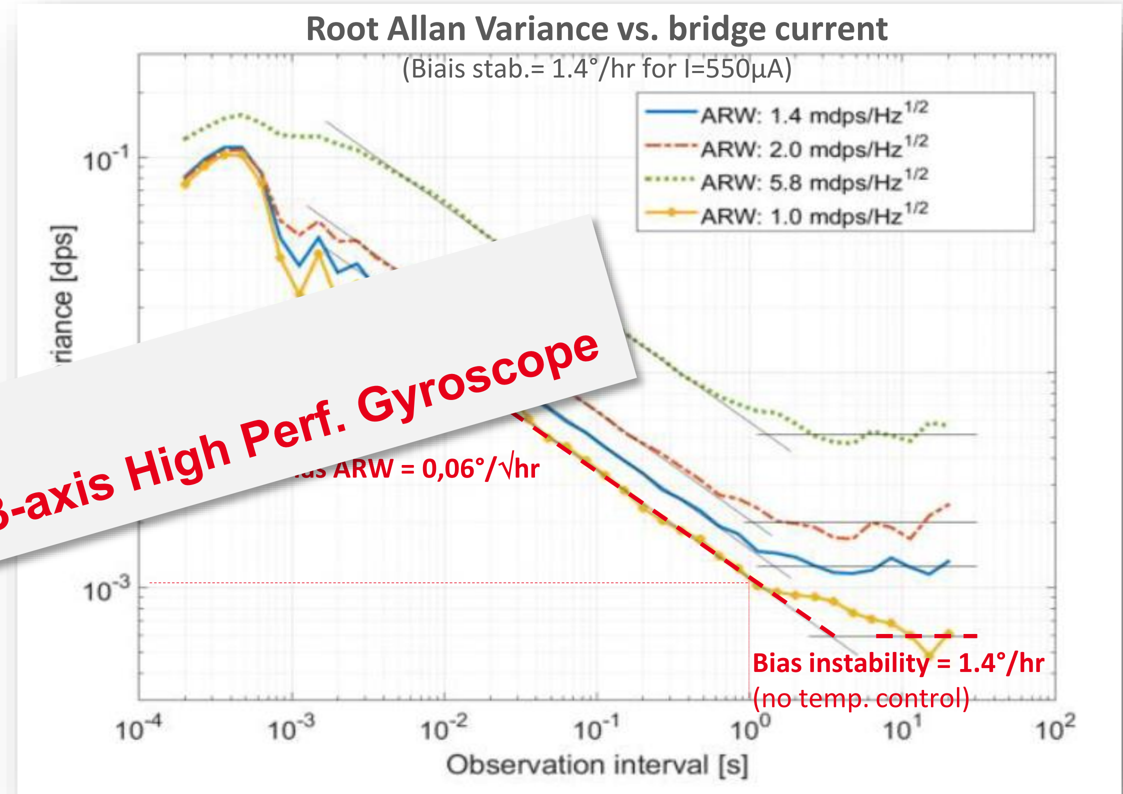
M&NEMS GYROSCOPE



Device area: 800µm x 450µm (0.36mm

To our knowledge

World's Smallest 3-axis High Perf. Gyroscope



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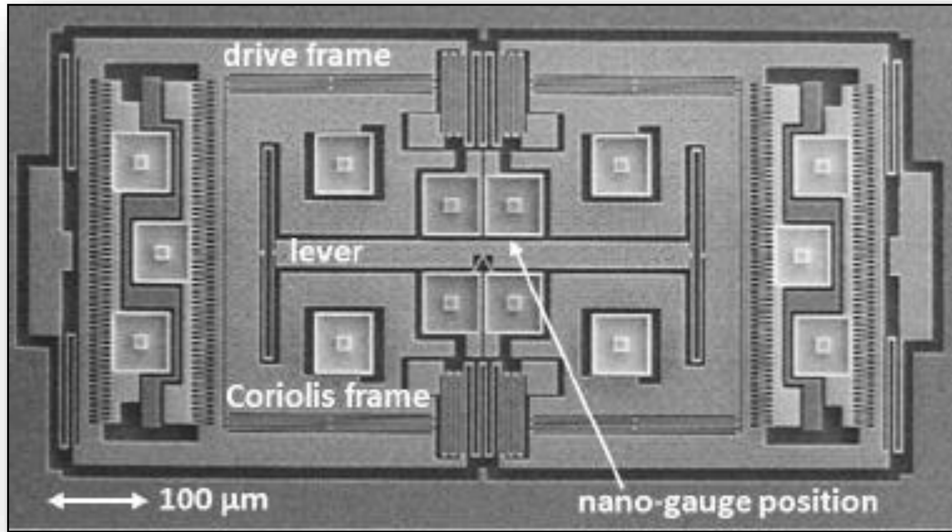
- Bias Instability = **1.4°/hr**
- ARW = **0.06°/√hr**
- 3-Axis Gyro in **2mm²**

leti ceatech

M&NEMS GYROSCOPE

POLITECNICO DI MILANO



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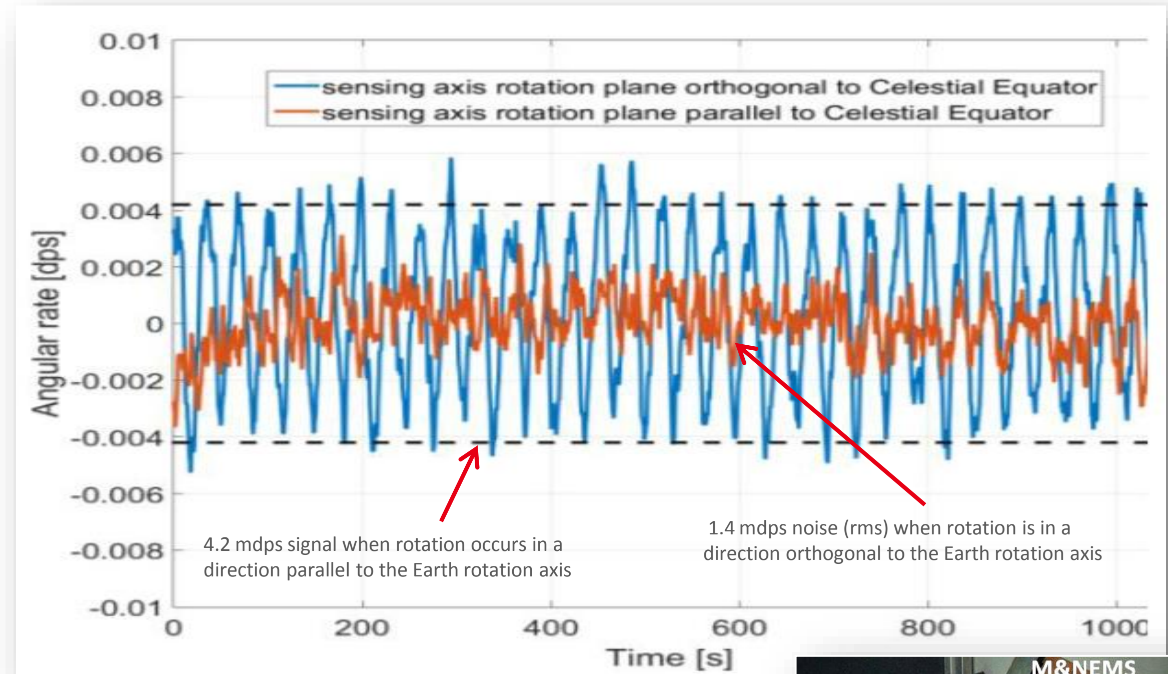

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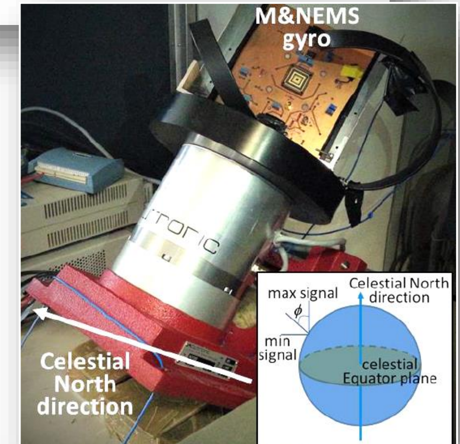
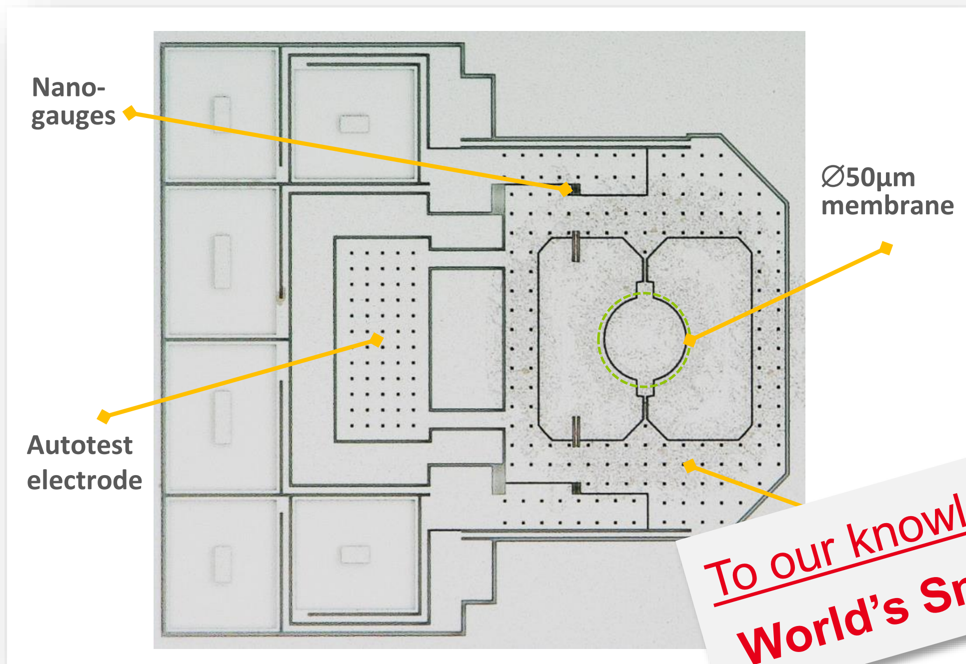
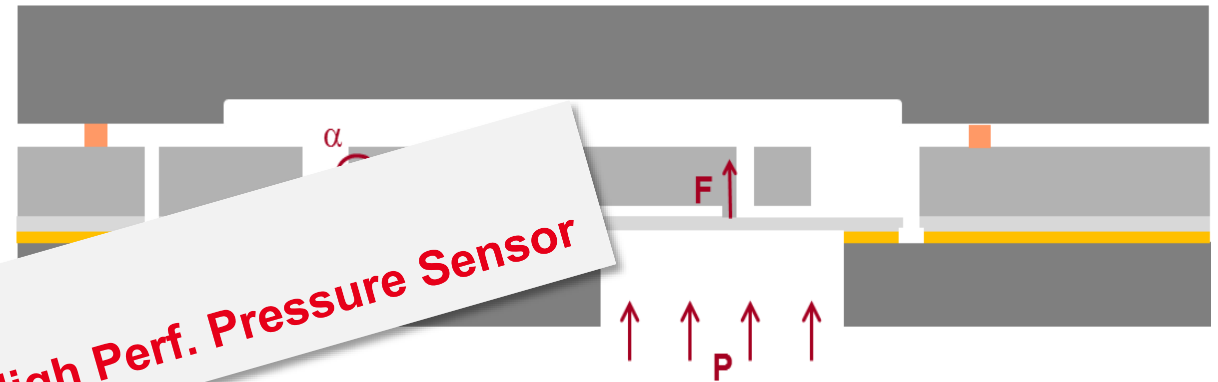
Earth Rotation Measurement



M&NEMS PRESSURE SENSOR





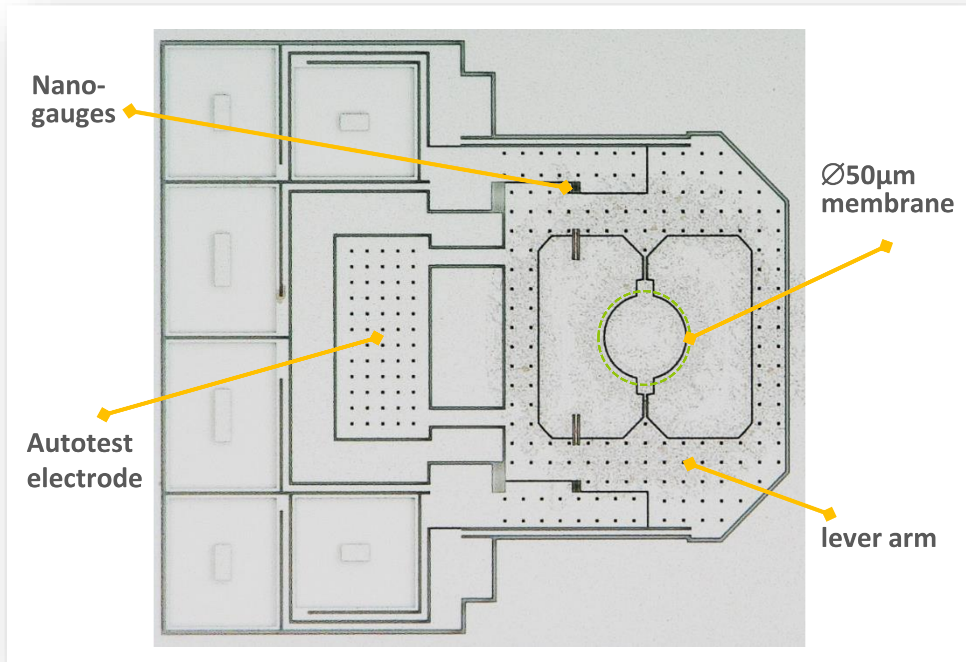
To our knowledge
World's Smallest High Perf. Pressure Sensor

- **High linearity**
- Gauge **protected from external environment**
- **Over-pressure protection** (stoppers)
- Vibration insensitive (balanced structure)
- Compatible with high temperature application

Barometric pressure sensor

- Range : **1.4 bar**
- Resolution : **1.2 Pa**
- Die size : **0.45 mm²** (Mechanical footprint : **0,12mm²**)

M&NEMS PRESSURE SENSOR



- **High linearity**
- Gauge **protected from external environment**
- **Over-pressure protection** (stoppers)
- Vibration insensitive (balanced structure)
- Compatible with high temperature application

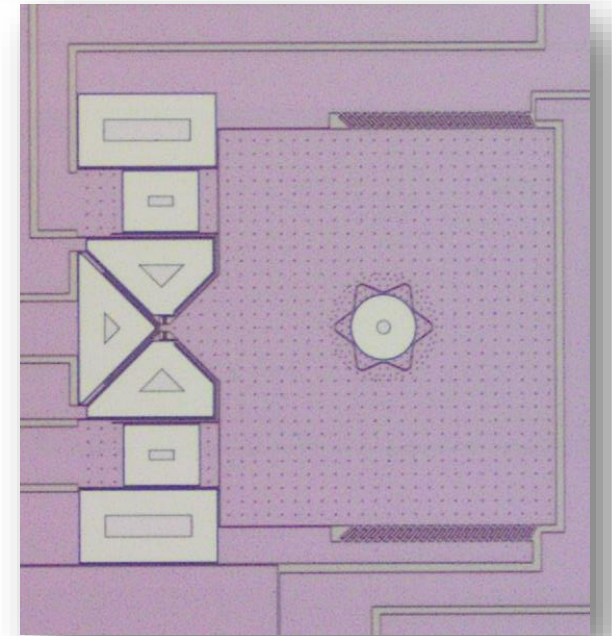
Thermal Cycling [-20°C / +125°C]

- TCO **< 1 Pa/°C**
- Non-Linearity **< 0.2% FS**
- TCS **< 10ppm/°C**
- Accuracy **< 100 Pa**

Results are obtained after only 1 cycle

M&NEMS – CONCLUSIONS

- **World-first high performances multi-sensors platform** demonstrated
- **Reliability for the automotive field** is addressed with very promising results (thermal behavior, shock, vibration…)
- **Further improvements are still to be explored** (design, technology, packaging…)
- **Under development :**
  - High-end gyroscope (0.1°/h)
  - Resonant detection for high-end 3-axis accelerometer, magnetometer and pressure sensor



Thank you for your attention

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