MEMS AT LETI: NEW TRENDS

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Head of Section – MEMS & Packaging
Outline

MEMS Activities overview

New trends:
- Issues related to consumer, wearable and IoT markets
- Solutions under development

Conclusion
**Microsystems Section**

**TECHNOLOGICAL PLATFORM**

- MEMS 8" (1000 m²) + FE 8" (3000 m²) Cleanrooms
- Specific MEMS equip.: DRIE, HF-vapor, bonder...
- 5 shifts working: 7 days/week – 24h/days

**Overall MEMS activities > 200 persons**

LCMC Lab.  
Sensors Components

LCMA Lab.  
Actuators Components

LCRF Lab.  
RF Components

LPI Lab.  
Packaging & Interposer

LCFC Lab.  
Characterization & Reliability
From MEMS design to system integration

MEMS Design → MEMS Technology → WLP & TFP Packaging → Electronic design → Characterizations → 3D assembly → Prototyping

Leti covers the whole chain of development
### MEMS devices 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 resonator
- 3-axis Compass
# MEMS devices background

<table>
<thead>
<tr>
<th>Gas sensor</th>
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<tbody>
<tr>
<td>NEMS-based + µGC gas sensor</td>
<td>µ-TOF Mass-spec for NRBC</td>
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<table>
<thead>
<tr>
<th>RF-MEMS</th>
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<tr>
<td>High-Q resonator (Si and HBAR)</td>
<td>Micro-switch</td>
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<tr>
<th>MEMS Actuator</th>
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<tr>
<td>Micro-valves</td>
<td>PZT-based Variable Lens</td>
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<tr>
<th>Energy harvesting</th>
<th></th>
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<tbody>
<tr>
<td>Piezoelectric AIN harvester</td>
<td>Electret-based harvester</td>
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</table>
# Technology background

## Nano-scale technologie

- NEMS resonator
- MEMS with nano-gap
- M&NEMS platform

## MEMS / CMOS Co-integration

- Above-IC co-integration
- Pre-CMOS co-integration

## Passive components integration

- 3D Integrated Capacitors
  - 500nF/mm²
  - (ALD medium k material – h=50µm)
- Electro-Magnetic Transformer
  - Breakdown 7.5 kV
  - $R = 4\Omega$, $L = 82\text{nH}$
- Magnetic core HF inductors (<100 MHz)
  - 10k[NIfe1µm / SiO2100nm]
- Magnetic shield RF inductors (2 -10 GHz)
  - CoFe/NI Mn exchange coupled material
Technology background

Hermetic packaging

Vacuum Wafer-level packaging & Getter
Thin-Film packaging

3D Technology

TSV-First (Poly-Si filled)
TSV-Mid (Cu-filled)
TSV last (Cu-liner)

3D Integration

Cu pillars (pitch 40µm)
Back to face interconnect
Thinning (20µm) & multi-die stacking (µ-bump or µ-insert)
Silicon Interposer
Smart Interposer

80µm thick interposer with embedded 3D capa

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Technology background

Material Expertise

Piezoelectric material
(actionneur, RF, high k)

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

Characterization Expertise

Residual Gas Analysis
Packaging reliability

Physics of contact
MEMS device & Passive component reliability

Electrical contact failure mechanisms
electromigration mechanisms,

« 3D » reliability

Thermal behavior, long term stability, resonance freq.,…
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Issues on Consumer/wearable/IoT market

Strong cost pressure

- Miniaturization
- Growing use of Combo sensors
- MEMS components
  - Well established
    - Accelerometer
    - Gyroscope
    - Magnetometer
    - Microphone
  - Sensor being adopted
    - Pressure
    - Humidity
  - Emerging MEMS
    - Autofocus
    - Gas sensor
    - Energy harvesting

Average Selling Price erosion by sensor function 2011-2017

From IHS / 2014
## Issues on Consumer/wearable/IoT market

### Strong cost pressure

### Miniaturization

### Growing use of Combo sensors MEMS components

- Well established
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### Typical package footprint for mobile devices sensors

<table>
<thead>
<tr>
<th></th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
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</thead>
<tbody>
<tr>
<td>Acc</td>
<td>4x4 mm²</td>
<td>3x5 mm²</td>
<td>3x3 mm²</td>
<td>2x2 mm²</td>
<td>1.6x1.8 mm²</td>
<td>1.6x1.8 mm²</td>
<td></td>
</tr>
<tr>
<td>Mag</td>
<td>2.5x2.5 mm²</td>
<td>4x4 mm²</td>
<td>3x3 mm²</td>
<td>2.2x2.2 mm²</td>
<td>2.4x2.4 mm²</td>
<td>3x3 mm²</td>
<td></td>
</tr>
<tr>
<td>Glo</td>
<td>4x4 mm²</td>
<td>2x2 mm²</td>
<td>1.6x1.8 mm²</td>
<td>2x2 mm²</td>
<td>3x3 mm²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-ax</td>
<td>4x4 mm²</td>
<td>2x2 mm²</td>
<td>1.6x1.8 mm²</td>
<td>2x2 mm²</td>
<td>3x3 mm²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-ax</td>
<td>4x4 mm²</td>
<td>2x2 mm²</td>
<td>1.6x1.8 mm²</td>
<td>2x2 mm²</td>
<td>3x3 mm²</td>
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*Component size is still decreasing*

- From Yole Development / 2013 -
Issues on Consumer/wearable/IoT market

Strong cost pressure
Miniaturization

Growing use of Combo sensors

MEMS components
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  - Accelerometer
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Combo vs. Discrete inertial sensor for consumer
2011-2018 market

Combo sensors will represent the majority of the market from 2016
- From Yole Development / 2013 -
**Issues on Consumer/wearable/IoT market**

- Strong cost pressure
- Miniaturization
- Growing use of Combo sensors

**MEMS components**

- **Well established**
  - Accelerometer
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- **Sensor being adopted**
  - Pressure
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- Emerging MEMS
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<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Example</th>
</tr>
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<tbody>
<tr>
<td>9-axis MEMS IMU (Bosch BMX055 – 5 dies)</td>
<td>[Image]</td>
</tr>
<tr>
<td>Microphone (Knowles SPA2629LR5H-B)</td>
<td>[Image]</td>
</tr>
<tr>
<td>Pressure sensor (ST LPS25H)</td>
<td>[Image]</td>
</tr>
<tr>
<td>Humidity sensor (Sensirion SHTC1)</td>
<td>[Image]</td>
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**No manufacturing standard**

1 Product = 1 Process
LETI’s Solution

Issues

- Strong cost pressure
- Miniaturization
- Growing use of Combo sensors

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Goal: “Generic”, efficient and reliable MEMS platform

- Innovative and high performances concept
- Unique Platform with the capability to address 11+ axis
- Differentiation: 20+ patents
M&NEMS "Generic" Platform

- Miniaturized sensors
- Generic platform
- Well known and robust piezoresistive detection
- Not sensitive to parasitics
- Strongly differentiated approach (20+ patents)

MEMS size inertial mass + Nano-size piezoresistive gauge

3-axis Accelero  3-axis Gyroscope  3-axis Magneto  Pressure sensor  High-SNR Microphone

2 New Innovative Sensors under development
M&NEMS "Generic" Platform

- 9-axis M&NEMS platform is currently being transferred to Tronics involving a Tier 1 pilot customer

- Tronics’ goals
  - 6DOF on a 4mm² die by 2014-2015
  - 9DOF on a 5 mm² die by 2015-2016
LETI’s Solution

**Issues**

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**LETI Solution**

- **Goal**: High optical quality & Low actuation voltage
- Liquid Lens
  + Piezoelectric actuation
- Startup creation
WAVELENS
PZT-based Variable Lens

- Optical aperture: from 1.6mm to 3mm (up to 20MP camera)
- Response time < 3ms
- Optical power variation: 10 diopters at 10V
- Consumption < 100µW
WAVELENS
PZT-based Variable Lens

0V / Focus at Infinity
LETI’s Solution

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LETI Solution

- **Goal**: High sensitivity and high selectivity gas detection

  NEMS Resonators
  + Gas Chromatography Column

- LETI / Caltech join development
- Startup creation
APIX
NEMS-based Gas Sensor

- 10 to 100x smaller
- Air gas carrier
- Sensitivity up to sub ppm

**Hydrocarbons**: industry, process monitoring, natural gas

**VOCs**: environment, hygiene & safety, air quality

LoD = 100's ppb
Outline

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Leti: the leading R&D institute on microsystems

- 30 years experience on MEMS
- 200 people involve on MEMS (sensor, actuator, RF, packaging, process, characterization)
- All 8” MEMS/NEMS technologies in-house
- 330 patents portfolio in the MEMS field
- 35 % under license or on co-ownership
- 35 new patents/year
- 25 on-going industrial collaborations
- 10 long-term strategic partnership
- 18 industrial transfers
- 5 startups creation
leti

a strong partner for innovation development research from technologies to applications,
in a dynamic and global environment