Murata 3D MEMS technology
Leti Days, July 3rd, 2018
Our Business
We are worldwide leaders in the design, manufacture and supply of electronic components and solutions.
We are Innovators in Electronics.

Our Strengths
• Advanced materials technology and expertise
• Broad product portfolio
• Extensive global manufacturing and sales network

Our Figures
• Net sales 1,135524 million JPY*
• Employees 59,978*
• Number of subsidiaries 97* (31 in Japan, 66 overseas)
• Established in 1944

*as of March 31, 2017
*Murata Manufacturing Co., Ltd. Is not included in the number of subsidiaries
Murata Finland, Operations

We design, develop, manufacture, test and deliver MEMS sensors with the world's best measurement accuracy and measurement repeatability, small size, extreme reliability and high performance.

Research & Development
Industry leading expertise in developing new technologies and products, including in-house design of MEMS, ASIC and packaging.

MEMS Manufacturing
Over 60 million silicon-based capacitive sensor elements are manufactured every year using MEMS (Micro Electro Mechanical Systems) processes in state-of-the-art cleanrooms (ISO 4, 5 and 8).

Assembly and Testing
Assembly of sensor components is carried out in ISO 7 and 8 cleanrooms, and testing in EPA* area.

*EPA=Electrostatic Discharge Protected area
## Product lineup

### Accelerometers & Inclinometers

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCA3300</td>
<td></td>
</tr>
<tr>
<td>SCA8x0/21x0/3100</td>
<td></td>
</tr>
<tr>
<td>T-series</td>
<td></td>
</tr>
<tr>
<td>SCC2000</td>
<td></td>
</tr>
<tr>
<td>SCC1300</td>
<td></td>
</tr>
<tr>
<td>SCR1100</td>
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</tbody>
</table>

High performance analog and digital accelerometers and inclinometers for safety critical automotive and industrial as well as healthcare applications

### Gyroscopes and Combined Sensors

<table>
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<th>Model</th>
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<tr>
<td>SCA10H</td>
<td></td>
</tr>
<tr>
<td>SCA11H</td>
<td></td>
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</tbody>
</table>

Gyros only or combined with accelerometers with excellent product features for automotive, industrial and healthcare applications

### Acceleration and Pressure Sensing Elements

Ideal for implantable medical devices, thanks to the inherent accuracy, reliability, small size and capacitive principle for low power solution

### Patient Monitoring Devices

<table>
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<td>SCA10H</td>
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</table>

Continuous contactless patient monitoring
Main markets & applications

We contribute to safer driving, higher quality of life and increased efficiency

**AUTOMOTIVE**

#1 in acceleration sensors for automotive active safety systems

- Electronic Stability Control (ESP/ESC)
- Advanced Driver Assistance Systems (ADAS)
- Hill Start Assistance (HSA)
- Electrically Controlled Susp. (ECS)
- Transmission Control (TCM)
- Electric Parking Brake (EPB)

**HEALTHCARE & MEDICAL**

#1 in activity monitoring in Cardiac Rhythm Management

- Pacemakers and ICDs
- Surgery tables and medical imaging
- Vital signs
- Bed occupancy
- Sleep quality, stress, relaxation

**INDUSTRIAL**

Wide range of sensing solutions across industries

- Construction tools and systems
- Heavy machines
- Structural health monitoring
- Weight scales
- Airplane instrument systems
- Robotics

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Vehicle Stability Control (ESC, ESP, VSC)

MEMS accelerometers and angular rate sensors utilized in ESC improve vehicle stability and safety on the road.

<table>
<thead>
<tr>
<th>Sensors</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCC2xxx Inertial</td>
<td>• Vibration robustness</td>
</tr>
<tr>
<td></td>
<td>• High performance</td>
</tr>
<tr>
<td></td>
<td>• Reliability</td>
</tr>
</tbody>
</table>

ABS* is not enough in a curve. ESC corrects for under- and over-steering. Yaw rate (Ω) and centrifugal acceleration (aT) from an angular rate sensor and a lateral acceleration from accelerometer are compared to those calculated from wheel speed and steering wheel angle.

*ABS = Anti-lock Braking Systems
Medical devices: pacemakers and ICDs

Murata acceleration and pressure sensing elements in pacemakers, ICD's and other implantable devices satisfy the strictest requirements:
- high reliability, stability and quality
- low power consumption, enabling <uA current consumption for 7-10 years battery life
- smallest possible size

<table>
<thead>
<tr>
<th>Applications</th>
<th>Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacemakers and ICD's</td>
<td>SCG-series accelerometer elements</td>
</tr>
<tr>
<td>Other implantable devices</td>
<td>SCB10H series pressure elements</td>
</tr>
</tbody>
</table>
Heavy machines

MEMS accelerometers and gyroscopes with excellent shock and vibration robustness.

<table>
<thead>
<tr>
<th>Main applications</th>
<th>Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavator scoop position</td>
<td>SCC2000</td>
</tr>
<tr>
<td>Bull-dozer blade control</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural machine auto steering</td>
<td>SCC2000</td>
</tr>
<tr>
<td></td>
<td>SCA3300</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Fork lift motion control</td>
<td>SCA3300</td>
</tr>
<tr>
<td></td>
<td>SCC2000</td>
</tr>
</tbody>
</table>
Best-in-class sensor performance

Murata 3D MEMS technology

- Stable capacitive sensing
- Single crystal silicon
- Thick, symmetrical 3D structures
- Glass cap wafer for insulation
- Hermetic sealing by wafer bonding
- Designs optimized for application requirements starting from operation principle

Superior product properties

High reliability
Best-in-class, proven measurement accuracy over lifetime in harsh environments (temperature, humidity)

High robustness
Excellent performance in vibrating environments, tolerates extreme mechanical shocks

Small size
Enabling design of smaller systems with lower costs

Low power consumption
High insulation resistance and large capacitance dynamics enable ultra-low current consumption circuit designs
MEMS process contributing to performance
C-SOI platform overview

Structure wafer
1. Cavity-SOI
2. Recess
3. Structure release

Cap wafer
1. Feed-through pillars
2. Glass process
3. Thin film process

Combined wafer
1. Anodic bonding
2. Cap wafer grinding
3. Metallization
MEMS Design contribution to performance
Example of X-gyro operating principle

- Capacitive linear comb structure between the masses excite and detect the anti-phase drive motion in plane of the wafer
- Out of plane displacement induced by rotation is double differentially detected by capacitive electrodes over the masses

\[ \Omega \]

\[ F_c \]

\[ \text{Y-Rotation} \rightarrow \text{Coriolis effect} \]
System architecture contributing to performance

- Figure: Block diagram of closed-loop sense resonator
  - Element: Secondary resonator (Q=50-500) with feedback electrode
    - Both primary resonance and secondary resonance designed at f0
      - No active resonance matching is needed
    - ASIC: Continuous-time CtoV-converter and high-Q (3-10) LPF with resonance frequency (f0) same as that of the element
    - Positive DC feedback
### Some performance metrics for reference

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Product SCC2XXX</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate noise density</td>
<td>0.008°/s /√Hz</td>
<td>Short term positioning</td>
</tr>
<tr>
<td>Rate bias instability</td>
<td>2 °/h</td>
<td>Long term integration</td>
</tr>
<tr>
<td>Rate offset error</td>
<td>±1.0°/s</td>
<td>Can be compensated partly</td>
</tr>
<tr>
<td>Rate sensitivity error</td>
<td>2%</td>
<td>Dynamic angle estimation</td>
</tr>
<tr>
<td>Accel offset error</td>
<td>± 50 mg</td>
<td>Angular accuracy &lt; ± 5 mg (SCA103T)</td>
</tr>
<tr>
<td>Accel sensitivity error</td>
<td>± 20 mg</td>
<td>Contributes in multi-axis and larger angles (max. value, @ 1g)</td>
</tr>
</tbody>
</table>

### Other values:
- Robustness (vibration)
- Environmental conditions
- Error tolerance
- Safety (ISO26262)
Murata 3D MEMS technology

- Capacitive sensing principle, Cavity-SOI technology, DRIE etching
- Wafer level capping and packaging for chip scale system in package
- Innovative accelerometer and gyro designs and detection architectures

Resulting in robust, small sized MEMS and low power products