Status of the MEMS industry: How mobile phone and high end applications are reshaping the MEMS business.
Yole Développement is a market, technology and strategy consulting company, founded in 1998. We operate in the following areas:

- Power Electronics
- Advanced Packaging
- MEMS & image sensors
- Photovoltaic
- Microfluidic & Med Tech
- Equipment and materials
- HB LED, LED & LD

Our expertise is based on research done by our in-house analysts, conducting open-ended interviews with most industry players.

- 30 full time analysts with technical and marketing degrees
- Primary research including over 3,500 interviews per year
Mission Statement: Knowledge-Based Company

• Help our customers develop their business through specific analysis, reports & services providing:
  – Accurate market data, market segmentation and marketing analysis
  – Technology evaluation; cost estimates and COO analysis
  – Patent portfolio analysis, licensing strategy and implementation
  – Identification of strategic development opportunities for companies and business units
  – Support for M&A, due diligence, and identifying new investors
  – Advertising opportunities in YOLE magazines, webcasts and specific events

• You get operational results from Yole analysis and actions
4 Business Models

• Custom Analysis:
  – Largest part of Yole activities
  – Covered by NDA agreement
  – A few days to several months of work, depending on objectives

• Published Reports:
  – An average of 40 reports published every year
  – Available individually or through Annual Subscription Program
  – Market and technology reports, Patent analysis, Reverse Engineering/Costing reports and Reverse Costing tools

• i-Micronews Media:
  – Newsletters and webcasts on 3D, MEMS, Power electronics, LED and imaging
  – Advertising services providing access to our 45 000+ subscribers to be visible and diffuse information on your company and products

• Yole Finance services:
  – M&A (buying and selling)
  – Due diligence
  – Fund-raising services
Our Global Activity

- 30% of our business is in North America
- 40% of our business is in EU Countries
- 30% of our business is in Asia
Some of Our Customers

Financial investors & industry advocates

Suppliers (equipment, wafers, materials)

Component manufacturers

Integrators, system suppliers & end users

R&D Organizations
MEMS MARKET TRENDS
An Expanding Array of Products
maturity of selected MEMS devices
with expected CAGR to 2015

Emerging

Development

Mature

Decline

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Continued Strong Growth
2011-2017 Forecast (in US$M)

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TOP 30 MEMS Players

Global ranking

2011 TOP 30 MEMS Players
Yole Développement March 2012

© April 2012

Yole Developpement
TOP 30 MEMS Foundries

Global ranking

2011 MEMS Foundries Ranking
Yole Développement March 2012

US$M

- STM
- SONY
- DASA
- IMT
- TSMC
- TI
- Xtab
- MICRALYNE
- TOUCH MICROSYSTEMS
- SEMEFA
- Honeywell
- SVTC
- Sensonor
- Tower Jazz
- UMC
- OLYMPUS
- SMIC
- Micrel
- Global Foundries
- Colibris
- Ohsion
- DNP

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“Alpha” MEMS Companies
Top 4 suppliers have >50% market share in 5 different CE MEMS markets

Top MEMS Suppliers in the Mobile Phone and Tablet Market
- 2011 Revenue ($M) - Breakdown by Product Type -
MEMS in cell phones and tablets
Application segment breakdown
-2011 - total = $1.7B

- Silicon microphones / Pressure sensors: 16.8%
- Optical components: 0.4%
- Other emerging sensors: 0.1%
- RF Devices: 21.6%
- Motion sensors: 61.1%

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2009-2011 market shares evolutions
ST is growing, Avago decrease InvenSense appears
2011 market shares for discrete inertial sensors

3-axis accelerometer in mobile phones and tablets - 2011 market share
- Total = $362.7M -
- Note: accelerometers in combos not counted -
Yole développement © March 2012

3-axis gyroscope in mobile phones and tablets - 2011 market share
- Total = $334.6M -
- Note: gyroscopes in combos not counted -
Yole développement © March 2012

3-axis magnetometer in mobile phones and tablets - 2011 market share
- Total = $325.7M -
- Note: magnetometers in combos not counted -
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- Note: magnetometers in combos not counted -
Yole développement © March 2012
Making Money in MEMS
microphone estimation

MEMS Microphone Cost Structure in 2012

- Gross margin (S&M, G&A, R&D, Op margin): 43.0%
- MEMS die: 16.5%
- ASIC die: 11.6%
- Final packaging: 25.2%
- Test & yield losses: 3.6%

2012: $508M; 1.4B units
### 2011 Key MEMS Player Activity Estimate

<table>
<thead>
<tr>
<th>Category</th>
<th>Company Names</th>
<th>Revenue Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabless / Fab-light</td>
<td>HP, Texas Instruments, Bosch, Analog Devices, Panasonic, Epson, Canon, Avago Technologies, Denso, Lexmark, SiTime</td>
<td>~$2B</td>
</tr>
<tr>
<td>IDMs</td>
<td>Texas Instruments, STI, TSMC, Silex Microsystems, Freescale, InvenSense, Infineon, RoHM, TDK</td>
<td>~$8B</td>
</tr>
<tr>
<td>ASIC foundries</td>
<td>TSMC, STI, Texas Instruments, Silex Microsystems, EnSilicon, sensoror, Sensonor</td>
<td>~$0.4B</td>
</tr>
<tr>
<td>MEMS foundries</td>
<td>XinTec, Teramikros, JCAP, JCAP, UMC</td>
<td>~$1B</td>
</tr>
<tr>
<td>WLP houses</td>
<td>XFC, TSMC, JCAP, Flexible Power, APM</td>
<td>~$430M</td>
</tr>
<tr>
<td>BE &amp; Test houses</td>
<td>KYEC, FREP, LINGSEN, MEM Hitech, Unisem, Freescale, epic, APM</td>
<td>~$250M</td>
</tr>
<tr>
<td>OSATs</td>
<td>Amkor Technology, Shinko, Shinko, KYOCERA, Unimicron, OakMitsui, Tship, Tecnico, NEC/Schott, Planck, JG Devices, UTAC</td>
<td>~$0.4B</td>
</tr>
<tr>
<td>Substrate houses</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Revenue estimates related to MEMS*
Next Wave of MEMS

Oscillators + micromirrors + displays + switches & variable capacitors + temperature sensors + AF + microspeakers + other emerging MEMS

From $13M to $2.3B market (2017)
(in cell phones and tablets)
**Emerging MEMS Overview**

- **Established MEMS includes:**
  - InkJet Heads, Pressure Sensors, Microphones, Accelerometers, Gyroscopes, Magnetometers, Inertial combos, Microbolometers, Other optical MEMS, Other RF MEMS (BAW...), Microfluidics for Research, Microfluidics for IVD, Microdispensers (microfluidics)

- **Emerging MEMS includes:**
  - PIR & Thermopiles, Microdisplays, Micromirrors for mobile phone and tablet embedded picoprojectors, Auto focus, RF MEMS switch & varicap for mobile devices, Oscillators, Others (microstructures, micro speakers...)

**2011 - 2017 MEMS market (M Units)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Emerging MEMS</th>
<th>Established MEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>142</td>
<td>5 775</td>
</tr>
<tr>
<td>2012</td>
<td>234</td>
<td>7 135</td>
</tr>
<tr>
<td>2013</td>
<td>368</td>
<td>8 754</td>
</tr>
<tr>
<td>2014</td>
<td>615</td>
<td>10 378</td>
</tr>
<tr>
<td>2015</td>
<td>1 139</td>
<td>12 054</td>
</tr>
<tr>
<td>2016</td>
<td>1 792</td>
<td>13 941</td>
</tr>
<tr>
<td>2017</td>
<td>2 620</td>
<td>16 181</td>
</tr>
</tbody>
</table>

**2011 - 2017 MEMS market ($M)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Emerging MEMS</th>
<th>Established MEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>$339M</td>
<td>$9 896M</td>
</tr>
<tr>
<td>2012</td>
<td>$445M</td>
<td>$11 065M</td>
</tr>
<tr>
<td>2013</td>
<td>$639M</td>
<td>$12 182M</td>
</tr>
<tr>
<td>2014</td>
<td>$956M</td>
<td>$13 740M</td>
</tr>
<tr>
<td>2015</td>
<td>$1 523M</td>
<td>$15 011M</td>
</tr>
<tr>
<td>2016</td>
<td>$2 080M</td>
<td>$16 554M</td>
</tr>
<tr>
<td>2017</td>
<td>$2 803M</td>
<td>$18 448M</td>
</tr>
</tbody>
</table>
### Emerging MEMS

#### Application breakdown

<table>
<thead>
<tr>
<th>Application Description</th>
<th>2011 market ($M)</th>
<th>2017 market ($M)</th>
<th>2011-2017 CAGR</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIR &amp; Thermopiles</td>
<td>$61M</td>
<td>$107M</td>
<td>9.8%</td>
</tr>
<tr>
<td>Microdisplays</td>
<td>$5M</td>
<td>$261M</td>
<td>91.0%</td>
</tr>
<tr>
<td>Micromirrors for mobile phone and tablet embedded picoprojectors</td>
<td>$1M</td>
<td>$434M</td>
<td>188.6%</td>
</tr>
<tr>
<td>Auto focus</td>
<td>$0M</td>
<td>$327M</td>
<td>-</td>
</tr>
<tr>
<td>RF MEMS switch &amp; varicap for mobile devices</td>
<td>$1M</td>
<td>$220M</td>
<td>160.4%</td>
</tr>
<tr>
<td>Oscillators</td>
<td>$24M</td>
<td>$463M</td>
<td>63.6%</td>
</tr>
<tr>
<td>Others (microstructures, micro speakers...)</td>
<td>$247M</td>
<td>$991M</td>
<td>26.0%</td>
</tr>
</tbody>
</table>

Note: Microbolometers were counted as emerging MEMS in our previous forecasts. Now this is not considered as emerging MEMS anymore.
MEMS Autofocus for Consumer Camera Modules
A new killer application for MEMS starting in 2013

- By 2017, we believe the WLAF market could be a $330M market, mostly for cell phones
- Existing players are in a product introduction phase and new players are emerging:
  - PoLight is expected full volume production beginning of 2013
  - Lensvector and Tessera Digital Optics are developing new products
  - WaveLens is a start up from CEA LETI. Wafer level liquid lens technology is developed both for visible auto focus and for infrared autofocus
  - Other players could appear. Rumors about MEMS AF development at several large Mems manufacturers…

› Piezo MEMS option:
  - Polight development (production 2012)
  - Very small size
  - Very fast
  - But degrades image quality (because a lens is added), but less degradation than with Liquid Crystal
  - Could be more expensive than VCM

› MEMS actuator option:
  - Tessera DOC development
  - Silicon actuator (2nd generation). Tessera keeps investing this year, but success is not sure
  - Low power consumption
  - But fragile & expensive
  - Different designs are needed at the system level (only one lens moved, not entire set of lenses)
Increasing Interest for Temperature and humidity Sensors

- **Low cost temperature sensors are commodity products**
  - Offered by TI, Maxim… (not MEMS technologies). E.g. Motorola Droid RAZR integrates a digital temperature sensor from TI
  - Combination with humidity sensors is also of interest for some mobile applications

- **Sensirion is a leading manufacturer of temperature and humidity sensors**
  - 300 employees
  - Largest markets are industrial, automotive for mass flow sensors and pressure sensors
  - Sensirion started to supply temperature + humidity sensors to Lenovo phones in China (low volumes)

- **MEMS vision is a new startup involved in this space**
  - Humidity sensors based on SiC MEMS above CMOS technology

- **This type of sensor has a bright future in mobile devices**
  - Smaller, cheaper version are expected (now less than $1 in volume)
  - Specific Android APIs from Android 4 have been developed → market can take off more easily (various uses: applications such as mobile weather station, sports, cosmetic – sense humidity of skin, user interface…)

Humidity Sensor SHT21

MEMS vision digital humidity and temperature sensor
MEMS Thermopiles Enable New Markets
E.g. Texas Instrument, Omron, Panasonic

- Texas Instrument introduced an infrared thermopile in 2011
  - Manufacturing on a 6 inch fab. CMOS is done first, then MEMS thermopiles on top of it
- Omron and Panasonic have announced Mems based thermopile simple imager for mobile applications
- Many different applications are being developed
  - This does not sense ambient temperature but temperature of objects (contact-less). Not really the same use as temperature sensors
  - Body heat is the next application
  - But many other applications are developed by users now
- Smartphone application is on the roadmap of all these manufacturers
  - Can IR imaging be implemented in a mobile phone?
Change in the market situation

• Because of the increase of the competition among Mems companies, all Mems manufacturers are searching to propose more devices to existing customers

• It drives also the interest on these new emerging devices from large companies
STMicroelectronics Partners

5 types of collaborations

High volume foundry customers with specific agreements (co-design...)

HP
Inkjet heads
Co-development, ST manufactures component
1998: Beginning of collaboration

Kodak
Inkjet heads
Cross Licensing with HP ST manufactures the entire head
Collaboration since end 2006 -- beg 2007 (never announced)

→ For HP: 6 inch fab in Singapore + 8 inch fab in Italy (more recently: for fixed heads)
→ For Kodak: 8 inch fab in Italy

New foundry customers

DEBIOTECH
Insuline nanopump (microfluidic)
Co-design, ST supplies sensor
2007: Beginning of collaboration
2010: commercialization

bTendo
Pico projector (mobile phones)
Co-design, production and promotion by ST
2011: beginning of collaboration

bluechip
Tracking tags (Biobanks)
Co-design, ST supplies components
2011: beginning of collaboration

VEREDUS
Lab on chip (microfluidic)
Co-development, ST supplies the chip
2009: development and design
2011: successful deployment

SENSIMED
Smart contact lens
Co-development, ST supplies components (pressure sensor + WLP)
2010: production

MAYO CLINIC
Platform for the remote monitoring of patients
Co-development, ST supplies components
2009: collaboration announcement

→ 8 inch MEMS foundry in Italy

Component sourcing

Honeywell
Inertial combo (6+ freedom degrees)
Honeywell supplies magnetometer wafers
2010: commercialization

OMRON
Microphone, gas meter flow sensor
Co-design, OMRON supplies key component
2009: collaboration for microphone
2010: microphone release, collaboration for gas meter

Technology providers (software licensing / production tools)

CEA-LETI
R&D collaboration
Started before 2000

PNI Corp
(not announced, not verified)
Software license from PNI for sensor fusion

SOUNCHIP
High precision personal audio system
Full production & commercialization, ST licenses Soundchip technology and gives access to design software
2011: beginning of collaboration

SPEA
Test bench development collaboration
2003: Beginning of collaboration

Customers / Partners for reference designs

CSR
Indoor navigation
Co-development, sensors by ST, fusion application by CSR
2012: application demonstration

FOXCONN
Camera stabilization
Co-design, ST supplies components
2011: beginning of collaboration

Motion sensor software for windows 8
Co-development of software
2011: release of software
The MEMS market is on a growing curve again and many changes are happening on the technical side, business model side and supply chain side.

- 20% CAGR in units
- 13% CAGR in revenues
- To become a $21 billion market by 2017.

Every year brings new business to the MEMS landscape.

- Today, combo sensors are reshuffling the cards in the motion sensing business
- But the MEMS market is still very fragmented, with a number of high volume MEMS applications still limited today

However, a whole range of new MEMS devices has now reached the market and new “emerging MEMS” devices are coming as well:

- Some of them have the possibility to ramp up to large volumes quickly: those that can be applied to mobile devices (RF MEMS switches, oscillators, auto-focus…)
- Both sensors (humidity, touchscreen,…) and actuators (switches, energy harvesting…) are driving future growth
- In addition to those emerging MEMS, growth of the MEMS market will come from existing sensors that are expanding into new market spaces, sometimes using new types of integration: e.g. pressure sensors for consumer.
• Please give me your business card if you want to get an electronic copy of this presentation.

• If you have questions, please come and discuss with us!
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