Nano Innovation 2020
Rome, 15-18 September
Conference & Exhibition

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Materials, Sensors and Actuators in MEMS technology evolution

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18 September 2020

It-fab
Italian Network for Micro and Nano Fabrication

We are creators and makers of technology

- One of the world's largest semiconductor companies
- 2019 revenues of **$9.56B**
- **46,000** employees of which **7,800** in R&D
- Over **80** Sales & marketing offices serving over **100,000** customers across the globe
- **11** Manufacturing sites
- Signatory of the United Nations Global Compact (UNGC), Member of the Responsible Business Alliance (RBA)

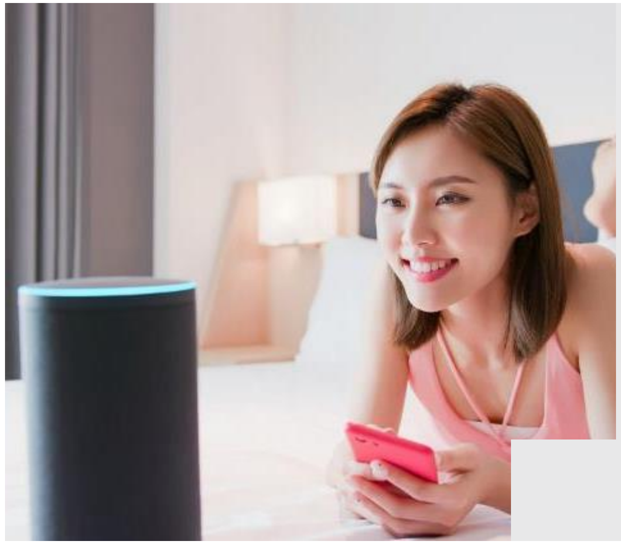
As of December 31, 2019

Where you find us

Making **driving** safer,
greener
and more connected

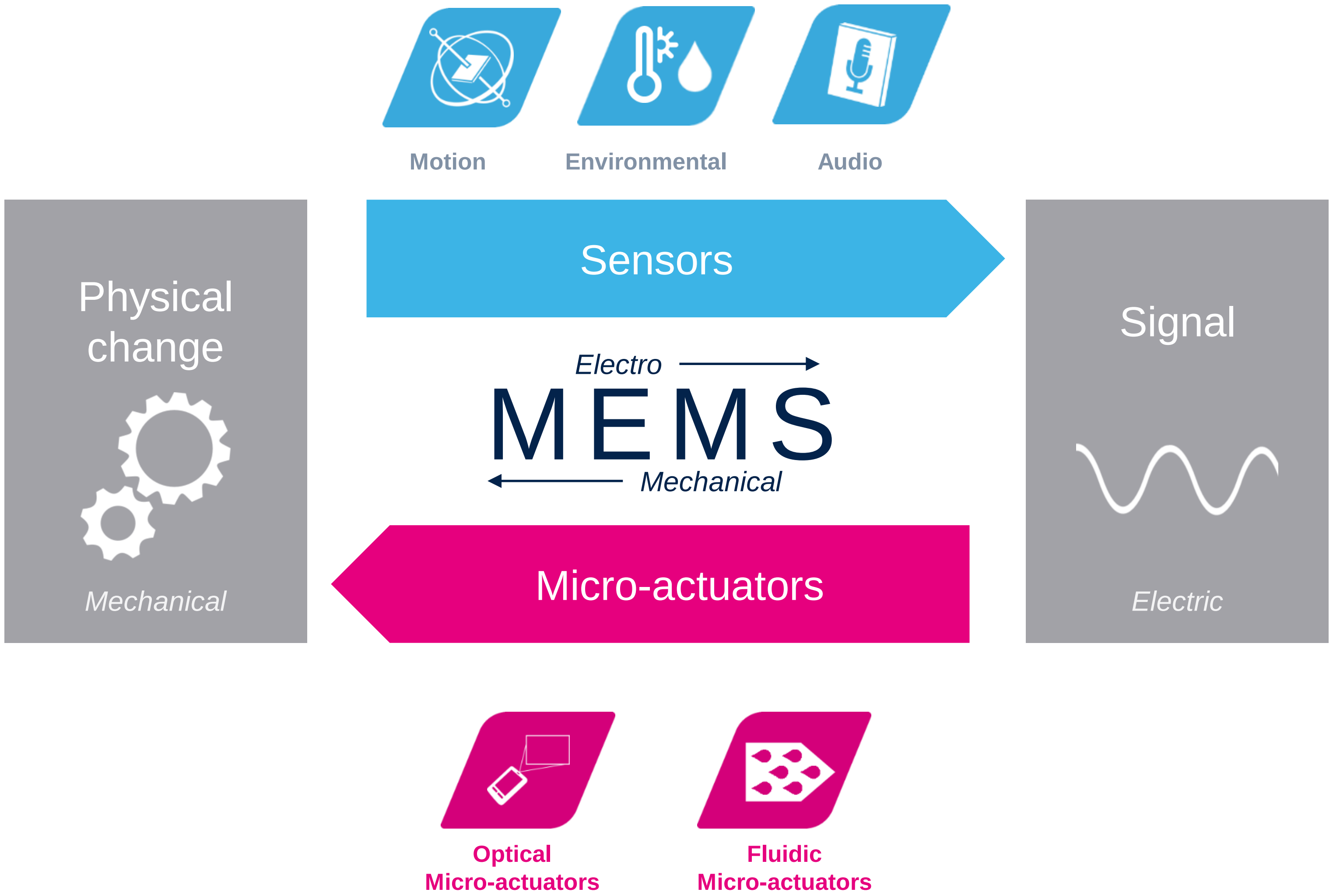
Enabling the evolution of **industry** towards smarter, safer and more efficient factories and workplaces

Making **homes & cities** smarter, for better living, higher security, and to get more from available resources

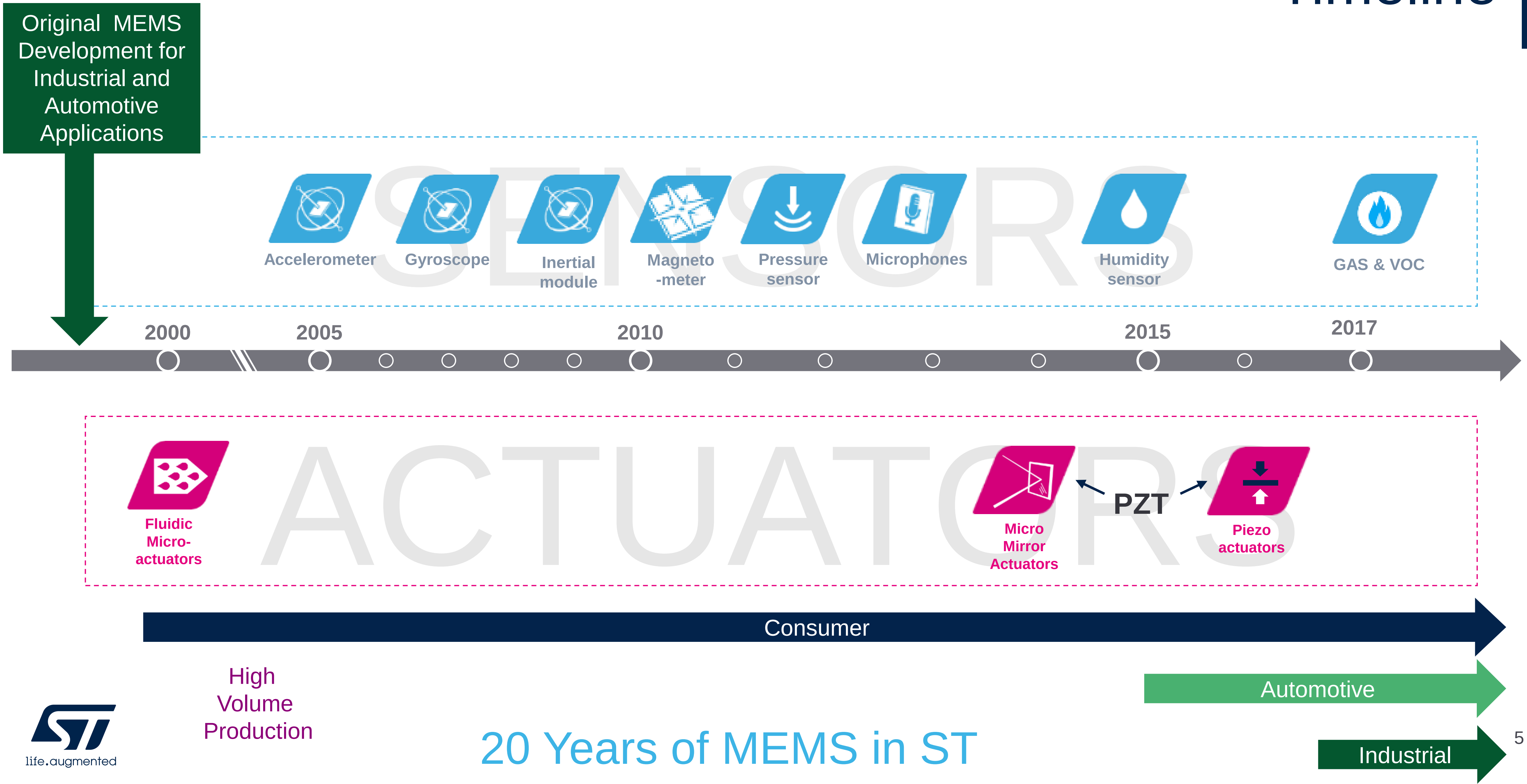


Making everyday **things** smarter, connected and more aware of their surroundings

MEMS for sensing and actuating

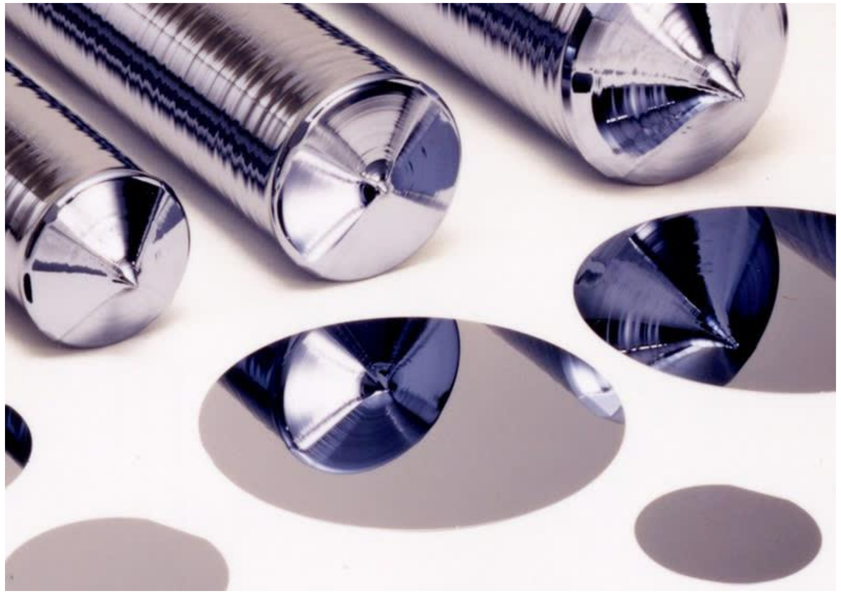


Timeline



Original MEMS Development for Industrial and Automotive Applications
SENSORS
Accelerometer
Gyroscope
Inertial module
Magneto -meter
Pressure sensor
Microphones
Humidity sensor
GAS & VOC
2000
2005
2010
2015
2017
ACTUATORS
Fluidic Micro-actuators
Micro Mirror Actuators
PZT
Piezo actuators
Consumer
High Volume Production
Automotive
Industrial
20 Years of MEMS in ST

Silicon vs steel



VS

Property	Silicon	Steel
Young's modulus	180 GPa	210 GPa
Yield strength	> 1 GPa	4.2 GPa
Density	2.3 g/cm^3	7.9 g/cm^3
Thermal expansion coefficient	2.3 ppm/K	12 ppm/K

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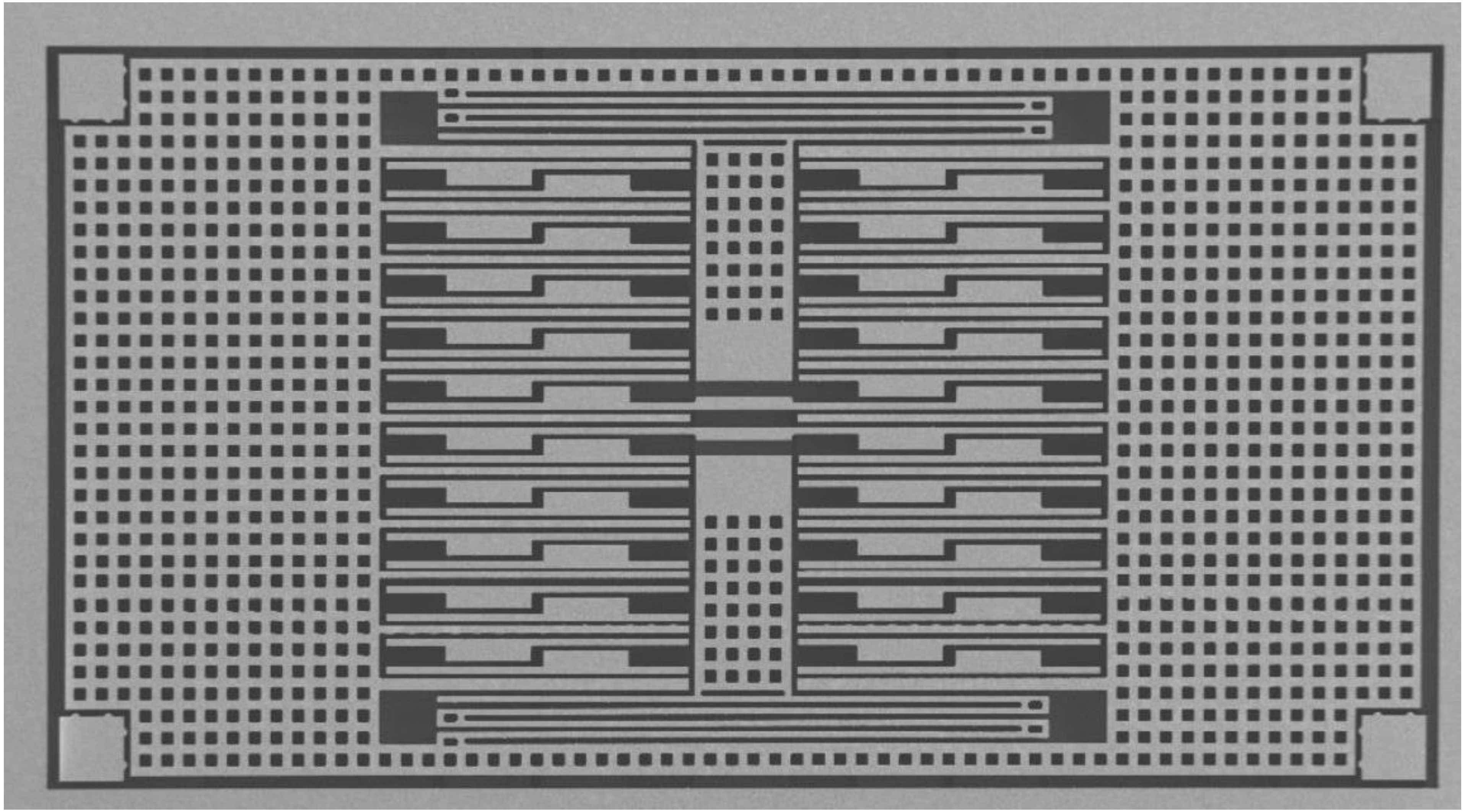
An example of motion MEMS: accelerometer



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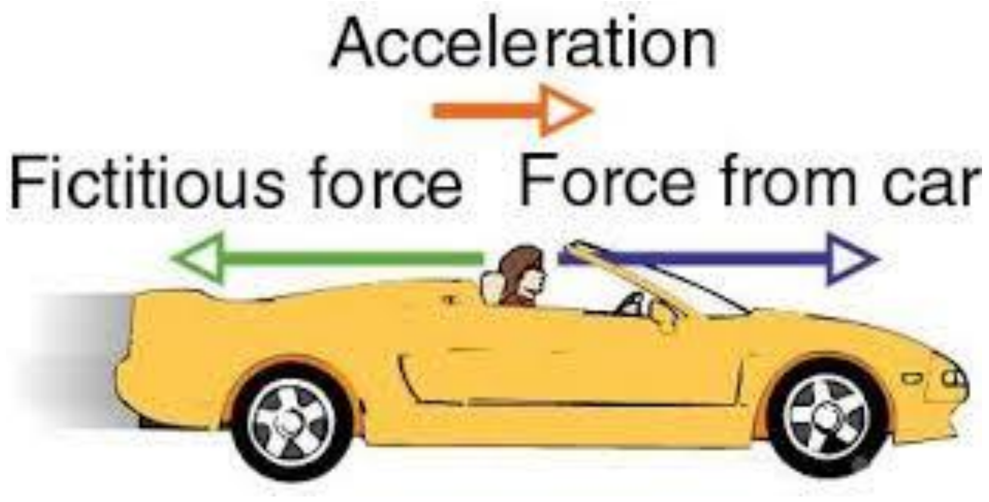
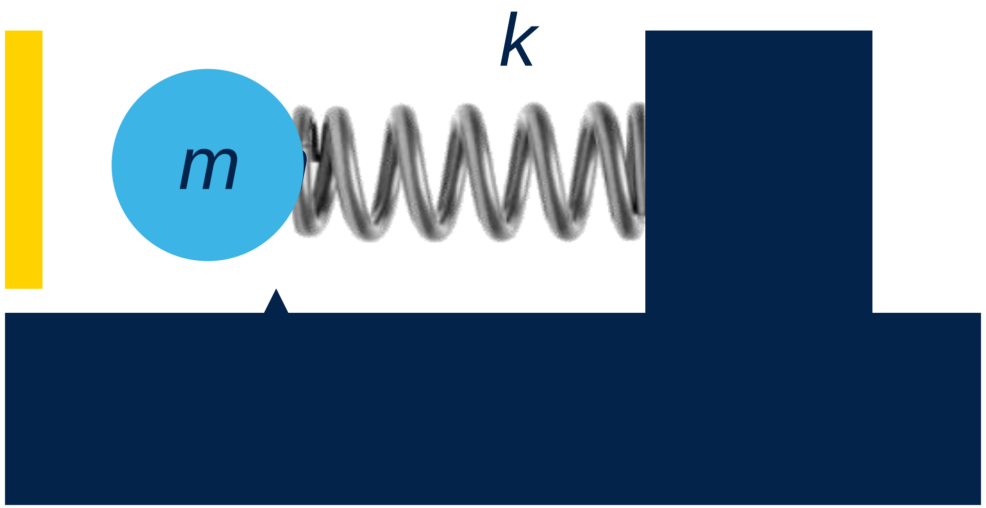
Accelerometer: how it works



$$F = m \cdot \mathrm{a}$$

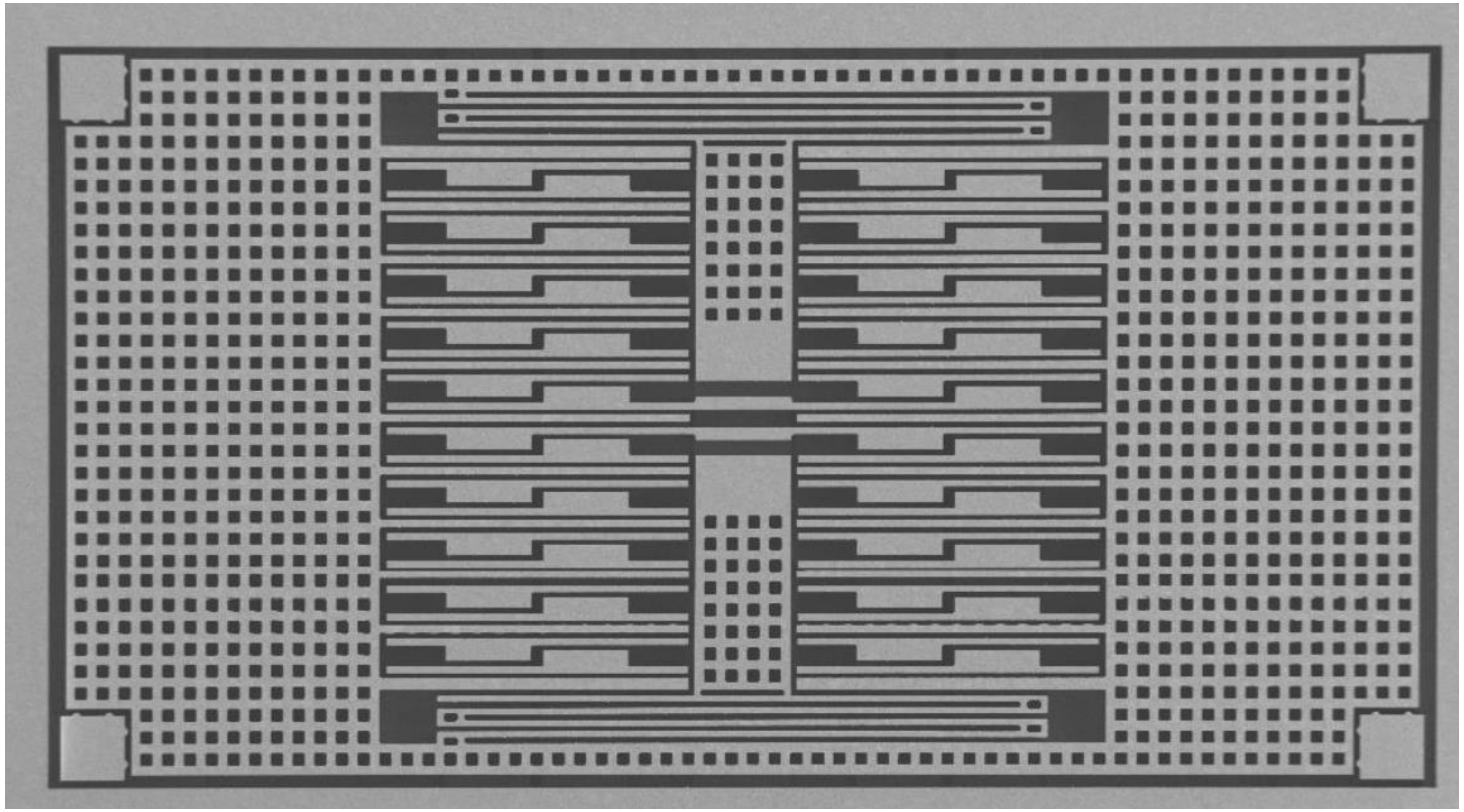
$$F = k \cdot \Delta x$$

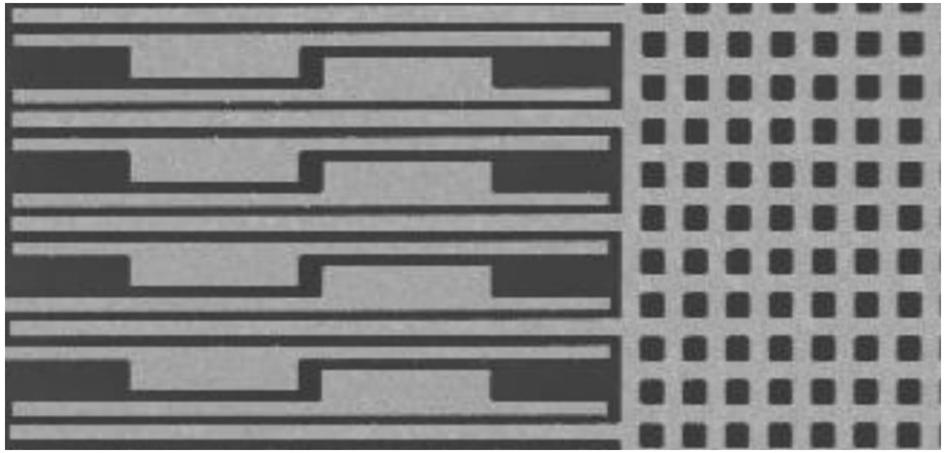
$$a = \frac{k}{m} \cdot \Delta x$$



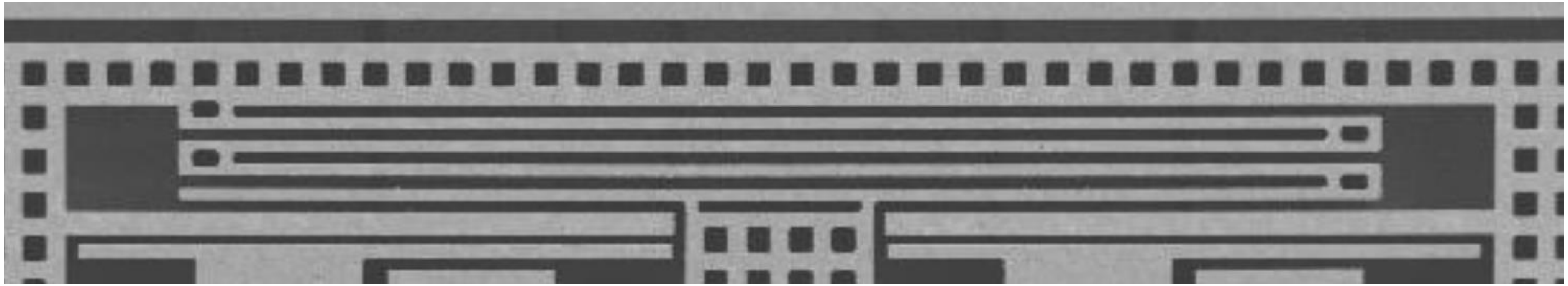
acceleration is measured by means of mass displacement

Motion MEMS: images





$$C = \frac{\varepsilon_0 \cdot S}{d}$$



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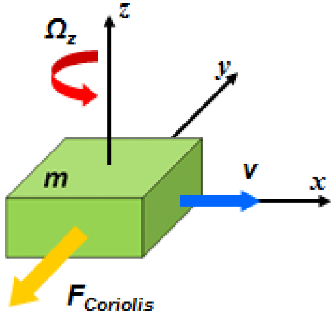
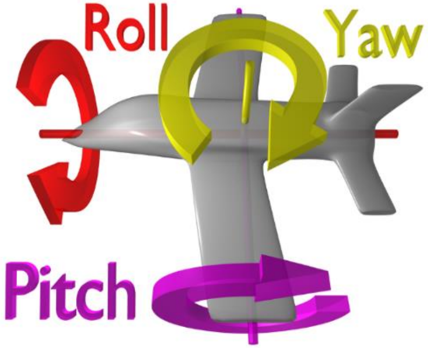
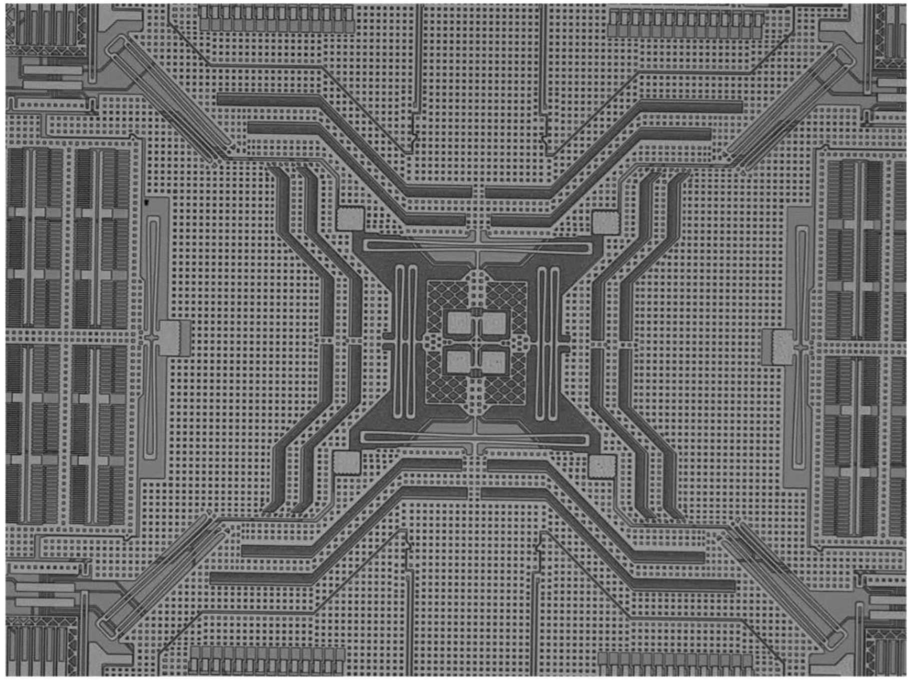
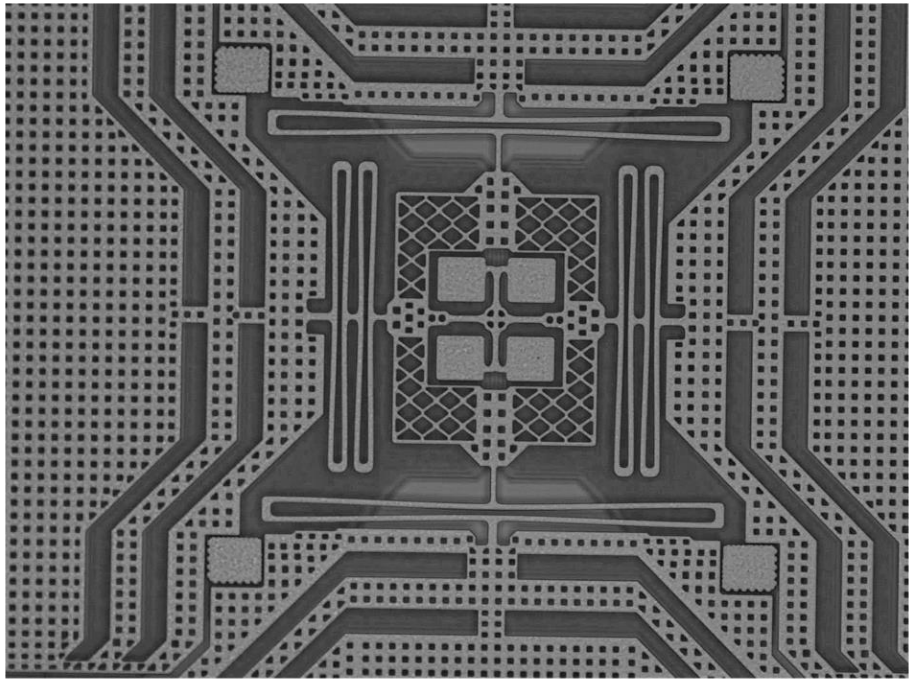
THELMA gyroscope at work



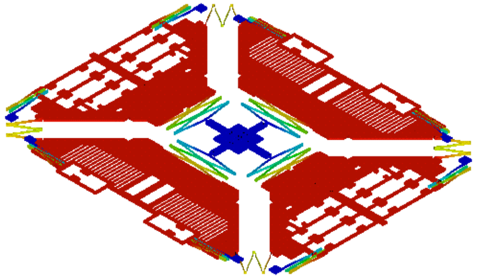


- beccheggio
- imbardata
- rollio.

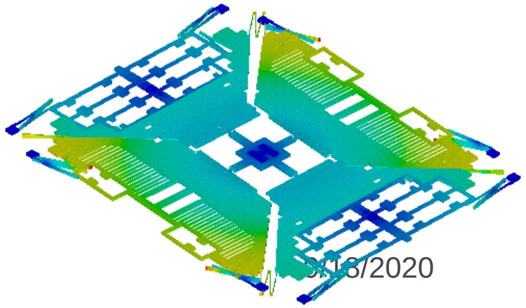




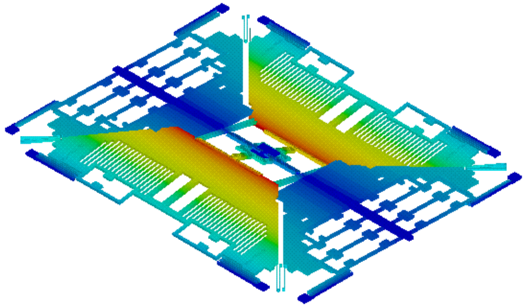
Drive mode



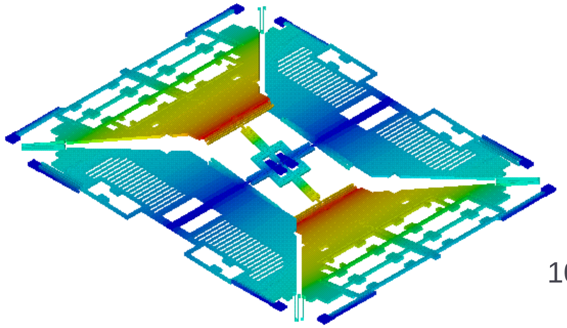
Yaw mode



Pitch mode



Roll mode



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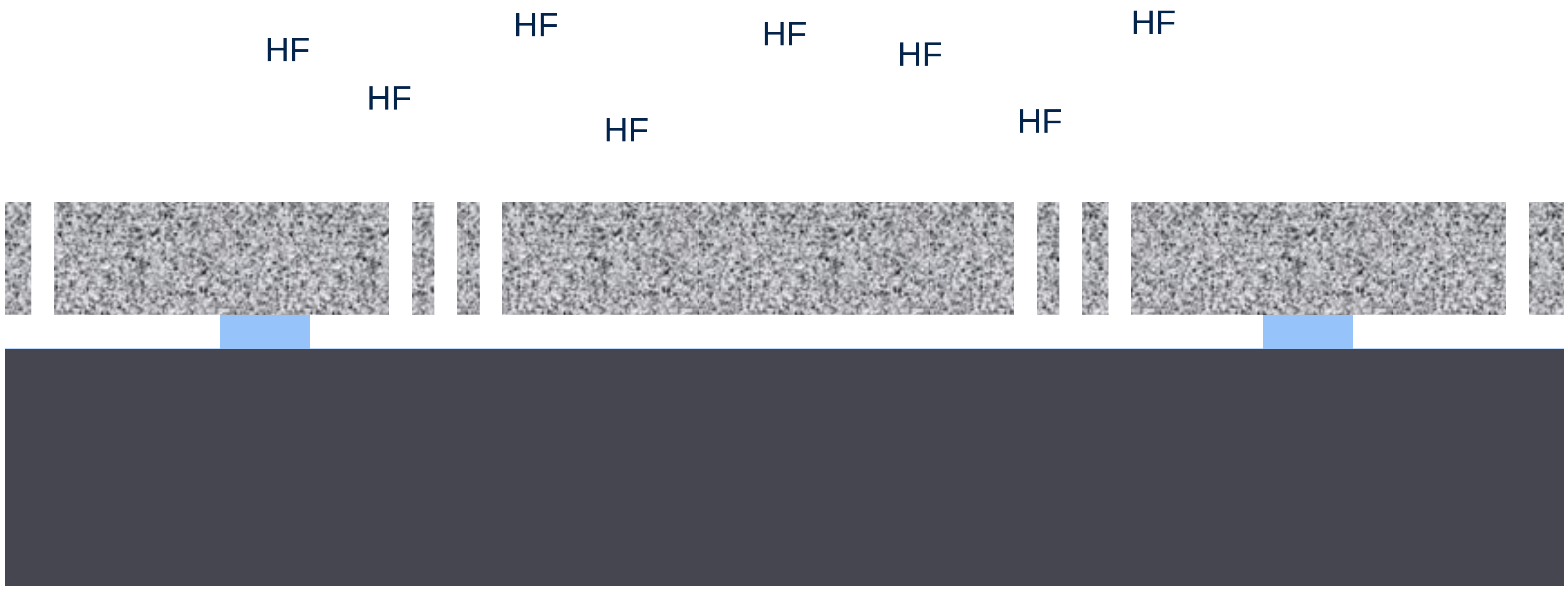
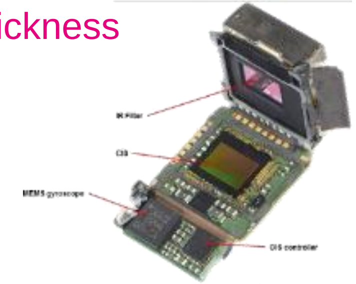
Motion sensors: how they are made



Motion MEMS today

Low-noise
low-thickness

Optical Image
Stabilization (OIS)
For Smartphones



New Market
penetration
Cost effectiveness

Recreational &
professional
Drones

Addressing existing and new applications and markets

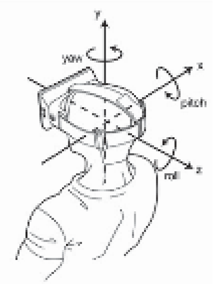
Wearable

Ultra-low power
For always-on
wearable devices

2015

Virtual Reality

High accuracy



2016

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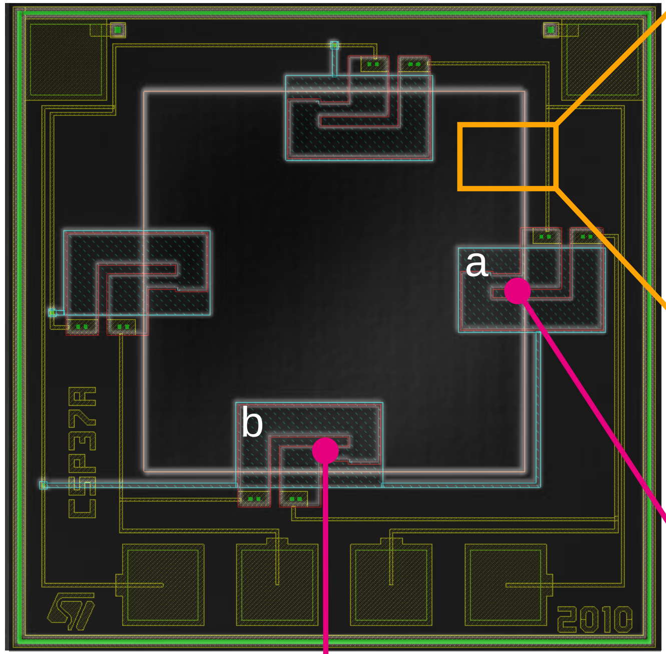
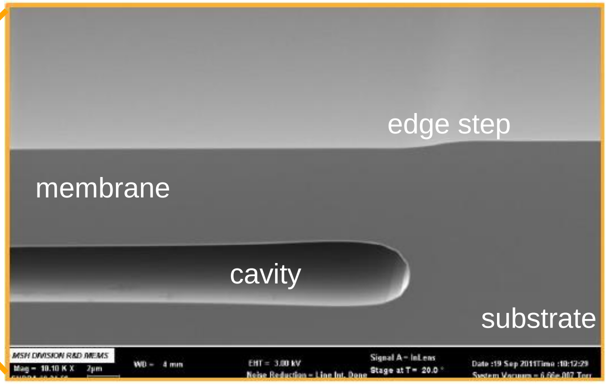
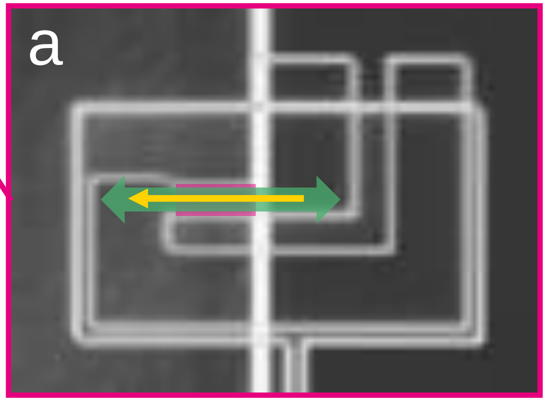
MEMS pressure sensor

- 4 p-Si resistors implanted on a flexible silicon membrane
- **Pressure induced stress is sensed by piezoresistive effect**
- 4 piezoresistors connected in a Wheatstone bridge configuration

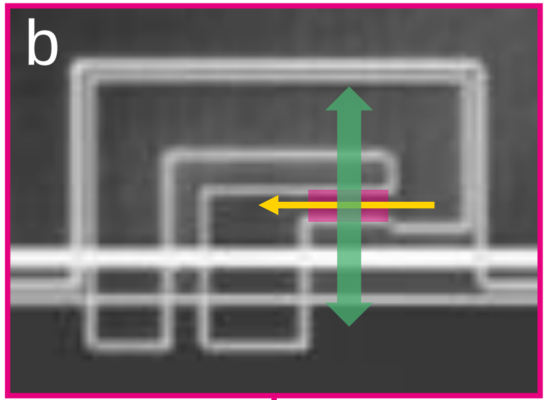




- Membrane thickness: 7 um
- Membrane width: 350 um
- Cavity height: 3.5 um



Increasing resistance



Decreasing resistance

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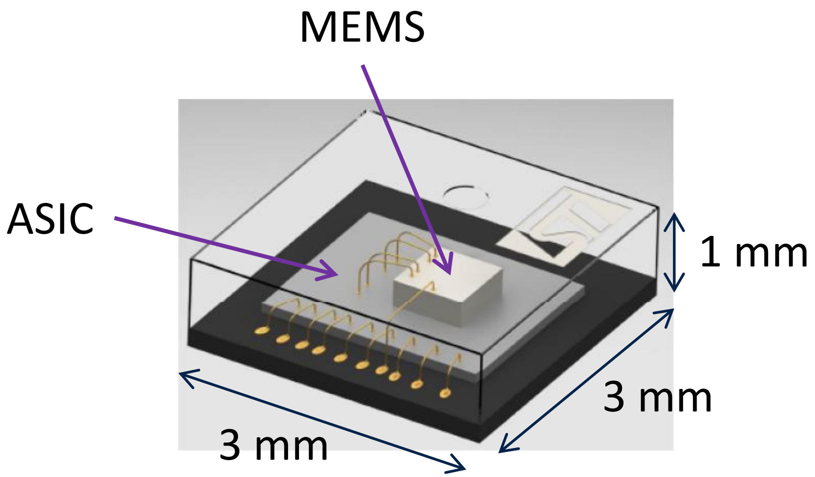
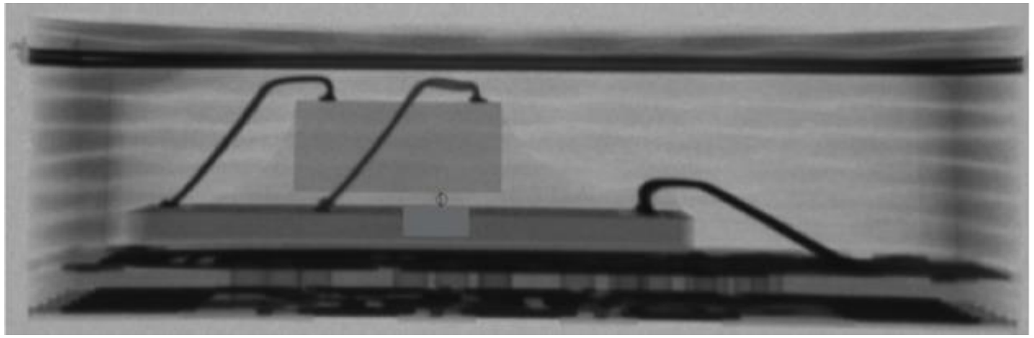
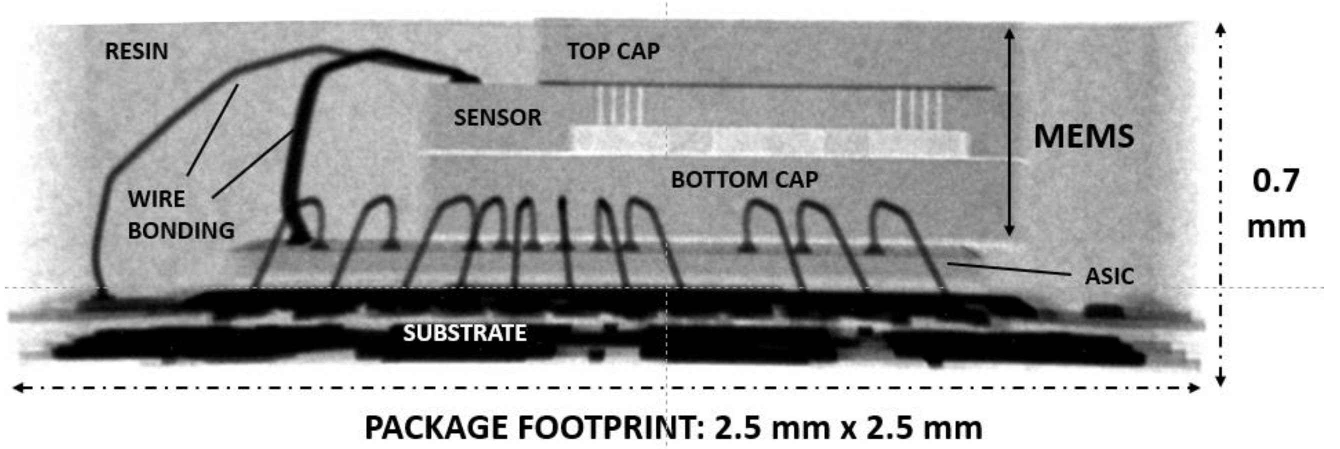
From cavity to full molded package



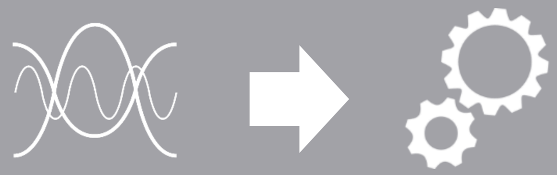




MEMS for micro-actuation

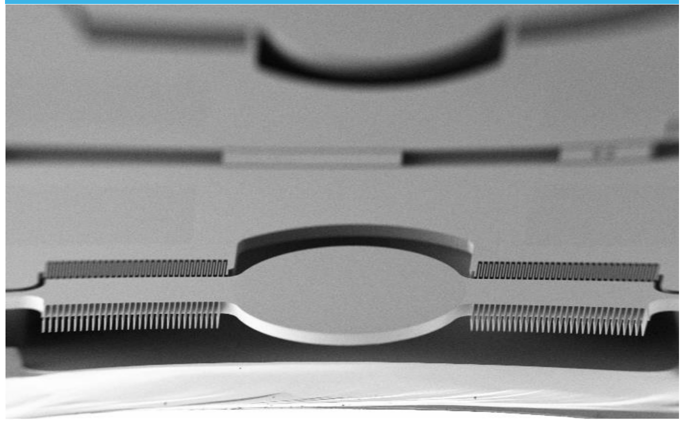
Convert an electric current into a mechanical output

causing the displacement or rotation of a mechanical structure



Electric *Mechanical*

Micro-machined device able to move a tiny object, either liquid or solid, with relatively small force and along a small distance



The MEMS actuators use different **transduction schemes** for their operation

Piezo-electric	Electro-static
Thermal	Electro-magnetic

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Micromirrors portfolio

Augmented Reality

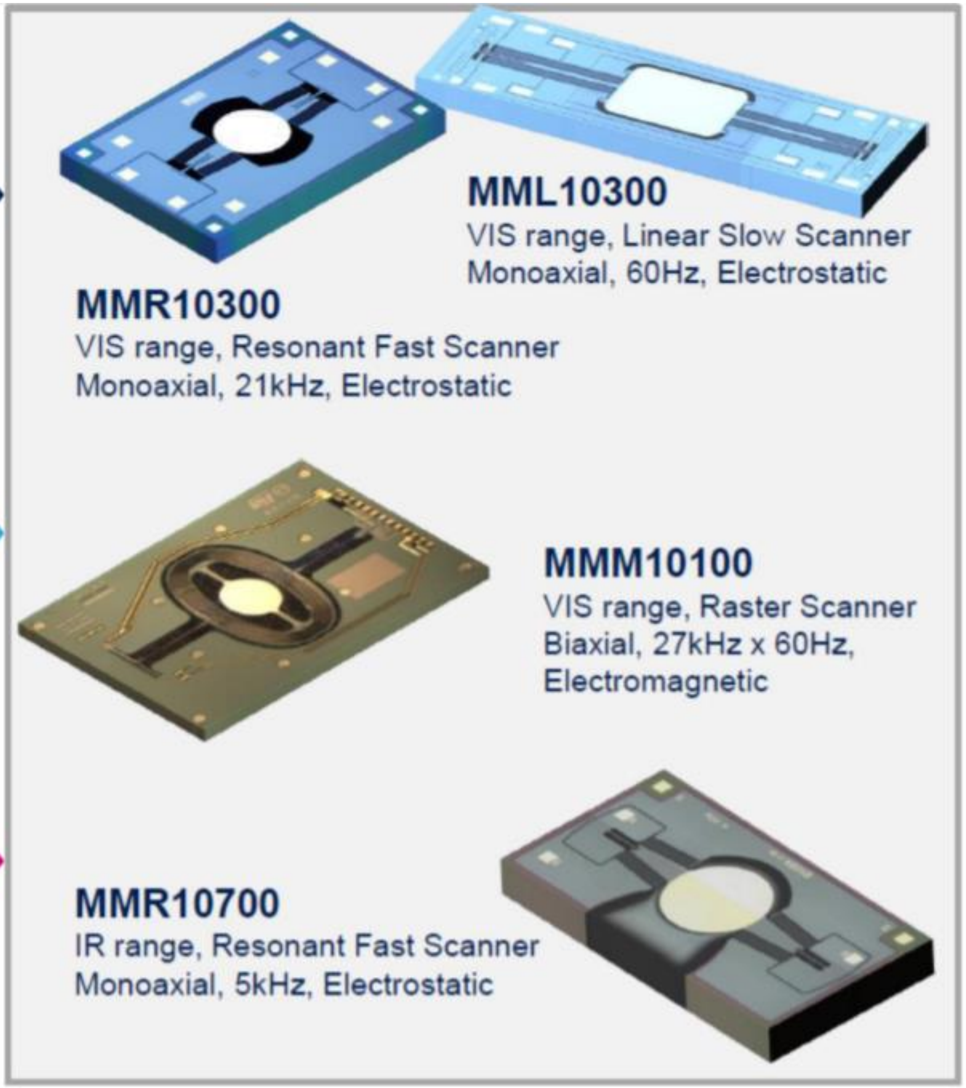
Visible Projection
Small volume occupation
Low Power Consumption

Projection

Visible Projection
High Brightness
High Resolution

Gesture & Face Recognition

Infrared Projection
Small volume occupation
Large Scan Angle



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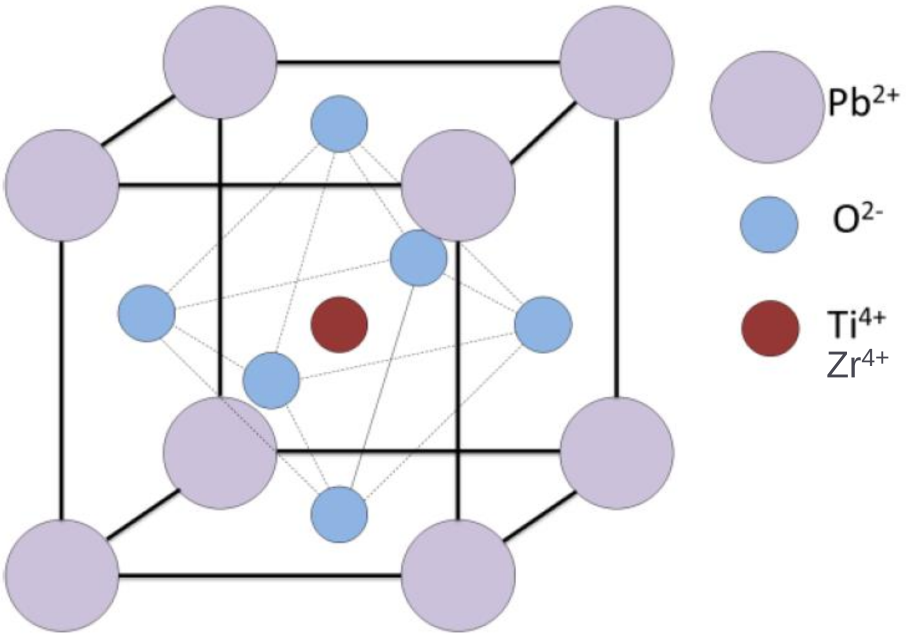
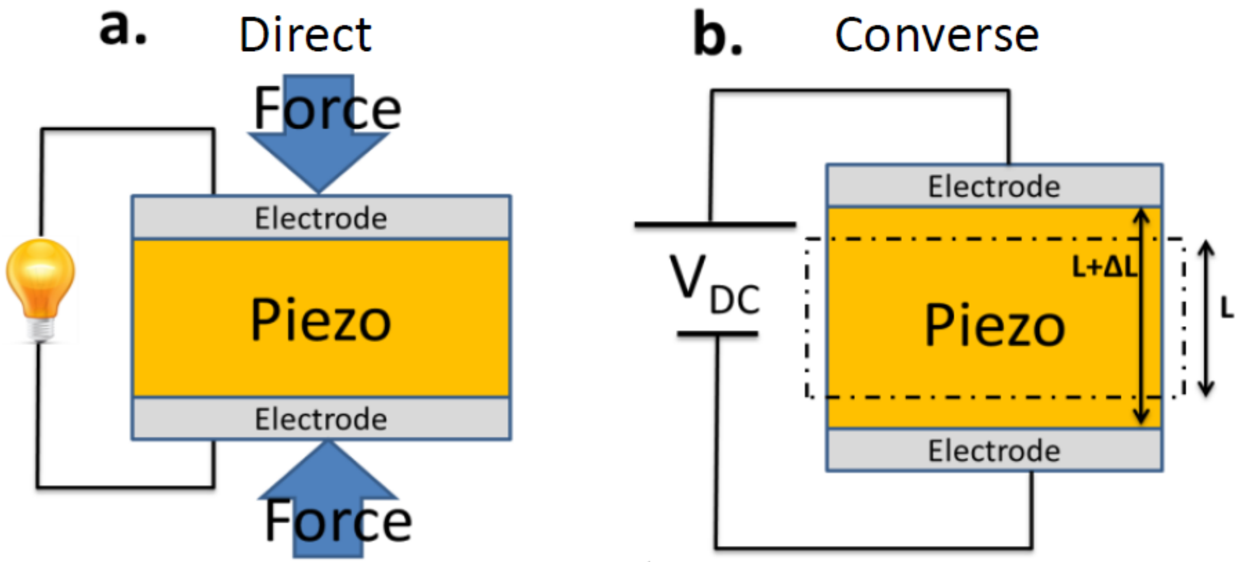
Piezoelectric actuation: PZT



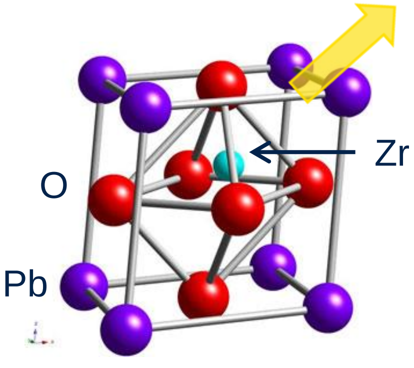


- The piezoelectric effect is a reversible process
  - **Direct piezoelectric effect:** Strain → Charge (**Sensing** applications)
  - **Converse piezoelectric effect:** Voltage → Stress/Strain (for **Actuators**)

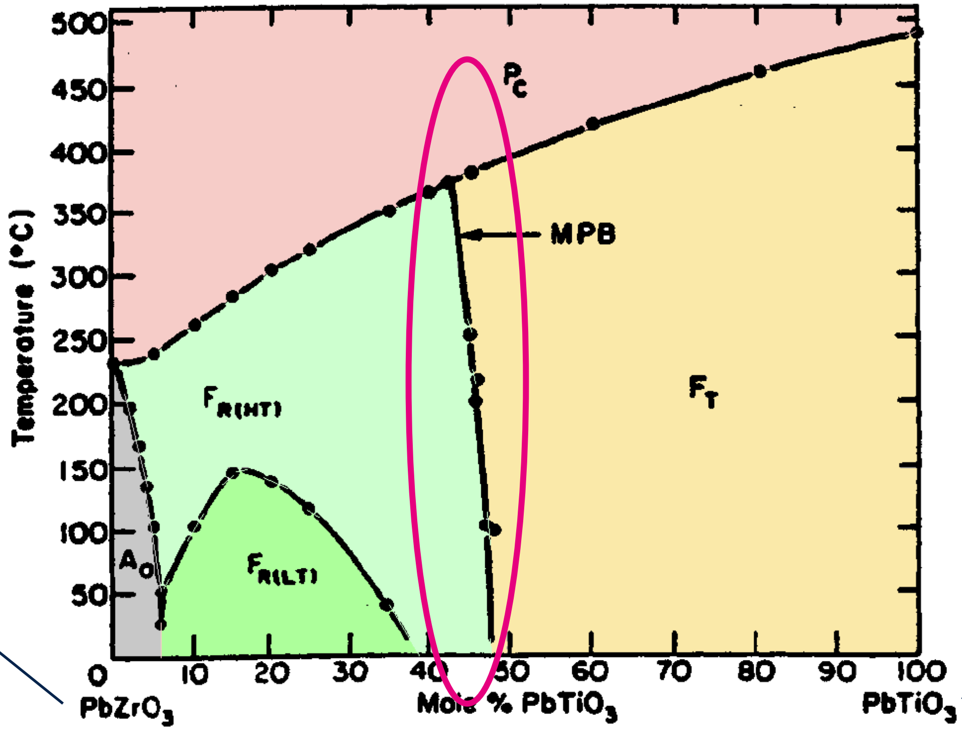
What is PZT

Solid solution: $Pb(Zr_x,Ti_{1-x})O_3$ – Perovskite structure

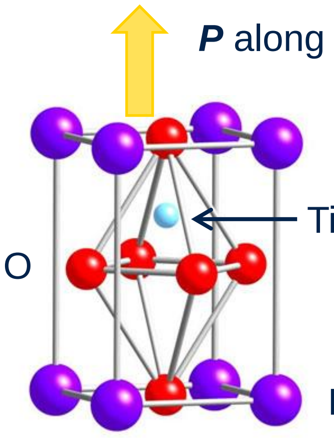
P along <111>



Pure PbZrO3
Rhomboedral



P along <100>



Pure PbTiO3
Tetragonal

PZT has the best ferroelectric and piezoelectric performances at morphotrophic phase boundary (**MPB**), where rhomboedral and tetragonal phases coexist. MPB = Zr/Ti ~ 52/48

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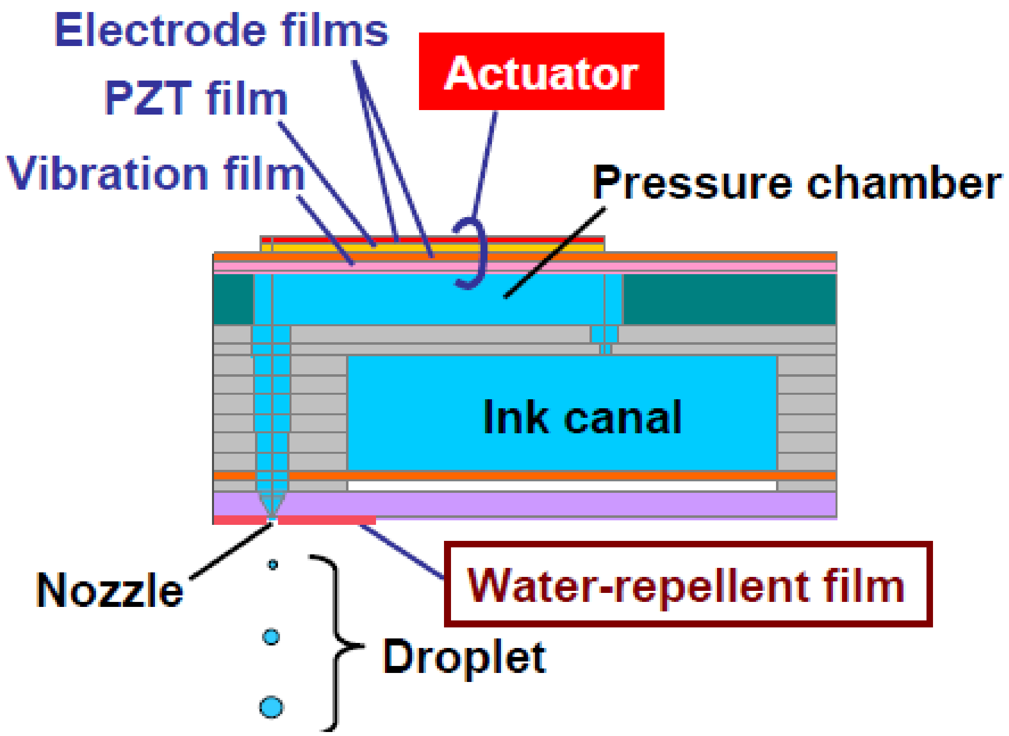
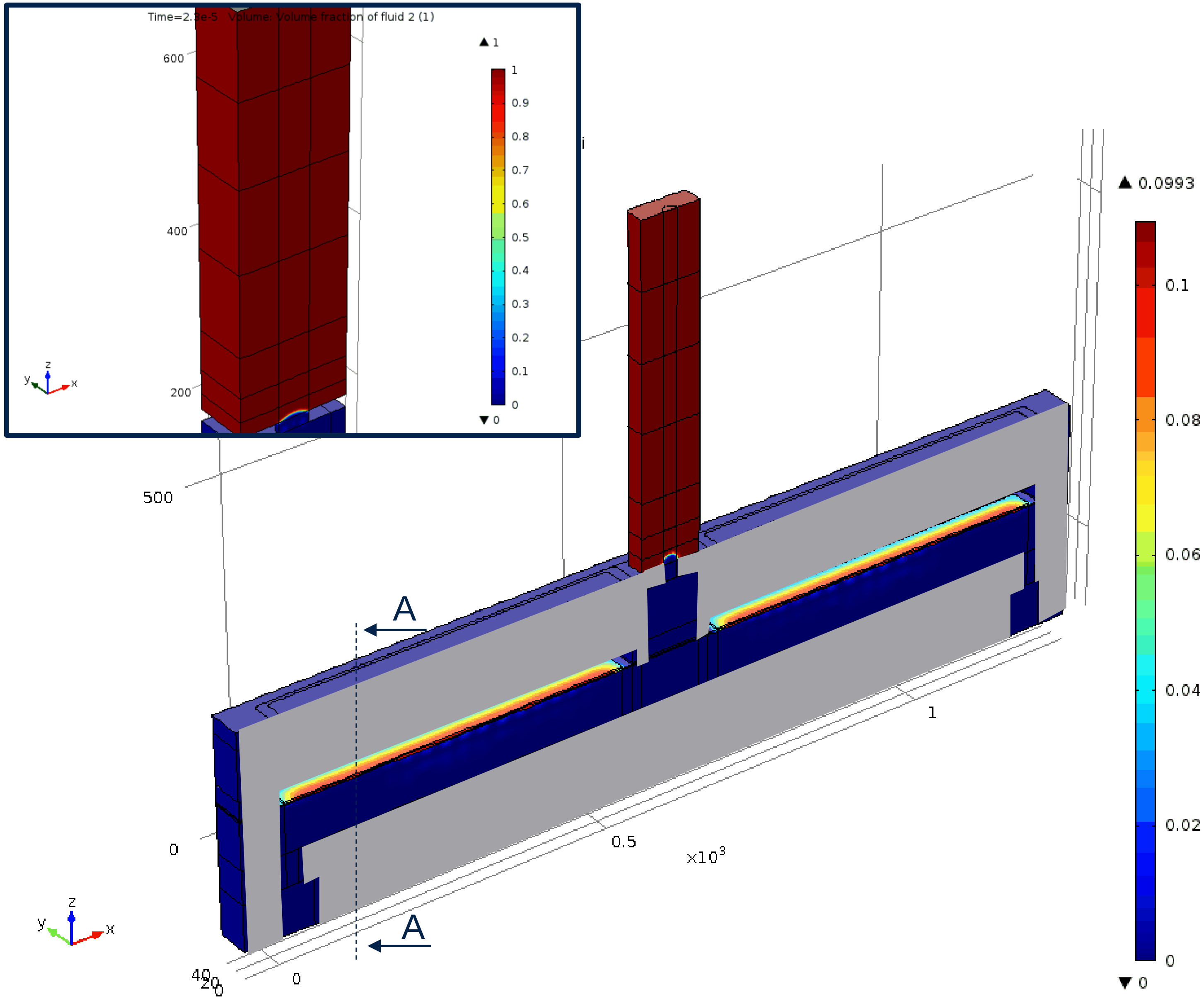
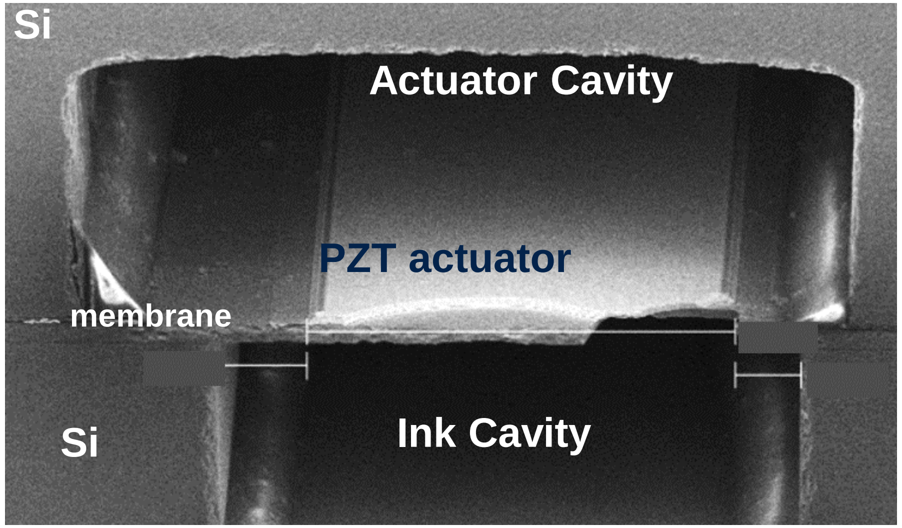
Thin film piezo inkjet



- **Working principle: ink volume displacement by a PZT actuated membrane**
- **Thin-Film Piezo vs Thermal Inkjet Benefits**
  - Compatibility with wide variety of inks
  - Higher printing speed
  - Superior print output quality
  - Extended print-head lifetime
  - Digital printing vs. analog printing

Thin film piezo inkjet





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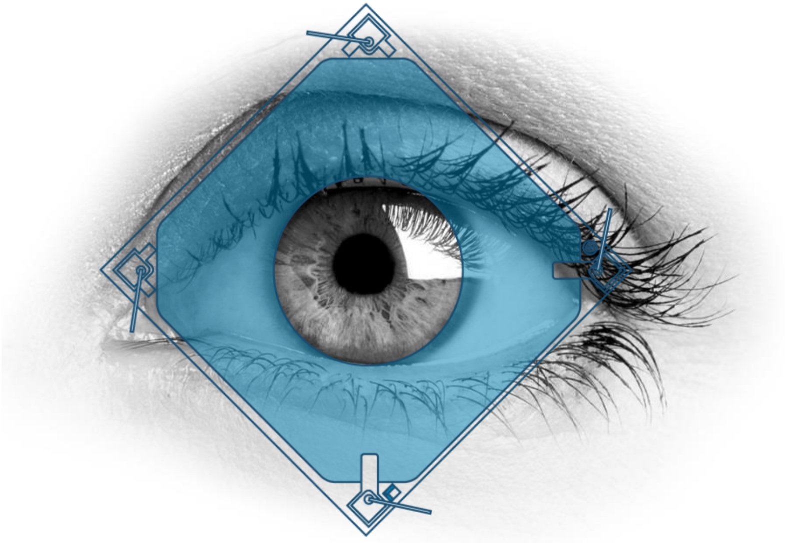
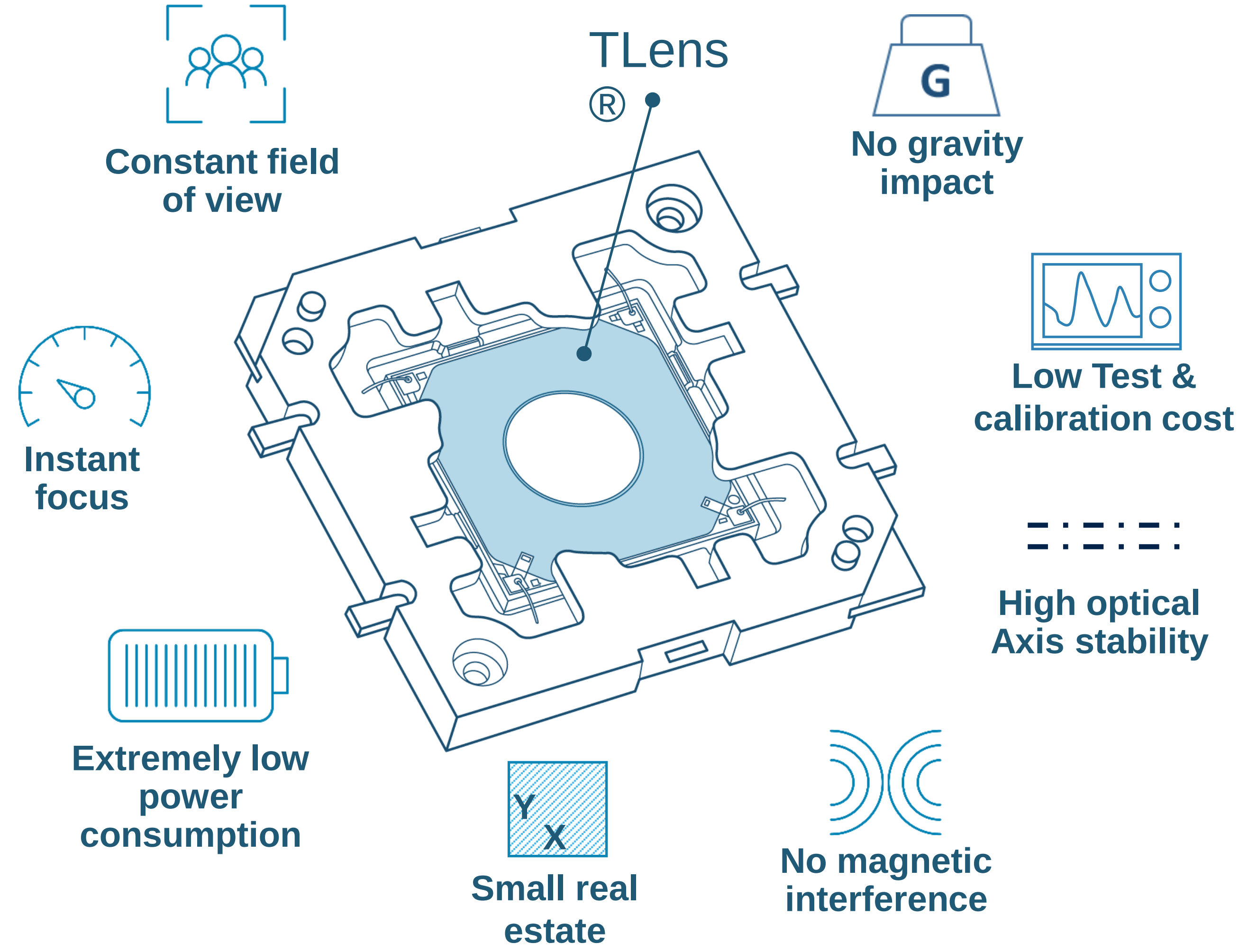
Polight tlens®

poLight TLens®
unique performance enables new use cases for smartphones not yet to be seen!



"We managed to replicate the human eye"



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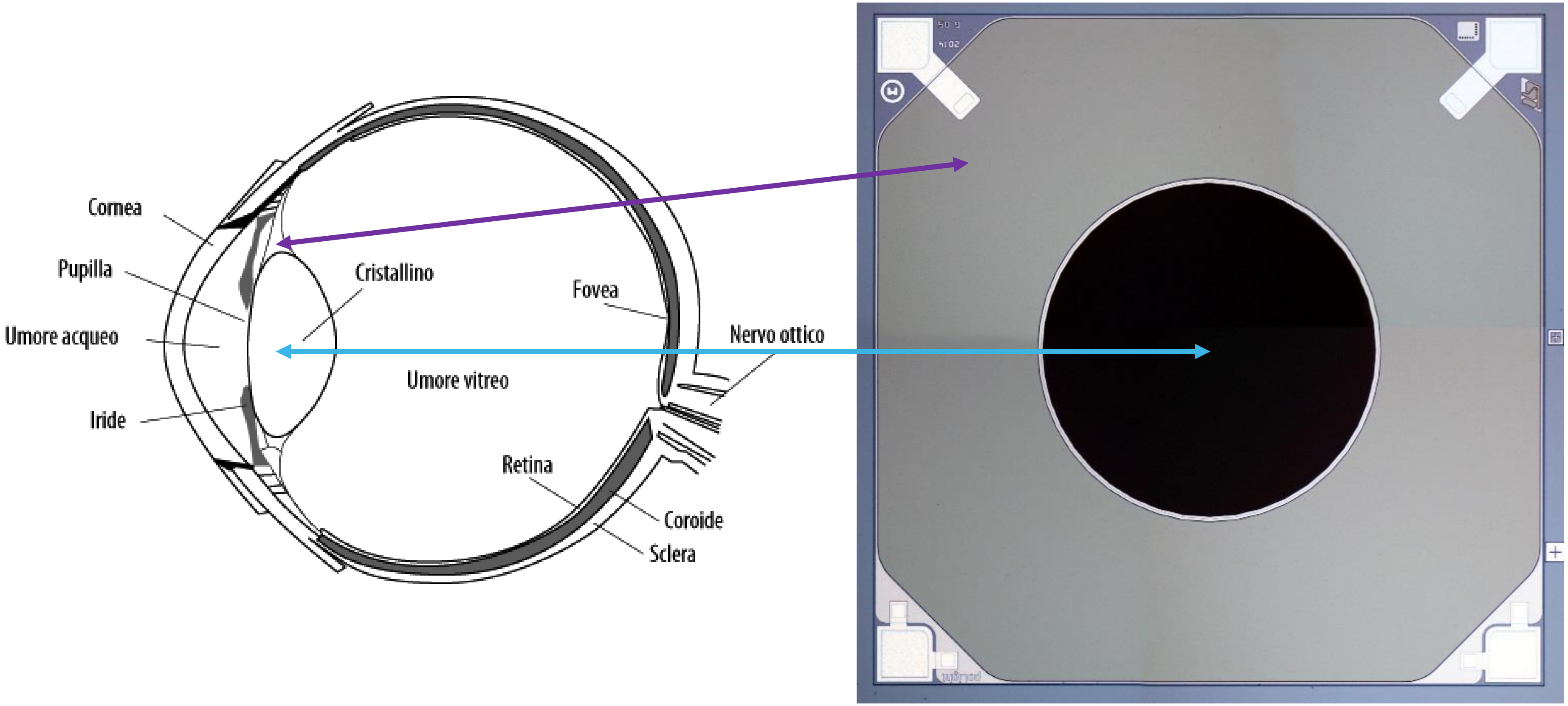
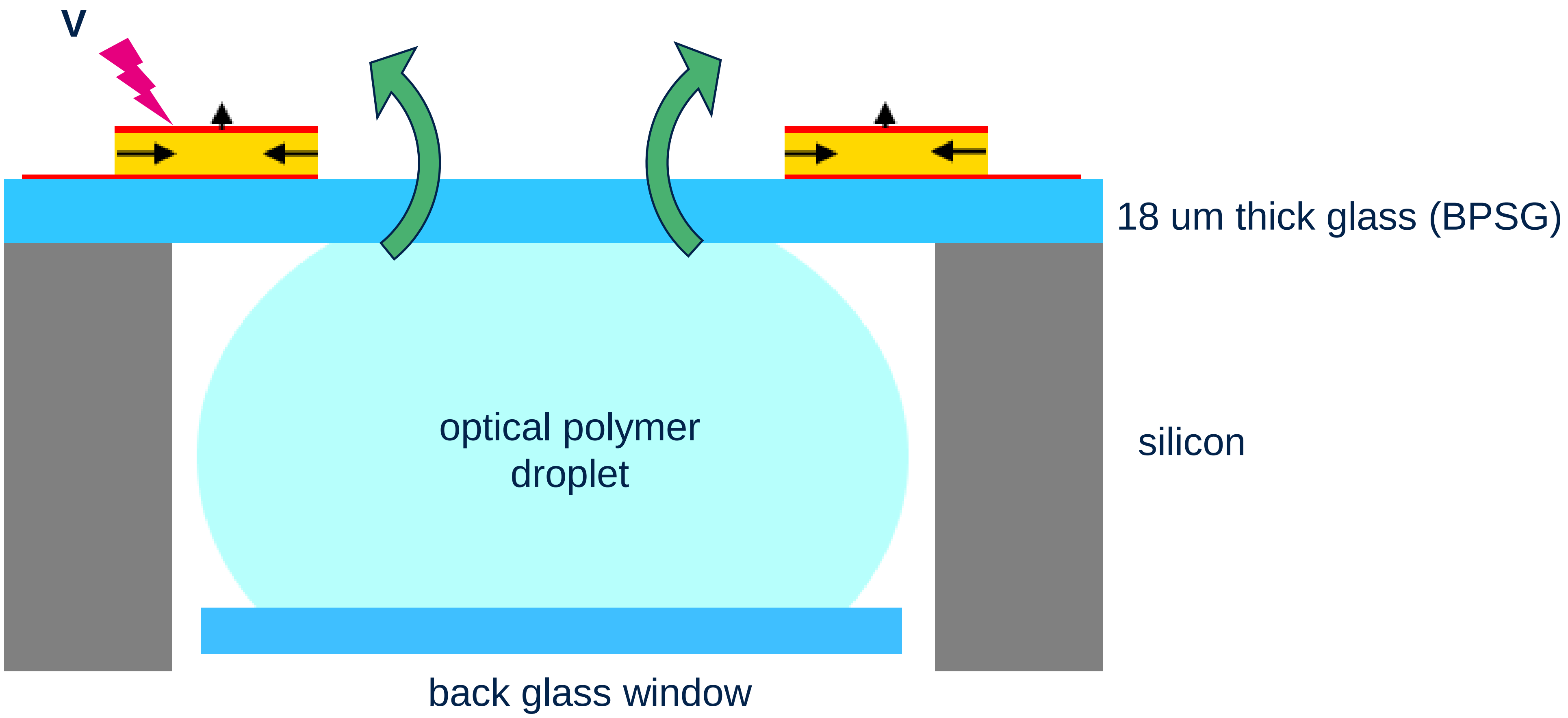
Working principle

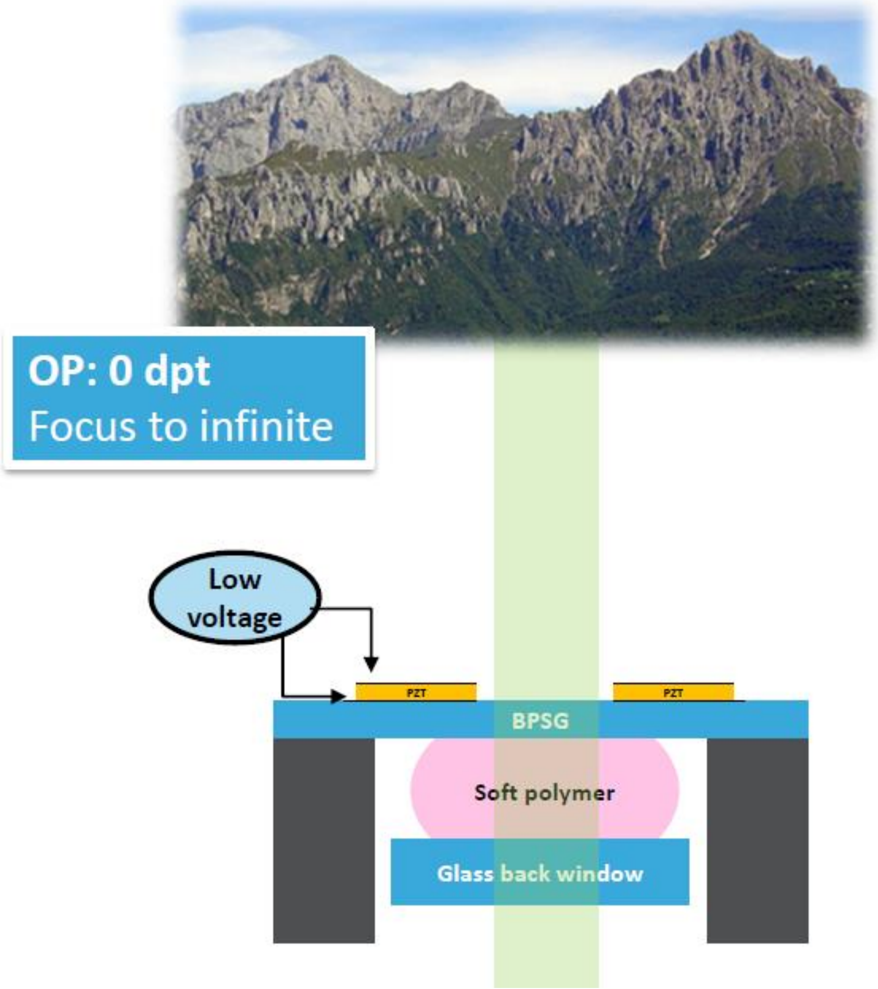


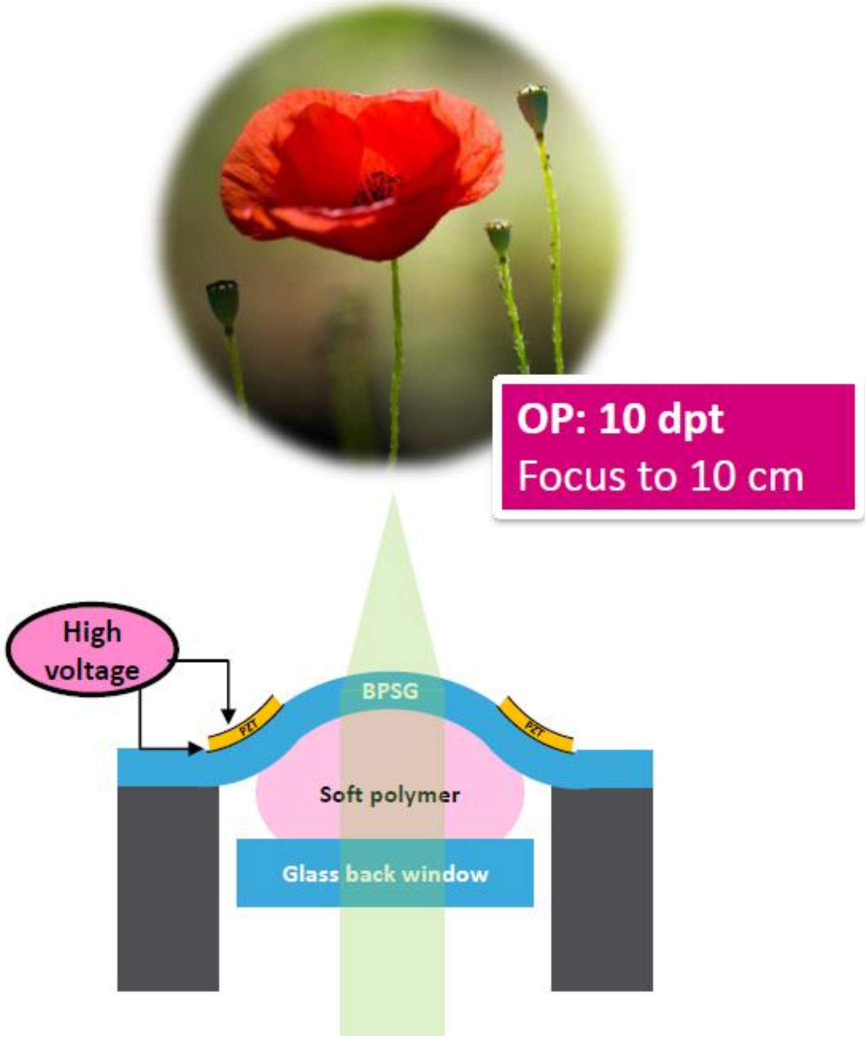
A piezoelectric thin film acts like the muscle

Device actuation

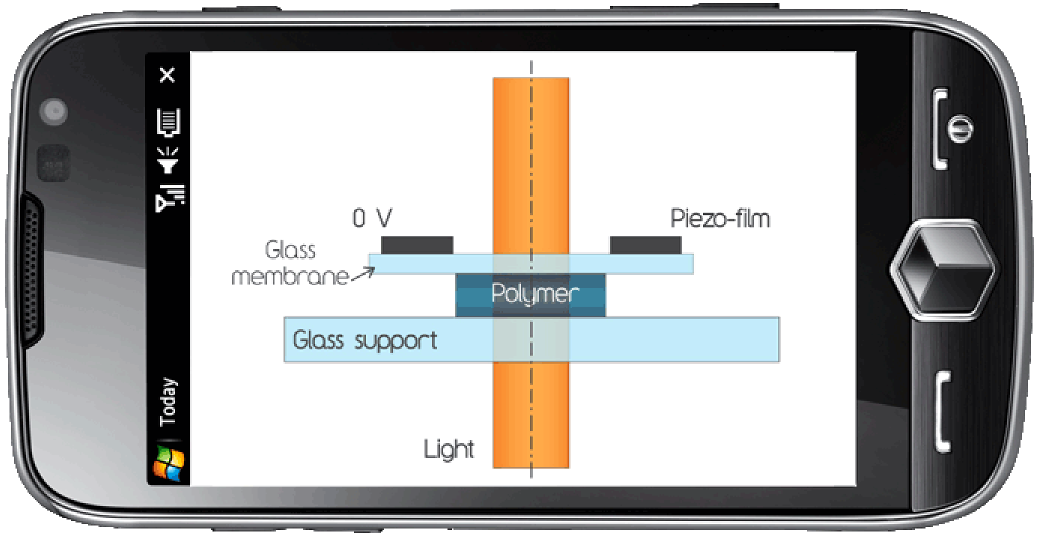


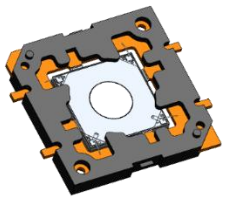
Optical power





Tlens®





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Conclusions

Sensors and actuators are enabling more and more sophisticated technologies

Great demand of development of new actuators based on PZT thin films

Just as for sensors, actuators are now waiting for new disruptive applications

Thank you

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