MEMS industry: Overall market status and Russia position

Semicon Russia 2015
Jérôme Azémar
Senior Technology and Market Analyst
azemar@yole.fr
PLAN

• Past: What do we learn from half-a-century of MEMS?

• Present: Where we are now?

• Future: MEMS industry game changers.

• Where is Russia in that playground?
The MEMS industry required high degrees of flexibility and innovation in order to constantly adjust to the rapid pace of change in the market.

**First Bell Labs transistor, 1947**

**1959, piezoresistive Si (Kulite)**

**1960s, sensor products from Honeywell, Fairchild**


**HALF A CENTURY OF MEMS HISTORY**

Key milestones of MEMS industry

- **1960s, sensor products from Honeywell, Fairchild**
- **1977, TI DLP research started**
- **1979, µmachined Ink Jet nozzle**
- **1987, ADI ships to Saab (50k)**
- **1993, TI DLP product**
- **1994, Bosch DRIE invented**
- **2003, Invensense founded**
- **2006, 8” MEMS line (ST)**
- **2007, MEMSiC IPO**
- **2009, Knowles Bunits shipments**
- **2010, Invensense $100M sales**
- **2012, STM 1st company to reach $1B MEMS sales / 9DOF**
- **2013, Bosch number one top MEMS vendor (Apple)**
- **2015, your story …**
- **2015, your story …**

MPU-6500 from Invensense (S+C source)

2013, Bosch number one top MEMS vendor (Apple)

2012, STM 1st company to reach $1B MEMS sales / 9DOF

2010, Invensense $100M sales

2010, 3A gyro single sensor design (ST)

2009, Knowles Bunits shipments

2007, MEMSiC IPO

2006, 8” MEMS line (ST)

2003, Invensense founded

2000, Optical MEMS bubble

2000, Optical MEMS bubble

1994, Bosch DRIE invented

1994, TI DLP product

1993, ADI ships to Saab (50k)

1987, ADI starts accelerometer effort
2000-2020 MEMS MARKET ($M)
A continuous growth over 20 years

A continuous growth (x5 in 20 years) without the IC cyclical pattern with high volatility

We are here …

The consumer wave is starting

2000-2020 (est.) MEMS Markets ($M)
Source Yole Développement
2000-2020 MEMS MARKET (MUNITS)
20% CAGR over 2004-2020

In 2030, a MEMS ASP at $0.3 ?
(Already a reality for accelerometers)
MEMS & SENSORS ROADMAP

From More than Moore towards Beyond Law

MEMS & Sensors enable key functionalities

Industry competition
Moore
Processing
Information age

Industry competition
More than Moore
Sensing
Interaction age

Industry Competition
Beyond Moore
Actuating
Enhancement age

Personal Computers
1980

Laptop
2010

Smartphones
Tables
Smart homes
Quantified self
Drones

Autonomous vehicles
Robotic Servants

Telekinesis
2040

Acceleration
MEMS market will almost double in value between 2014 & 2020 (we exclude glass/polymer-based microfluidics chips)

11.2% CAGR over 2015–2020
MEMS shipments will almost triple from 2014 to 2020 (we exclude glass/polymer-based microfluidics chips)

**MEMS market forecast shipments (in M units)**

©2015 Yole Développement - April 2015

- Oscillators
- RF MEMS
- Microdispensers (microfluidics)
- Other optical MEMS
- Projection systems
- Micro displays
- PIR & Thermopiles
- Microbolometers
- Inertial combos
- Digital Compass
- Gyroscopes
- Accelerometers
- Microphones
- Pressure Sensors
- InkJet Heads

17% CAGR over 2015–2020
Consumer is still the main driver

MEMS $M forecast per application
©2015 Yole Développement - April 2015

Consumer (incl. wearable) is more than 60%
This ranking shows a clear emerging of what could be a future “MEMS Titan”: Robert Bosch.

$400M difference between first & second.
TOP 30 MEMS PLAYERS POSITIONING

MEMS business size vs. 2014/2013 CAGR

Most of the MEMS players had a positive growth between 0 & +10%
TOP 30 MEMS PLAYERS POSITIONING

Device vs. System makers & number of MEMS devices: The 3 « Great Walls of MEMS » rule!

Entering the MEMS business and being successful is a long & complex process!
What will / could change the future of MEMS?

- **NEW DEVICES & APPLICATIONS:**
  - New large volume markets (wearables, IoT …)
  - Pressure sensors for consumer
  - New MEMS devices such as gas sensors
  - A shift in value from Si (material) to the full solution (sensor fusion – brain!)

- **NEW DISRUPTIVE TECHNOLOGIES / DESIGN:**
  - Packaging solutions e.g., TSV
  - New materials (e.g., thin film PZT for microphone, industrial IJH, autofocus …)
  - 300mm MEMS line(s) for large volume to lower cost
    - But only a few companies can afford such investment (at least 3 industrial projects worldwide)
    - Which rationale?
  - From MEMS to NEMS
  - Further integration (e.g., optical MEMS)

- **NEW PLAYERS:**
  - Emerging MEMS foundries in China
    - Many MEMS foundry projects being built
    - At least $150M+ invested in MEMS
  - The entry of a major player coming from the semiconductor to compete with the big 3
  - Is there a room for Russia?
EXAMPLE OF EMERGING APPLICATION: CHEMICAL & GAS SENSORS

Air quality is becoming a priority.

MEMS is not a new detection principle but a new manufacturing platform that allow cost reduction/miniaturization of existing technologies.
FROM MICRO MACHINES TO NEMS

Smaller, smaller & smaller …

For chemical & inertial sensors, NEMS are already products.
Packaging has been the workhorse of many MEMS players.

TSV IN MEMS

2014/15 market status (courtesy of Yole Advanced Packaging team)
3-AXIS ACCELEROMETER PACKAGE SIZE COMPARISON

TSV in consumer products

TSV achieve 55% package reduction size

<table>
<thead>
<tr>
<th>Mfr.</th>
<th>Component Ref.</th>
<th>Package Size</th>
<th>Wire bonding Nb</th>
<th>ASIC/MEMS Dies Connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>STMicroelectronics</td>
<td>LIS2DH</td>
<td>2.0x2.0x1.0mm</td>
<td>22</td>
<td>Die level: Wire bonding</td>
</tr>
<tr>
<td>mCube</td>
<td>BI3L</td>
<td>2.0x2.0x0.9mm</td>
<td>8</td>
<td>Wafer level: Fusion bonding</td>
</tr>
<tr>
<td>Bosch Sensortec</td>
<td>BMA355</td>
<td>1.2x1.5x0.8mm</td>
<td>8</td>
<td>Die level: Wire bonding</td>
</tr>
</tbody>
</table>

Bosch achieved 55% in package reduction and has the thinner package (0.8mm)

STST = S_{mCube} > SBosch
TST > T_{mCube} > TBosch

Surface: STST = 4mm²
Package thickness: TST = 1mm

Surface: S_{mCube} = 4mm²
Package thickness: T_{mCube} = 0.9mm

Surface: SBosch = 1.8mm²
Package thickness: TBosch = 0.8mm
MEMS ON 12 INCHES

Does it make sense?

- The logic behind is different from the IC world → no transistor shrinkage.
- Going 300 mm would bring numerous challenges:
  - It takes time to have good production yields
  - Tools are 40-50% more expensive / 200 mm
  - Cleaner environment / 200 mm could be required
  - Are volumes large enough?
    - For a 2x2mm² MEMS, 1Munits = 1 wafer (30) lot!
    - For 20Bunits (total MEMS market) = 660k 12” wafers.

- BUT it could make sense:
  - More dies/wafer for same number of steps
  - Less tools required
  - Sensor fusion requires complex ASIC at 0.13µm node (most CD are 0.18µm today, going 0.13µm needs 300 mm).

- By moving 300mm, a major player could capture most of the MEMS foundry business worldwide.
SENSOR FUSION

New challenges ahead

• Value is in the **solution**, not in the silicon anymore.

• Improvements expected at the **hardware level** (e.g. power management ...).

• Which **architecture**: fusion at the sensor level, at the sensor hub MCU level, at the processor level ...?

• Software developments should be tailored for precise end-applications and the **technology has to be adapted to the user**, not the opposite.

• An **ecosystem** needs to be put in place involving the development of specific applications.
WEARABLE ELECTRONIC & IOT

Requiring sensor fusion / processing

• Fitness / activity monitoring, healthcare, sports applications
• In many cases the sensor acts as a hub

Wearable electronics is a new big opportunity for sensors

Apple watch (2015)
→ Integrates accelerometer + gyro + magnetometer + pressure

Moto 360 by Motorola (End 2014)

Pebble Watch (0.4 MUnits sold in 2013)
→ Features STMicroelectronics accelerometer
INDUSTRIES EVOLVE THROUGH FOUR STAGES …

MEMS are today at the early Focus Stage (adapted from HBR 2002/Toshiba 2008)

An industry moves through 4 stages in ~25 years

- **Opening Stage**
  - Generally begins with single player
  - Top 3 holds 10-30% market share

- **Scale Stage**
  - About building scale thru consolidation
  - Top 3 holds 15-45% market share

- **Focus Stage**
  - Ferocious consolidation, key players expand
  - About 5-12 players
  - Top 3 holds 35-70% share

- **Balance & Alliance**
  - Titans emerge
  - Top 3 typically hold 70-90% market share

The MEMS Industry today!
New opportunities?

Who will be tomorrow’s MEMS titans?
EMERGING MEMS COUNTRIES: RUSSIA?

Investment initiatives but no clear visibility

• Current visibility out of Russia: Is there a real MEMS industry?
  • Few players identified and essentially laboratories: St-Petersburg University, etc…
  • No real international presence: No volume product, few papers.

• Can Russia make an entrance in MEMS?
  • Strong skills in materials
  • Long history and know-how in semiconductors industry (Mikron, etc…)
  • High potential financial support from Russian government and industry
  • European partnerships already exist
  • High demand from European markets to not be dependent of Asia (Already visible in Advanced Packaging)

• Another country is showing an example: China

• MEMS Market will be possible only if strong local support and market are available and if there is no further waiting (Is it too late?)
EMERGING MEMS COUNTRIES: CHINA

Examples of MEMS players & foundry investment initiatives

China, the most dangerous threat for MEMS foundry business?

- **SHR Automation**
  - MEMS foundry project
  - MEMS pressure
  - Inertial
  - MEMS tools
  - Inertial
  - Inertial

- **China National Machinery**
  - $160M investment
  - Microphones
  - MEMS foundry project

Examples of MEMS players & foundry investment initiatives:

- SHR Automation
- China National Machinery
- Microphones
- $160M investment
CONCLUSIONS

• New challenges ahead for the MEMS industry …

• We reached a landmark with the smartphone industry, the growth ahead will call for new tech challenges.

• We have seen different market leaders in the past and the competition is still very open.

• There are opportunities for future investment cycles (software, 300 mm – risky -, new detection approaches, new sensors …).

• Russia seems to have missed the market for long time but has internal know-how
Any question?
RELATED REPORTS

- Information in this presentation is extracted from the following reports:
  - Status of the CMOS Image Sensors Industry
    Released in Jan. 2015
  - Status of the MEMS Industry
    Released in May 2015
ABOUT THE AUTHOR

Biography & contact

Jérôme Azémar

- Jérôme Azémar is a Senior Technology & Market Analyst and Business Developer at Yole Développement. As an analyst, Jérôme provided numerous market research and strategy analysis on Power Electronics, Compound Semiconductors, Advanced Packaging and Semiconductor Manufacturing and he performed several presentations and market briefings in semiconductors conferences.

Upon graduating from INSA Toulouse with a master’s in Microelectronics and Applied Physics, he joined ASML and worked in Veldhoven for three years as an Application Support Engineer, specializing in immersion scanners. During this time he acquired Photolithography skills which he then honed over a two-year stint as a Process Engineer at STMicroelectronics. While with ST he developed new processes, co-authored an international publication and worked on metrology structures embedded on reticules before joining Yole Développement in 2013.

azemar@yole.fr
Yole Développement

From Technologies to Market
FIELDS OF EXPERTISE

Yole Développement’s 30 analysts operate in the following areas

- Imaging
- Photonics
- MEMS & Sensors
- Compound Semi.
- LED
- Power Electronics
- PV
- MedTech
- Manufacturing
- Advanced Packaging
4 BUSINESS MODELS

- Consulting and Analysis
  - Market data & research, marketing analysis
  - Technology analysis
  - Strategy consulting
  - Reverse engineering & costing
  - Patent analysis

- Reports
  - Market & Technology reports
  - Patent Investigation and patent infringement risk analysis
  - Teardowns & Reverse Costing Analysis
  - Cost Simulation Tool

- Financial services
  - M&A (buying and selling)
  - Due diligence
  - Fundraising
  - Maturation of companies
  - IP portfolio management & optimization

- Media
  - i-Micronews.com website
  - @Micronews e-newsletter
  - Technology magazines
  - Communication & webcast services
  - Events

www.yole.fr
www.i-Micronews.com/reports
www.yolefinance.com
www.bmorpho.com
A GROUP OF COMPANIES

Market, technology and strategy consulting
www.yole.fr

M&A operations
Due diligence
www.yolefinance.com

Fundraising
Maturation of companies
IP portfolio management & optimization
www.bmorpho.com

Manufacturing costs analysis
Teardown and reverse engineering
Cost simulation tools
www.systemplus.fr

IP analysis
Patent assessment
www.knowmade.fr
40% of our business is in EU countries
30% of our business is in Asia
30% of our business is in North America
Our analysts provide market analysis, technology evaluation, and business plan along the entire supply chain.
CONTACT INFORMATION

- **Consulting and Specific Analysis**
  - North America: Steve LaFerriere, Director of Northern America Business Development, Yole Inc.
    Email: laferriere@yole.fr
  - Japan: Yutaka Katano, General Manager, Yole Japan & President, Yole K.K.
    Email: katano@yole.fr
  - EMEA: Jerome Azemar, Senior Analyst and Business Development Manager, Yole Développement
    Email: azemar@yole.fr
  - RoW: Jean-Christophe Eloy, President & CEO, Yole Développement
    Email: eloy@yole.fr

- **Report business**
  - North America: Steve LaFerriere, Director of Northern America Business Development, Yole Inc.
    Email: laferriere@yole.fr
  - EMEA: Jerome Azemar, Senior Analyst and Business Development Manager, Yole Développement
    Email: azemar@yole.fr
  - Japan & Asia: Takashi Onozawa, Sales Asia & General Manager, Yole K.K.
    Email: onozawa@yole.fr
  - Korea: Hailey Yang, Business Development Manager, Korean Office
    Email: yang@yole.fr

- **Financial services**
  - Jean-Christophe Eloy, CEO & President
    Email: eloy@yole.fr

Follow us on