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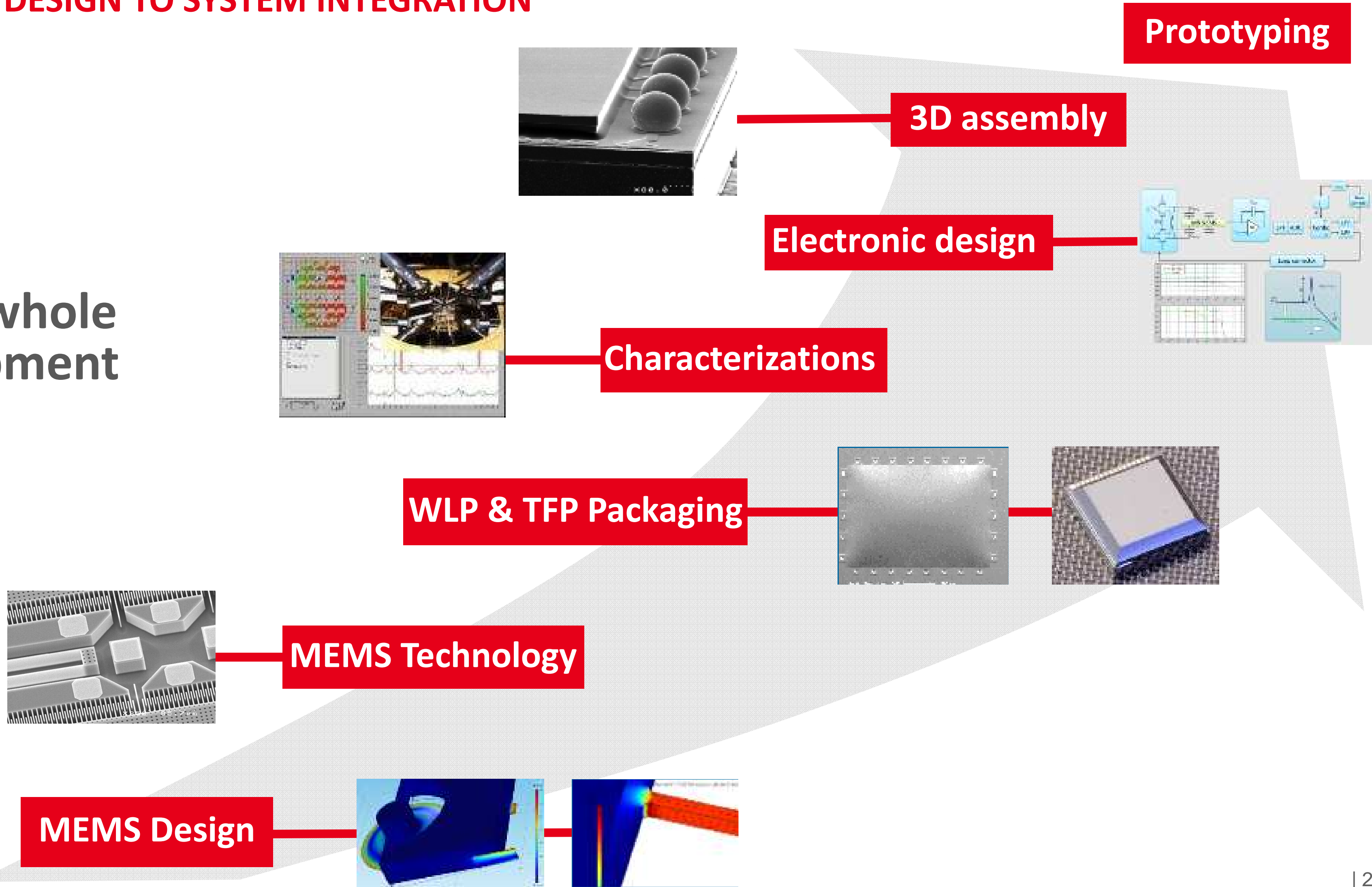
LETI MEMS ACTIVITIES OVERVIEW

Leti MEMS Workshop | June 20, 2017

A ONE-STOP MEMS R&D SOLUTION

FROM MEMS DESIGN TO SYSTEM INTEGRATION

LETI covers the whole chain of development



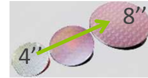
30+ YEARS BACKGROUND ON MEMS SENSORS

Key dates

1984
Word 1st "Comb drive" accelero patent

1996
Spinoff

2007
Caltech Alliance on NEMS

2005
Word 1st MEMS 200 cleanroom


2011
Spinoff

2011
Spinoff

2013
Spinoff

2014
Startup

2015
Word 1st 300mm MEMS wafer

80s | 90s | 00s | 10s

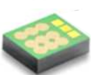
industrial transfers

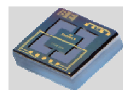
1980
Weight sensor
Terraillon

1981
Hygrometer

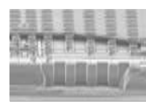
1987
Quartz accelero
THALES

1996
Geophone

Pressure

Accelero

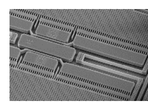
1998
High perf. pressure
THALES


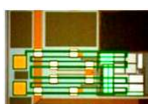
2005
Accelerometer

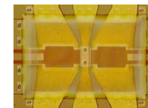


2008
TSV for imager

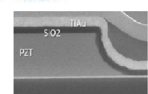
2011
Inertial platform



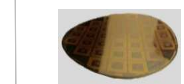
2012
Above-IC GMR sensor
CONFIDENTIAL (US)


2013
Thin Film pack.
CONFIDENTIAL (Ger)


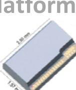
2013
PZT Solgel

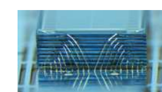


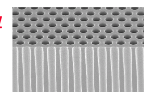
2013
300mm HD interposer

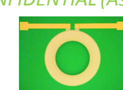
2013
100µm MEMS wafer thinning
CONFIDENTIAL (JP)


2014
M&NEMS platform

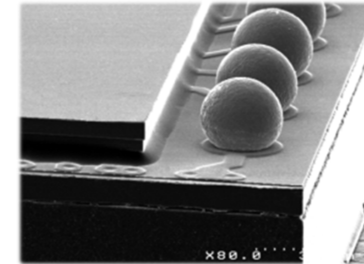


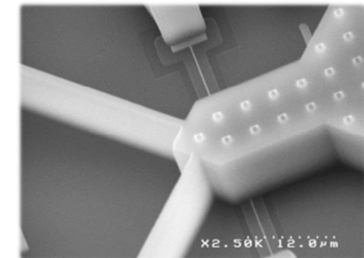
2016
Capacitance stacking
muRata


2017
Nanoporous capactor
muRata


2017
PZT Solgel
CONFIDENTIAL (Asia)


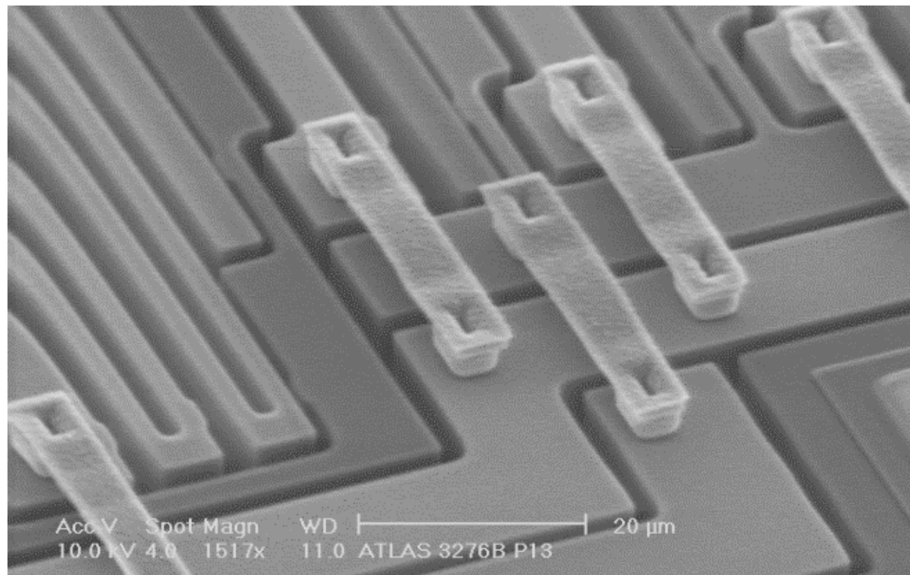
Highlights on Leti’s MEMS realizations



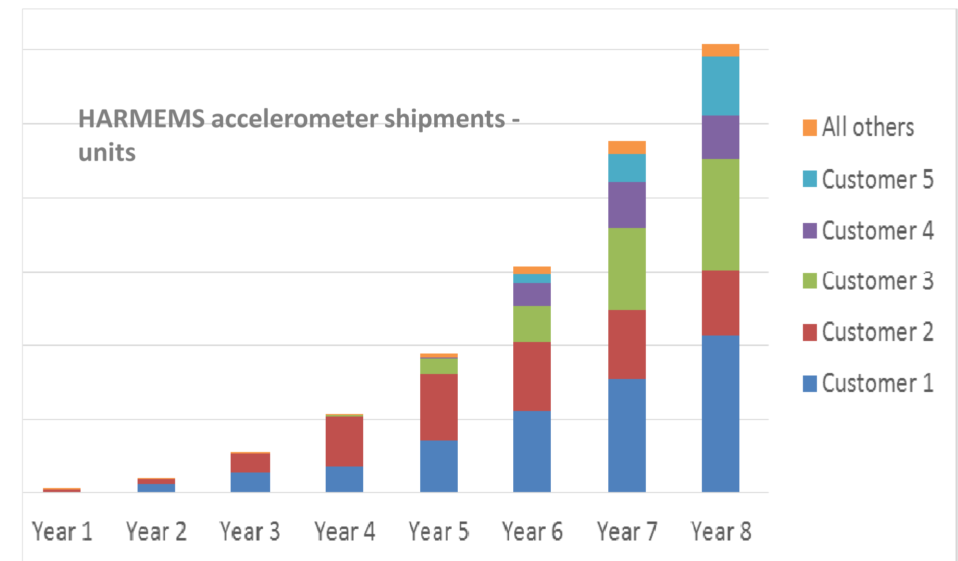


KEY ACCOMPLISHMENTS

Example of sensor technology transfer for the Automobile Market

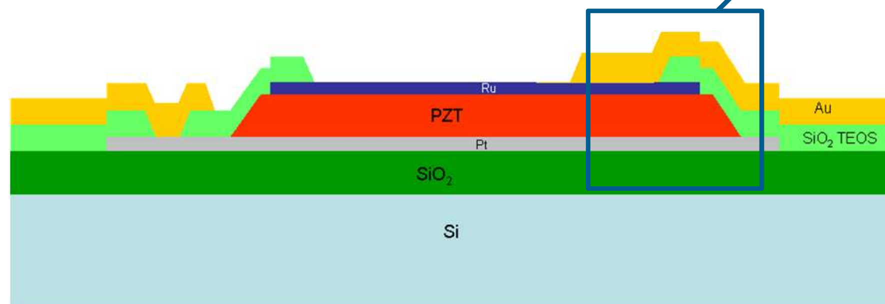


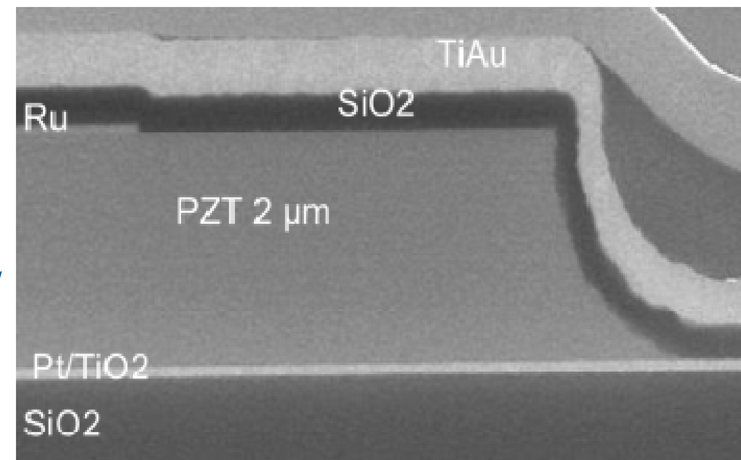
- Development and transfer of the HARMEMS technology to Freescale
- HARMEMS accelerometer shipments: **350+ million units**



KEY ACCOMPLISHMENTS

Example of technology transfer to industrial company





- Transfer to ST of a **Generic PZT stack** for MEMS sensors and actuators
- Now in production

KEY ACCOMPLISHMENTS

LETI ANNOUNCES THE WORLD'S FIRST 300mm MEMS WAFER (2015)

Demonstration done on M&NEMS accelerometers

- **70,000** 3-axis accelerometers per wafer

Moving to 300mm allows

- **Cost reduction** of at least 30% compare to a 200mm technology
- **Co-integration with advanced CMOS nodes** (.13µm and beyond)
- **Access to the existing 300mm TSV technology**

KEY ACCOMPLISHMENTS

LETI startups in Microsystems in last 5 years

Multi-gas analyzers coupling gas chromatography and NEMS

Piezo-MEMS variable focus lens for mobile phone camera

MEMS-based NDIR sensor for air quality monitoring

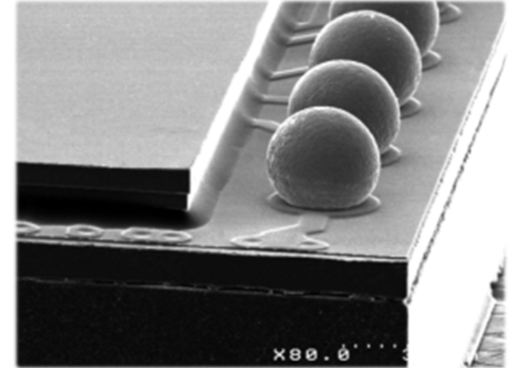
Innovative piezoelectric energy harvesting

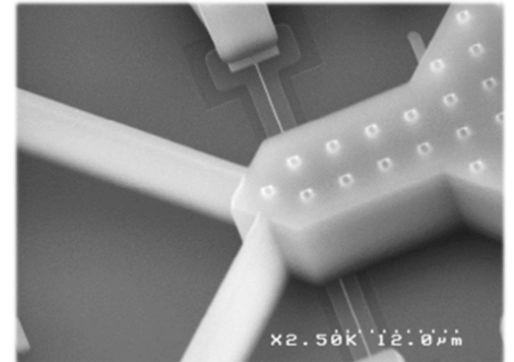
Integration of MEMS and electronic devices into textiles

MEMS and QCL-based photo-acoustic gas analyzer

Technological Differentiation

M&NEMS Platform





MEMS ISSUES FOR NEW MARKETS

Issues

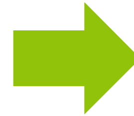
Strong cost pressure

- Miniaturization
- Process Sharing

Growing use of Combo sensors

MEMS components

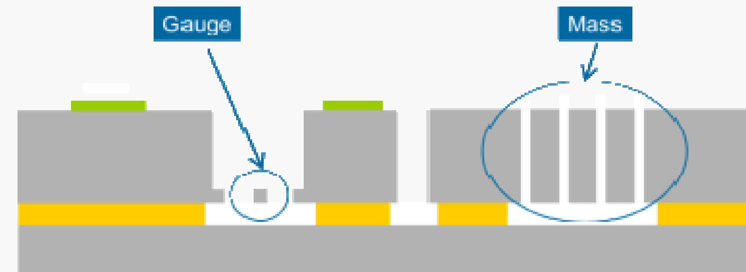
- Accelerometer
- Gyroscope
- Magnetometer
- Pressure sensor
- Microphone
- …



LETI's Solution

Goal : "Generic", efficient and reliable MEMS platform

M&NEMS Platform

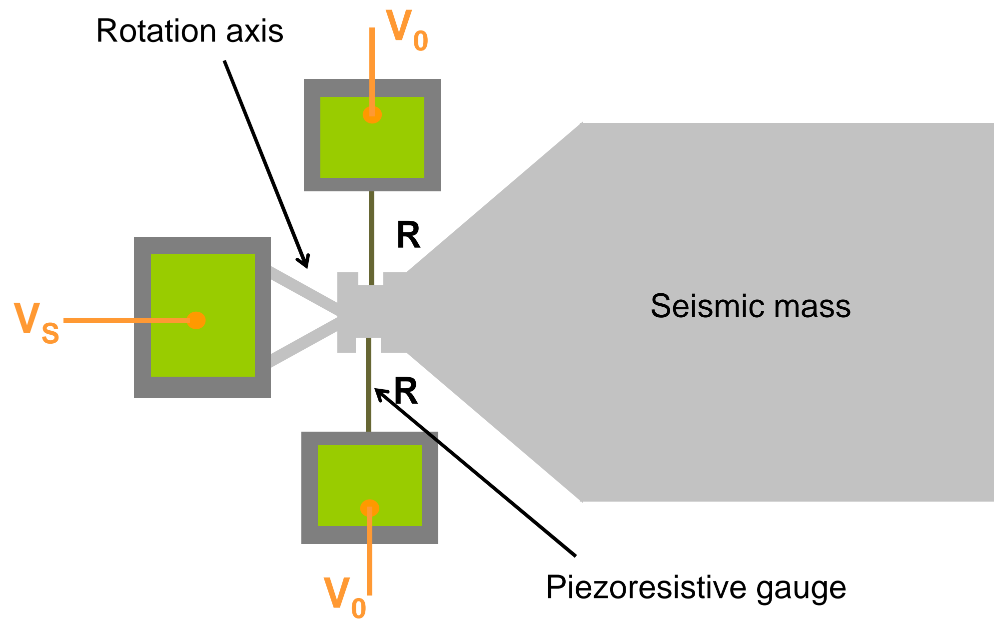


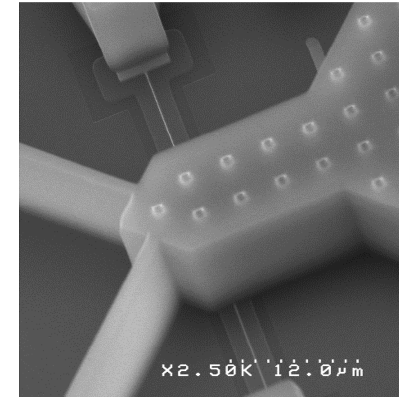
MEMS size mechanical part

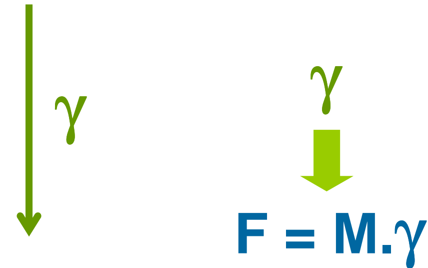
Separate optimization

Nano-size piezoresistive gauge

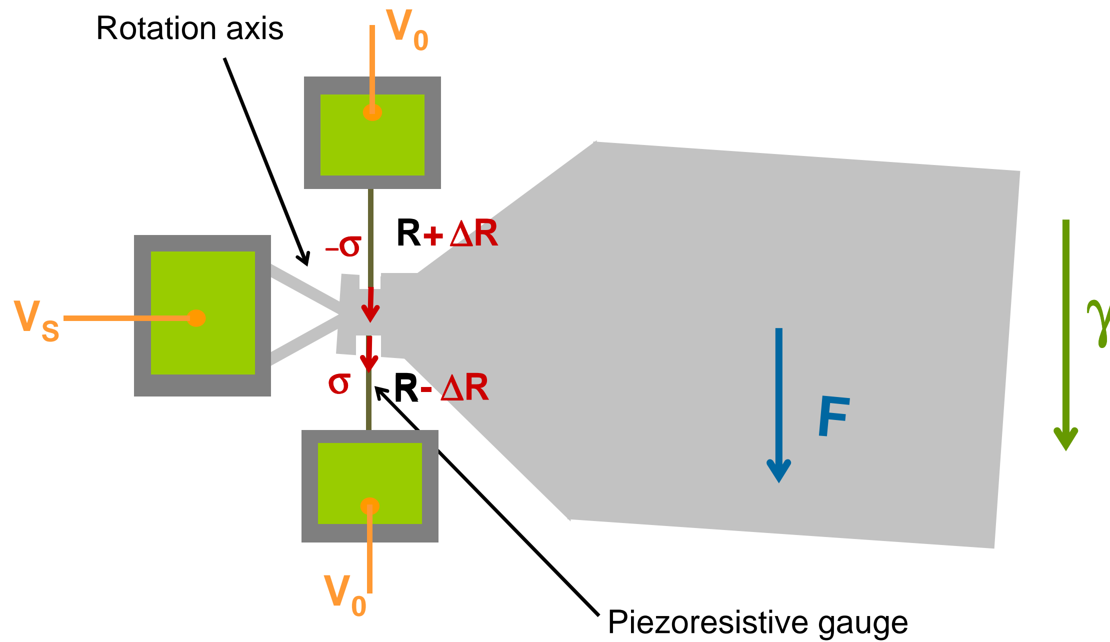
M&NEMS WORKING PRINCIPLE

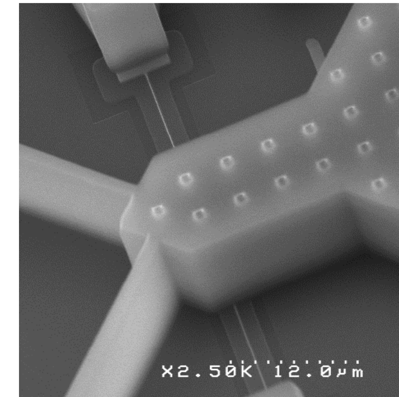






M&NEMS WORKING PRINCIPLE





γ

⇓

F = M.γ

⇓

σ

⇓

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

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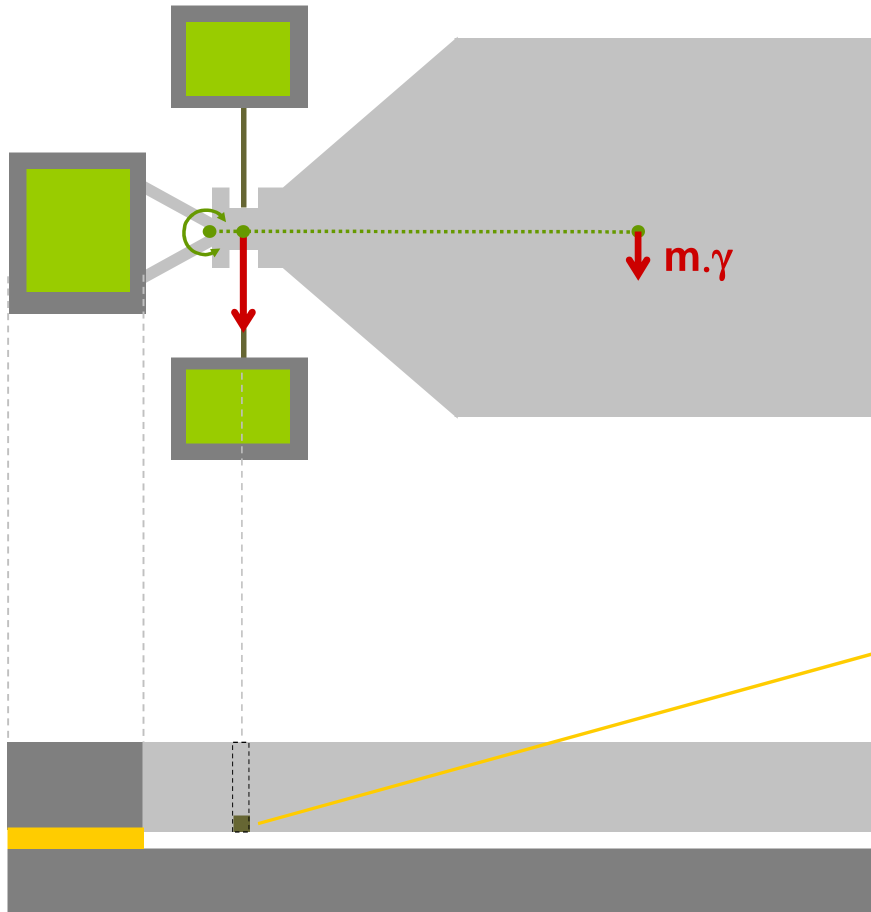
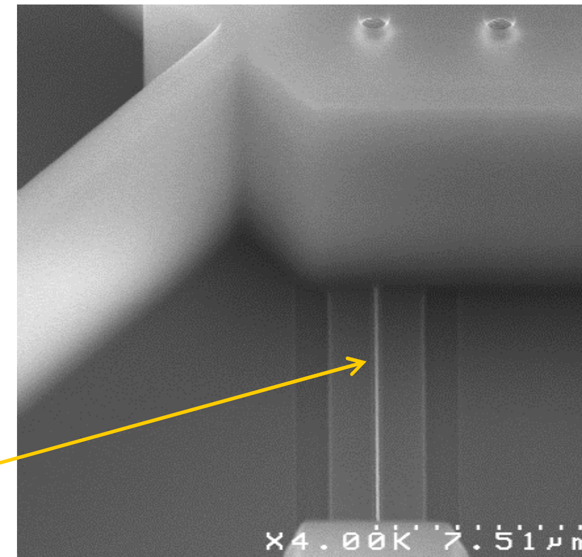
M&NEMS WORKING PRINCIPLE



Design lever effect

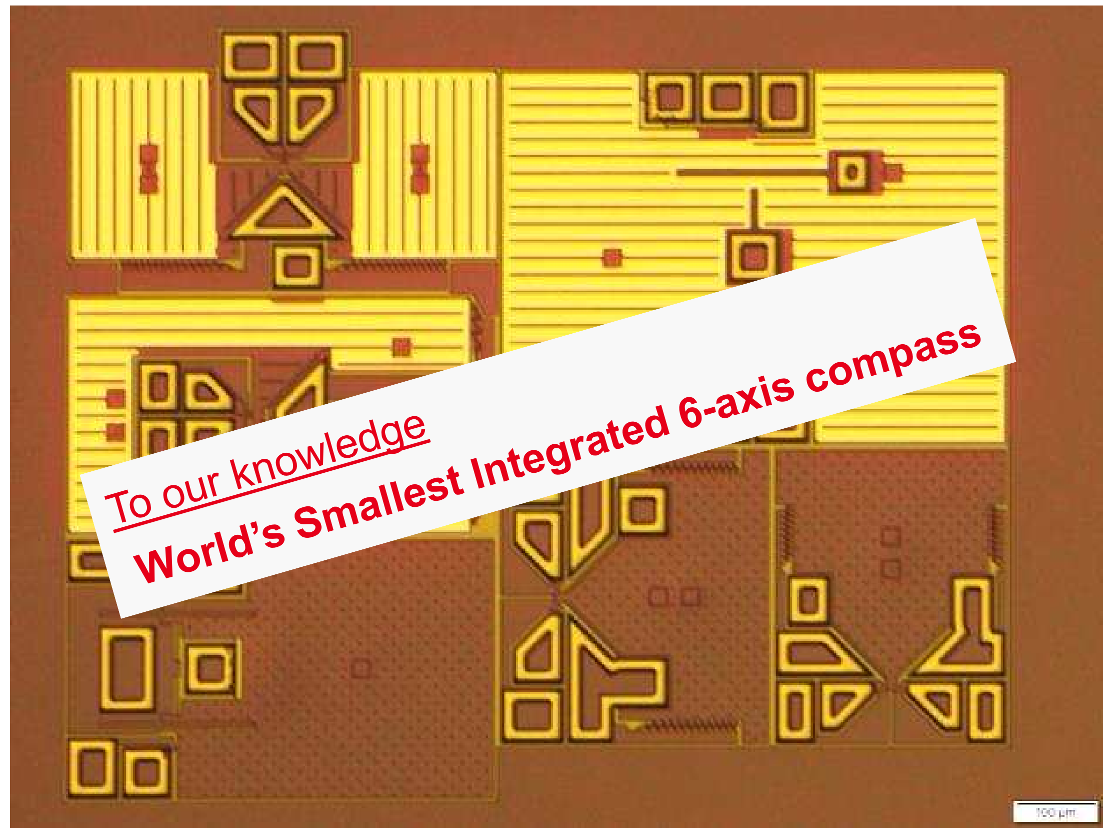
Stress magnification : x30



Influence of 2 different thicknesses

Stress magnification : x100

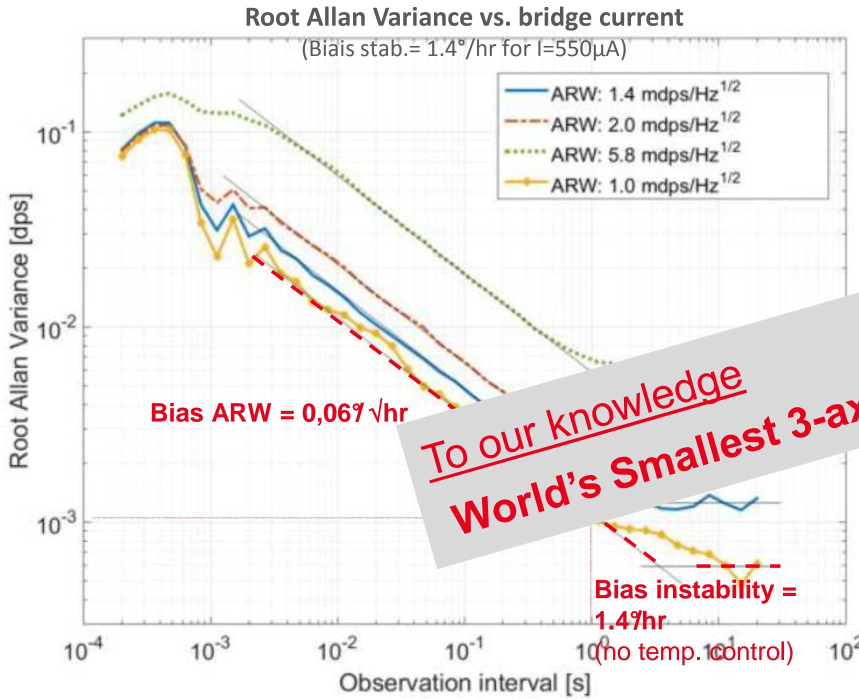
M&NEMS 6-AXIS COMPASS



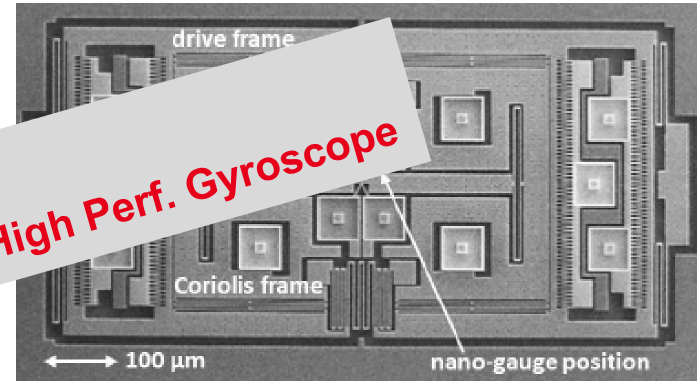
6-axis M&NEMS compass

(mechanical footprint≈1,1mm²)

M&NEMS GYROSCOPE



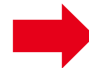
POLITECNICO DI MILANO



Device area: 800µm x 450µm (0.36mm²)

To our knowledge
World's Smallest 3-axis High Perf. Gyroscope

- **Bias instability = 1.4°/hr**
- **3-Axis Gyro in 2mm²**
- **Open-loop detection**
- **Q-factor : 3,000** (4 mbar WLP)



Possible further improvements by :
- **Lowering package pressure (4 → < 1mbar)**
- **Increasing MEMS thickness (20 → 60µm)**
- **…**

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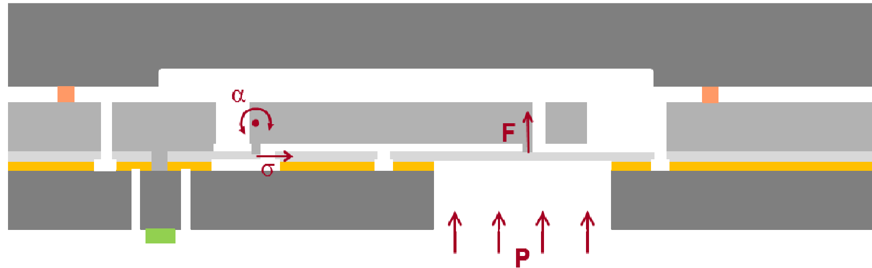
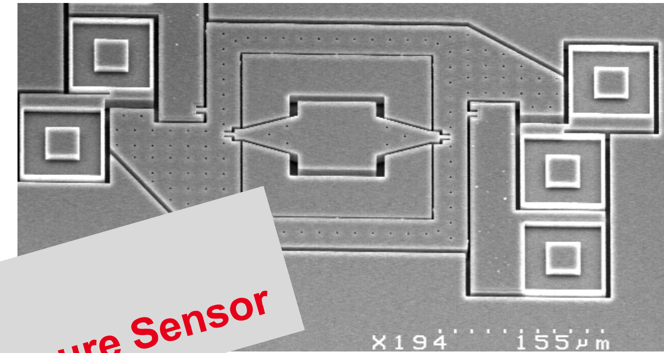
M&NEMS PRESSURE SENSOR



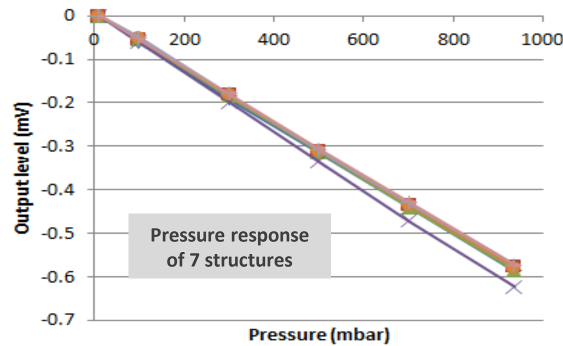


To our knowledge

World's Smallest High Perf. Pressure Sensor

First design (consumer)

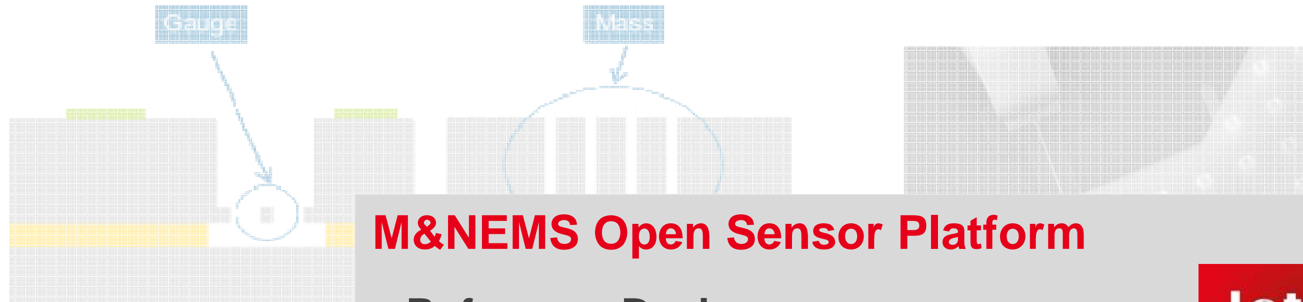
- Range : **> 1.4 bar**
- Resolution : **2 Pa**
- Die size : **0,45 mm²** (Mechanical footprint : **0,12mm²**)
- Non-linearity **< 0.15% FS**



Main Interests

- Small footprint
- **High linearity**
- **Reliability**:
  - ✓ Protected gauge from external environment
  - ✓ Over-pressure protection (stops)
- **Auto-test electrode**
- 2 configurations: **Absolute / Differential**
- Co-integration with other sensors
- Compatible with high temperature application

M&NEMS: WORLD-FIRST MULTI-SENSORS PLATFORM



MEMS size r

Nano-size pie

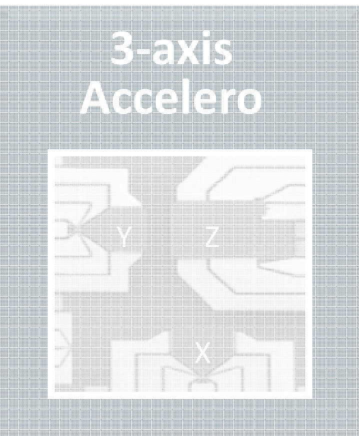
- Innovative Approach
  (20+ patents)
- Ultra-Miniaturized sensors
  x: 6-axis combo in 4mm²)
- igh performance
  x: 1.2°/h gyro instability)
- ow power consumption
  x: 1mW 3-axis gyro)

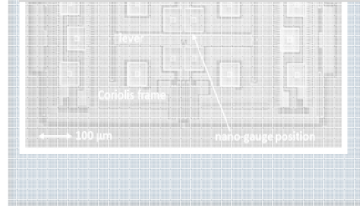
M&NEMS Open Sensor Platform

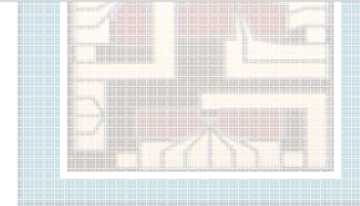
- **Reference Designs**

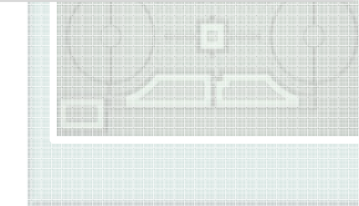
- **MEMS PDK** supported by
  - ✓ Ready-to-use design flow
  - ✓ Layout for physical verification
  - ✓ Models for ASIC co-simulation

- **Fabrication** (MPW) and MEMS **Characterization**



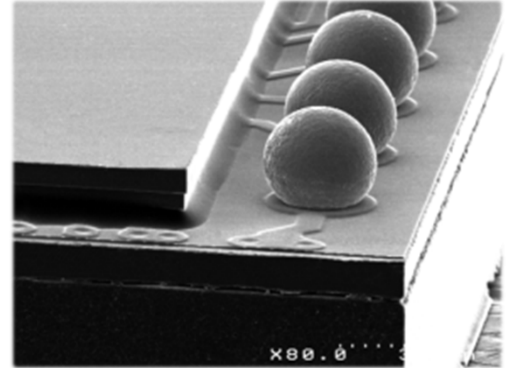


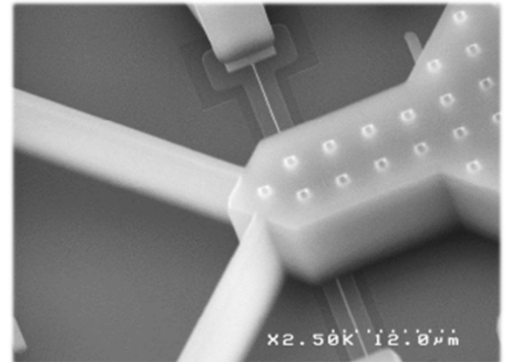




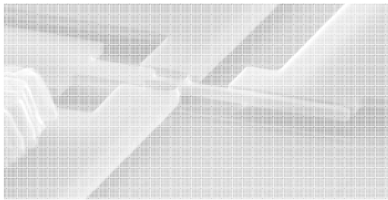
Technological Differentiation

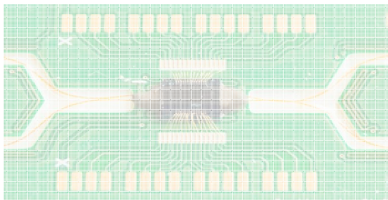
Gas Sensors



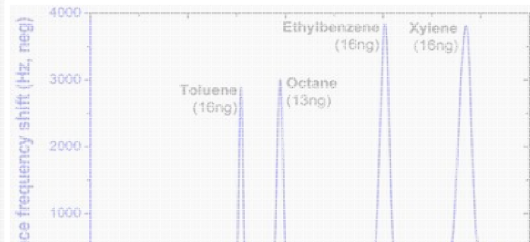


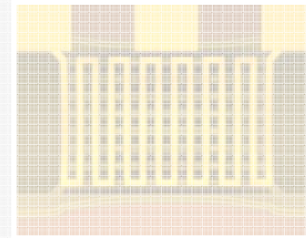
GAS SENSOR : UNIQUE MEMS / CHEMICAL EXPERTISE

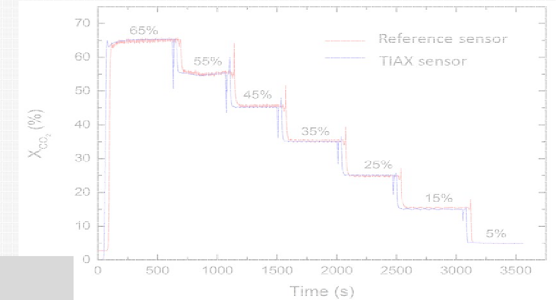




NEMS-based sensor







MEMS-based Gas sensor

- **4 Technologies**
  - ✓ Gravimetric
  - ✓ Infrared
  - ✓ Photo-acoustic
  - ✓ Thermo-Conductivity

- **3 Startups**

Air Quality city map

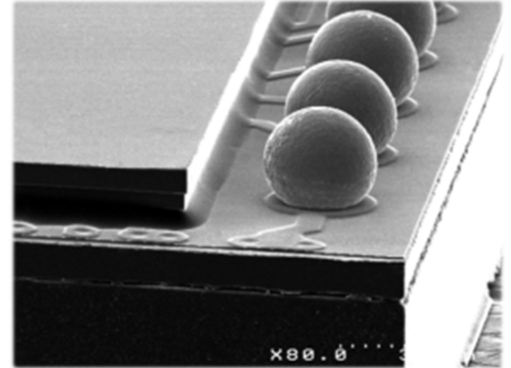
- ✓ Range 100-300 ppm
- ✓ LOD 40 ppm @1000 ppm
- ✓ Max power up to 2 mW

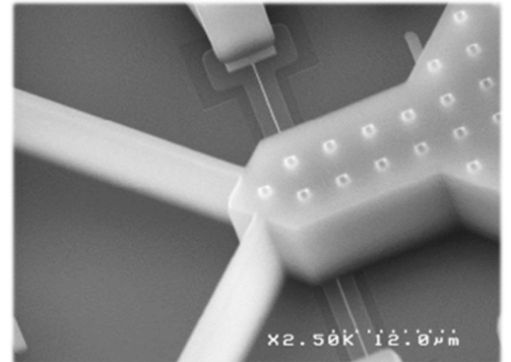
NDIR based sensor

Photo-Acoustic sensor

Technological Differentiation

Piezoelectric material





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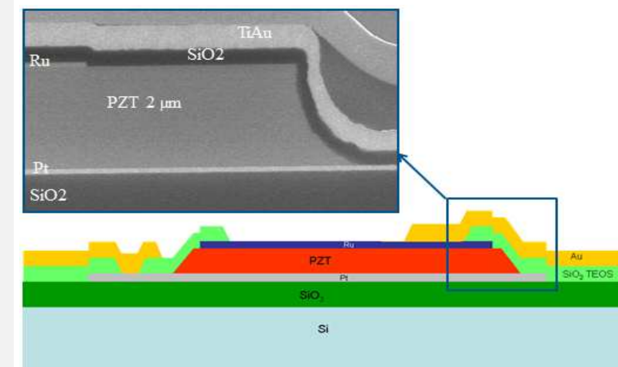
PIEZOELECTRIC MATERIAL: STATE OF THE ART EXPERTISE

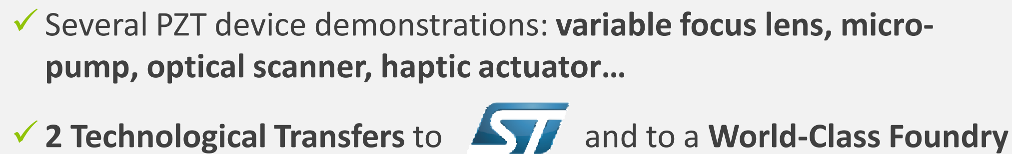
PZT

Technology

- ✓ Well mastered Solgel technology with **state of the art piezoelectric properties**
- ✓ A **complete 8'' pilot line**: from PZT material to MEMS devices



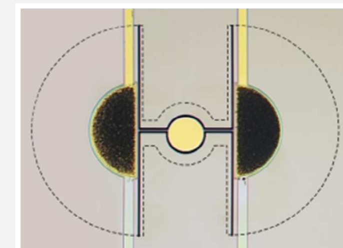
Achievements

- ✓ Several PZT device demonstrations: **variable focus lens, micro-pump, optical scanner, haptic actuator…**
- ✓ **2 Technological Transfers** to  and to a **World-Class Foundry**

Variable focus lens

On-Going Developments

- ✓ Improvement of PZT actuator reliability and performances with doping
- ✓ PZT **dry etching** (In collaboration with tool supplier)
- ✓ **Lead-Free piezoelectric material development and integration**
- ✓ Investigation of emerging PZT-MEMS devices : Loudspeaker, Pyroelectric device for gas sensor…


Optical scanner

PIEZOELECTRIC MATERIAL: STATE OF THE ART EXPERTISE

AlN

Technology

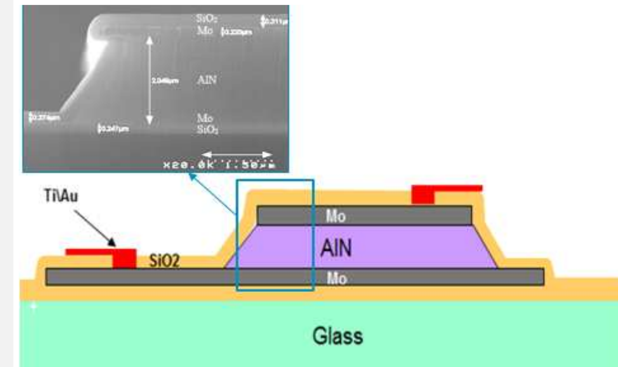
- ✓ **7 years of industrial development** with ST ⇒ high maturity process, reliability, throughput…
- ✓ A **complete 8'' pilot line**: from AlN material to MEMS devices

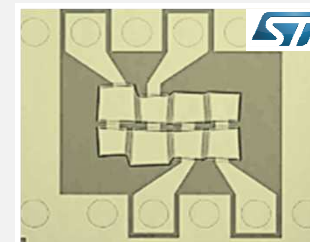
Achievements

- ✓ Several AlN device demonstrations : **BAW filter, Haptic actuator** …
- ✓ **On-going Technological Transfer to a World-Class Foundry**

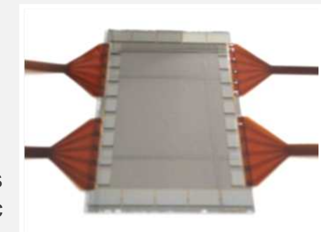
On-Going Developments

- ✓ For RF devices : Lamb waves filter…
- ✓ For sensors: **High-SNR Microphone, Pyrometer** for gas sensor
- ✓ For actuators: **pMUT**
- ✓ **Transparent piezoelectric actuator** for haptics…





BAW filter



AlN-on-glass for haptic

Thank you for your attention

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