Materials, Sensors and Actuators in MEMS technology evolution

Andrea Picco, PhD
18 September 2020
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)
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

Sensors

- Motion
- Environmental
- Audio

Micro-actuators

- Optical
- Fluidic

Physical change

Electro

MEMS

Mechanical

Signal

Electric

STI

4
20 Years of MEMS in ST
### Silicon vs steel

<table>
<thead>
<tr>
<th>Property</th>
<th>Silicon</th>
<th>Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young’s modulus</td>
<td>180 GPa</td>
<td>210 GPa</td>
</tr>
<tr>
<td>Yield strength</td>
<td>&gt; 1 GPa</td>
<td>4.2 GPa</td>
</tr>
<tr>
<td>Density</td>
<td>2.3 g/cm³</td>
<td>7.9 g/cm³</td>
</tr>
<tr>
<td>Thermal expansion coefficient</td>
<td>2.3 ppm/K</td>
<td>12 ppm/K</td>
</tr>
</tbody>
</table>
An example of motion MEMS: accelerometer
Accelerometer: how it works

\[ F = m \cdot a \]
\[ F = k \cdot \Delta x \]
\[ a = \frac{k}{m} \cdot \Delta x \]

acceleration is measured by means of mass displacement
\[ C = \frac{\varepsilon_0 \cdot S}{d} \]
THELMA gyroscope at work

Drive mode

Yaw mode

Pitch mode

Roll mode
Motion sensors: how they are made
Motion MEMS today

Addressing existing and new applications and markets

Optical Image Stabilization (OIS)
For Smartphones

Ultra-low power
For always-on wearable devices

Wearable

New Market penetration
Cost effectiveness

Recreational & professional Drones

Virtual Reality
High accuracy

Low-noise low-thickness

2015

2016
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
From cavity to full molded package

MEMS

ASIC

3 mm

1 mm

3 mm

3 mm

0.7 mm

PACKAGE FOOTPRINT: 2.5 mm x 2.5 mm
MEMS for micro-actuation

Convert an electric current into a mechanical output causing the displacement or rotation of a mechanical structure

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
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

- **MMML10300**
  - VIS range, Linear Slow Scanner
  - Monoaxial, 60Hz, Electrostatic

- **MMR10300**
  - VIS range, Resonant Fast Scanner
  - Monoaxial, 21kHz, Electrostatic

- **MMM10100**
  - VIS range, Raster Scanner
  - Biaxial, 27kHz x 60Hz, Electromagnetic

- **MMR10700**
  - IR range, Resonant Fast Scanner
  - Monoaxial, 5kHz, Electrostatic
The piezoelectric effect is a reversible process.

- **Direct piezoelectric effect**: Strain $\rightarrow$ Charge (Sensing applications)
- **Converse piezoelectric effect**: Voltage $\rightarrow$ Stress/Strain (for Actuators)
PZT has the best ferroelectric and piezoelectric performances at
morphotrophic phase boundary (MPB), where rhomboedral and tetragonal
phases coexist. MPB = Zr/Ti \sim 52/48
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
poLight TLens®
unique performance enables new use cases for smartphones not yet to be seen!

"We managed to replicate the human eye"
A piezoelectric thin film acts like the muscle
Device actuation

18 um thick glass (BPSG)

optical polymer droplet

back glass window

silicon

V
Optical power

OP: 0 dpt
Focus to infinite

Low voltage

BPSG
Soft polymer
Glass back window

High voltage

BPSG
Soft polymer
Glass back window

OP: 10 dpt
Focus to 10 cm
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