BioMEMS & Emerging Non-Invasive Biosensors: Microsystems for Life Sciences & Healthcare

2018 report

Courtesy of DunAn Microstaq, Inc.
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- Technology challenges at the sensor level
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- Power consumption challenges
- Biocompatibility and materials
- Sensor performances

## Changes in Business models

- From sensor to integrated solutions – Complexity leading to changes in the supply chain
- Focus in the microfluidics field
- The fight to acquire value

## Description of MEMS components, applications and supply chain

- Pressure sensors
- Microphones
- Accelerometers
- Gyroscopes
- Temperature sensors
- Optical MEMS
- Microfluidic chips - Microdispensers
- Flow sensors
- Gas sensors
- Emerging MEMS
  - Neural implants
  - Ultrasound sensors

## Conclusions

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Asma Siari graduated with an Advanced Master’s degree in International Strategy & Marketing BtoB from EM Lyon Business School (France).

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OBJECTIVES OF THE REPORT

• This is Yole Développement 2018 update of BioMEMS market and technologies report for Life Sciences & Healthcare.

• Report objectives:

  • Provide forecast metrics for each BioMEMS sensor:
    • BioMEMS market revenue and volume shipment forecasts at the sensor level for each sensor type and at global level
    • BioMEMS sensors’ ASP forecast, revenue forecast, volume shipments forecast
    • Dynamic of the market

  • Deliver an in-depth understanding of the ecosystem and players
    • Who are the players from the various areas: foundry, IDM, packaging, system level integrator, etc.
    • Who are the key suppliers, position in the supply chain and market share

  • Explain the key drivers of Life Sciences & healthcare transformation
    • A focus on the new trends: mHealth, IoMT, wearables…
    • Description of the societal, economical and technical impact

  • Share key technical insights and analysis on future technology trends and challenges
    • The industry’s state-of-the-art technologies
    • Emerging technologies and roadmaps: non-invasive sensors, emerging MEMS
WHO SHOULD BE INTERESTED IN THIS REPORT?

- **MEMS companies**
  - To have a broad overview of all bioMEMS applications & markets
  - To identify new markets and growth opportunities
  - To monitor and benchmark potential competitors
  - To understand market and technology trends

- **R&D players**
  - To understand new challenges in bioMEMS

- **Equipment & Material suppliers**
  - To understand the technical evolution of bioMEMS devices.
  - To identify business opportunities and prospects

- **Financial & Strategic investors**
  - To understand the potential for bioMEMS devices
  - To know the latest moves within the industry
  - To get a list of bioMEMS players and their activities

- **OEMs & System Integrators**
  - To evaluate benefits of using bioMEMS in your systems
  - To know the top players for each type of devices
LIST OF COMPANIES MENTIONED IN THIS REPORT

300+ slides of market and technology analysis


And many others…

Information gathered through direct discussions with players all along the supply chain
Cost of care

- Cost of care is exponentially increasing from people managing their health to complex chronic disease and acute care. If acute disease are not manageable, chronic disease need to be controlled.
- The challenge for health organizations is to make people staying on the left side.
GLOBAL HEALTHCARE TRANSFORMATION

(Bio)MEMS devices will participate to healthcare transformation

• A MEMS device – Micro ElectroMechanical Systems – is a component made by semiconductor processes with successive photolithography and etching process steps on silicon, glass or quartz substrates.

• A BioMEMS device is a MEMS device involved in life science and healthcare applications. A specific focus is made on medical-grade products integrating bioMEMS devices.

Focus on a MEMS Spectrometer used for point of care testing: illustration of the MEMS dies, MEMS chip and Spectrometer module; Source: Si-Ware
GLOBAL HEALTHCARE TRANSFORMATION

BioMEMS for which use?

• Accelerometers
• Gyroscopes
• Pressure
• Microphones
• Ultrasound
• Flowmeters
• Optical MEMS/MOEMS
• Thermopiles
• Gas sensors
• Microfluidics

Physical

Inertial

Sound

Optical

Environmental

BioMEMS report 2018 is focusing on these 10 MEMS components with addition of emerging MEMS from neural implants to microneedles.
On the full spectrum of healthcare industry, each application has more than 1 opportunity to use MEMS device.
HOW SENSORS HAVE EVOLVED AND WHERE THE MARKET IS HEADING

1st generation of wearable electronic sensors: tracking parameters such as pulse rate, sleeping habits, calories and temperature

2nd generation of implantable biosensors: Tracking and analyzing physiological changes in chronic diseases

Wave focusing on implantable continuous glucose monitoring

Wave for blood pressure without the need for applied pressure

Increasing focus on making healthcare more patient-centric using less painful technologies

Period with emerging capabilities of self powered electronics, stretchable, flexible for more comfort on any part of the body

Next generation of biosensors: Enabling more precise and accurate sensing mechanism

Macro-sensors

Micro-sensors

Nano-sensors

Period with emerging capabilities of integrated circuit miniaturization and low power consumption

Fitness dedicates sensors are reported to be the mature market

Period with emerging capabilities of self powered electronics, stretchable, flexible for more comfort on any part of the body

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Microfluidics is still top leader market in value with strong growth announced.

Microfluidics

BioMEMS market dynamic: 2017-2023 forecast

Out of the graph (in the range of $B)

Revenues ($M)

CAGR 2017-2023

Market size:

2017

2023

$2.8B

$6.1B

Microfluidic chips
Pressure sensors
Microphones
Accelerometers
Gyrosopes
Optical MEMS
Thermopiles & PIR
Flowmeters
Gas sensors

2017

2023

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BIOMEMS MARKET DYNAMIC 2017 - 2023
HEALTHCARE TRANSFORMATION: GLOBAL TRENDS

- Healthcare drivers and challenges
- Factors impacting healthcare transformation
- BioMEMS opportunities in this context
EMERGING NON-INVASIVE SENSORS

- Applications driving demand for non-invasive sensors
- Technology landscape and roadmap
- Example of non-invasive sensors and projects
- Profiles of non-invasive companies
• Merger & acquisition in the BioMEMS field and application
• Global BioMEMS market forecast 2017-2023 – revenues and shipment
• ASP evolution forecast on the period 2017-2023
• Market dynamics with CAGR_{2017-2023}
CHANGES IN BUSINESS MODELS

- Consumer companies and Medical device companies positioning
- Consumer healthcare trends
- Value acquisition – from sensor to integrated solution
• Technology drivers and trends for BioMEMS sensors
• Description of the technology trends: Power requirements, packaging and biocompatibility, performances, miniaturization...
DESCRIPTION OF MEMS DEVICES AND APPLICATIONS

- Dedicated part per sensor type with detailed description
- Market data and dynamics
- Players, supply chain and market share
- Market and technology trends
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More than ever, companies are showing a growing interest in the healthcare domain. In the last 2-3 years, major players like Google, Apple, and Amazon have highlighted challenging projects, i.e. measuring blood glucose via smartwatches or smart lenses. Also, sensor makers are developing new technologies and platforms to answer the specific requirements of medical grade products. Demand for MEMS devices is increasing exponentially thanks to a democratization of medical devices that’s bringing them closer to consumers and creating a high demand for portable and wearable devices enabling patient monitoring at the point of need. In order to satisfy demand, almost all MEMS foundries are proposing manufacturing services dedicated to healthcare applications.

With the addition of microfluidic chips (Si-based, polymer-based, glass-based) the BioMEMS market, represented by silicon MEMS devices used for life sciences and healthcare applications, is expected to more than double – from $2.8B in 2017 to $6.1B in 2023, with a CAGR of 14.9% from 2017 - 2023. This makes bioMEMS a must-have for today’s global sensor makers.

MEMS TECHNOLOGY IS CONSOLIDATING ITS HEALTHCARE MARKET PENETRATION, AND FOR THE NEXT FIVE YEARS WILL CONTINUE ITS HUGE 14.8% GROWTH

Microfluidics demand still drives the BioMEMS market thanks to point of care applications and an increasing demand for next generation sequencing. Also, the “acquisitions race” by large diagnostics companies is still ongoing. Pressure sensors are more mature sensor devices used in respiratory and blood monitoring, still reaching volumes of several hundred million units per year. Nevertheless, these mature devices are expected to enjoy a new wave of interest thanks to fresh demand for smart connected objects like inhalers and sleep apnea monitoring systems.

It is also worth noting that the transformation of global healthcare is spurring strong efforts to acquire new functionalities and access to new diagnostic capabilities with micromachined ultrasound transducers (CMUT and PMUT) and gas sensors. Moreover, MEMS sensor innovation has triggered developments in neurotechnologies, with neural implants for therapeutic applications (still at research level today) paving the way for better quality-of-life for patients with neurodegenerative diseases.

This report describes in detail the different sensor types, markets, and trends, as well as a global overview of the dynamic BioMEMS market, from 2017 - 2023.
HEALTHCARE TRANSFORMATION: AN OPPORTUNITY FOR BIOMEMS DEVICES

Healthcare is rapidly changing thanks to a convergence of factors: economical, societal, and technological. First, cost of care has risen to an incredible level for health organizations and governments. Budgets have reached a critical threshold while demography is exploding and chronic diseases are the scourge of industrialized countries. According to the World Health Organization (WHO), 422M people have diabetes, and 1.5B are at risk for cardiovascular events. The $2T yearly cost of chronic diseases supported by society is now unsustainable.

Second, people have easier access to information through apps and the web via smartphones and tablets. More than 2B smartphones are used worldwide, ready to connect with smartwatches or ear pods measuring heartbeat and analysing gestures.

Third, MEMS technology is now mature enough to offer medical-grade measurement with miniaturized and low power-consumption sensors, at a lower price than conventional technologies. BioMEMS devices are key solutions for a high level of electronic integration, contributing to development of a new generation of easy-to-use medical devices for consumer and patients, with a lower rate of hospitalization and the ability to help avoid unnecessary visits. For example, asthma detection devices integrating MEMS microphones and accelerometers can prevent an asthma attack by alerting the patient through his smartphone at exactly the right moment, prompting him to take his medicine and thus avoid a medical emergency.

Trends for consumer healthcare and mHealth, as well as major trends for BioMEMS adoption, are explained in Yole Développement’s (Yole) report.

Prevalence and cost of chronic diseases

<table>
<thead>
<tr>
<th>Disease</th>
<th>Prevalence (in million patients)</th>
<th>Annual cost (in billion dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes</td>
<td>422M</td>
<td>$827B</td>
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<tr>
<td>Sleep Apnea</td>
<td>100M</td>
<td>$25B</td>
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<tr>
<td>Epilepsy</td>
<td>50M</td>
<td>$15.5B</td>
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<tr>
<td>Infertility</td>
<td>48.5M</td>
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<tr>
<td>Parkinson</td>
<td>10M</td>
<td>$25B*</td>
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<td>Undiagnosed sleep apnea cost</td>
<td>$15B*</td>
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<td>Cardiovascular events</td>
<td>1.5B</td>
<td>$950B</td>
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<tr>
<td>Sleep Apnea</td>
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<td>Epilepsy</td>
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Source: Reports from World Health Organization

(Yole Développement, August 2018)
data acquisition for the benefit of patients, i.e. early diagnosis. From development to manufacturability, through clinical test approval, there’s still much hard work ahead. But with the promise of profoundly changing healthcare’s integration with our daily life, we get closer every day!

OBJECTIVES OF THE REPORT
• Explain which MEMS are used in which healthcare applications, and why
• Provide an overview of the main players at every level of the supply chain, including market share
• Identify the threats and opportunities related to bioMEMS, along with market and technology trends
• Highlight promising technologies and booming applications
• Compare the bioMEMS market to the global MEMS market and explain the similarities/differences
• Discuss where and how bioMEMS will be used in the future

COMPANIES CITED IN THE REPORT (non-exhaustive list)

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MARKET & TECHNOLOGY REPORT

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Jérôme Mouly, Sébastien Clerc and Asma Siairi are part of the Life Sciences & Healthcare division at Yole Développement (Yole) co-authored the BioMEMS & Non-Invasive sensors: microsystems for Life Sciences & Healthcare 2018 Report.

Jérôme Mouly serves as a Senior Technology & Market Analyst and Business Developer specialized in microtechnologies for inkjet & bioMEMS sensors. Since 2000, he has participated in more than 100 marketing and technological analyses for industrial groups, start-ups and institutes. Previously, Jerome was involved in a support action for value creation of smart miniaturized systems research projects at Yole Finance Innovation, part of Yole Développement. Jérôme holds a Master of the Physics from the University of Lyon (France).

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Asma Siairi works as a Technology & Market Analyst, Biotechnologies & Molecular Innovations, Asma Siairi is involved in the development of technology & market reports as well as the production of custom consulting projects. After a Master’s degree in Biotechnologies, Diagnostic Therapeutics & Management, Asma served as Research Assistant at the Moores Cancer Center (San Diego, CA). Asma is graduated with an Advanced Master’s degree in International Strategy & Marketing BtoB from EM Lyon Business School (Lyon, France).
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**ABOUT YOLE DEVELOPPEMENT**

Founded in 1998, Yole Développement has grown to become a group of companies providing marketing, technology and strategy consulting, media and corporate finance services, reverse engineering and reverse costing services and well as IP and patent analysis. With a strong focus on emerging applications using silicon and/or micro manufacturing, the Yole group of companies has expanded to include more than 80 collaborators worldwide covering MEMS and image sensors, Compound Semiconductors, RF Electronics, Solid-state lighting, Displays, Software, Optoelectronics, Microfluidics & Medical, Advanced Packaging, Manufacturing, Nanomaterials, Power Electronics and Batteries & Energy Management.

The “More than Moore” market research, technology and strategy consulting company Yole Développement, along with its partners System Plus Consulting, PISEO and KnowMade, support industrial companies, investors and R&D organizations worldwide to help them understand markets and follow technology trends to grow their business.

**CONSULTING AND ANALYSIS**

- Market data & research, marketing analysis
- Technology analysis
- Strategy consulting
- Reverse engineering & costing
- Patent analysis
- Design and characterization of innovative optical systems
- Financial services (due diligence, M&A with our partner)

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Yole Développement

*From Technologies to Market*
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3 BUSINESS MODELS

- **Consulting and Analysis**
  - Market data & research, marketing analysis
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  - Reverse engineering & costing
  - Patent analysis
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- RF devices & technologies
- Imaging
- Medical technologies (MedTech)
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- Manufacturing
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- Compound semiconductors
- Solid state lighting
- Displays
- Software
- Memory

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  - A review of your competitors evolution
  - An understanding of your manufacturing and production costs
  - An understanding of your industry technology roadmap and related IPs
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  - MEMS Microphone – Patent Landscape Analysis
  - Knowles MEMS Microphones in Apple iPhone 7 Plus – Patent-to-Product Mapping 2017
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  - Gas & Particles 2018 – Market & Technology Report
  - LiDARs for Automotive and Industrial Applications 2018 – Market & Technology Report
  - LiDAR for Automotive 2018 – Patent Landscape Analysis
  - MEMS Packaging 2017 – Market & Technology Report

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  - RF Acoustic Wave Filters 2017 – Patent Landscape Analysis
- **LINKED REPORTS** – by Yole Développement, System Plus Consulting and KnowMade
  - 5G impact on RF Front End Modules and Connectivity for Cellphones 2018 – Market & Technology Report – Update
  - RF Front End Modules for Cellphones 2018 – Patent Landscape Analysis
  - Advanced RF System-in-Package for Cellphones 2018 – Market & Technology Report – Update *
  - RF GaN 2018 – Patent Landscape Analysis

SOFTWARE
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  - Status of the CMOS Image Sensor Industry 2018 – Market & Technology Report - Update
  - CMOS Image Sensors Monitor 2018* – Quarterly Update**
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  - LiDARs for Automotive and Industrial Applications 2018 – Market & Technology Report
  - LiDAR for Automotive 2018 – Patent Landscape Analysis

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- **LINKED REPORTS** – by Yole Développement and System Plus Consulting
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  - Memory Market Monitor 2018 (NAND & DRAM)
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  - Memory Pricing Monitor 2018 (NAND & DRAM)
- REVERSE ENGINEERING & COSTING REVIEW – by System Plus Consulting
  - DRAM Technology & Cost Review 2018
  - NAND Memory Technology & Cost Review 2018
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  - 3D Non-Volatile Memories – Patent Landscape

COMPOUND SEMICONDUCTORS
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  - Status of Compound Semiconductor Industry 2018*
  - GaAs Materials, Devices and Applications 2018
  - InP Materials, Devices and Applications 2018
  - Bulk GaN Substrate Market 2017
- LINKED REPORTS – by Yole Développement, System Plus Consulting and KnowMade
  - SiC Transistor Comparison 2018 – Structure, Process & Cost Report
  - Power SiC 2018 – Patent Landscape Analysis
  - GaN-on-Silicon Transistor Comparison 2018 – Structure, Process & Cost Report

POWER ELECTRONICS
- MARKET AND TECHNOLOGY REPORT – by Yole Développement
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  - Discrete Power Packaging 2018 – Update*
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  - Power ICs Market Monitor 2018 – Quarterly Update**

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  - Li-ion Battery Packs for Automotive and Stationary Storage Applications 2018 – Update
- PATENT ANALYSES – by KnowMade
- LINKED REPORTS – by Yole Développement and KnowMade
  - Solid State Electrolyte Battery 2018 – Market & Technology Report
  - Solid-State Batteries 2018 – Patent Landscape Analysis

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- LINKED REPORTS – by Yole Développement and System Plus Consulting
  - VCSELs Comparison 2018 – Structure, Process & Cost Report

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- MARKET AND TECHNOLOGY REPORT – by Yole Développement
  - Quantum Dots and Wide Color Gamut Display Technologies 2018 – Update
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  - MicroLED Display – Patent Landscape Analysis

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- MARKET AND TECHNOLOGY REPORT – by Yole Développement
  - BioMEMS & Non Invasive Emerging Biosensors: Microsystems for Medical
  - Applications 2018 – Update

- Point-of-Need Testing Application of Microfluidic Technologies 2018 – Update
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- PATENT ANALYSES – by KnowMade
  - Microfluidic IC Cooling – Patent Landscape
  - Circulating Tumor Cell Isolation – Patent Landscape
  - OCT Medical Imaging – Patent Landscape
  - Pumps for Microfluidic Devices – Patent Landscape 2017
  - Microfluidic Technologies for Diagnostic Applications – Patent Landscape 2017
  - FLUIDIGM – Patent Portfolio Analysis 2017

- LINKED REPORTS – by Yole Développement, System Plus Consulting and KnowMade
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  - Organ-on-a-Chip – Patent Landscape Analysis

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