

STATUS OF THE MEMS INDUSTRY 2018

Market & Technology report - May 2018

Megatrends are invigorating the MEMS industry.

WHAT'S NEW

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- Global market megatrends, plus focus on sensor megatrends
- Updated global sensor market forecast in value and units for MEMS, as well as CMOS image sensors, magnetic sensors, gas sensors, fingerprint sensors, optical sensors, spectral sensors, and RF devices
- Updated forecast for RF devices and optical sensors (3D sensing, spectral sensors, etc.)
- Updated pressure sensor forecast based exclusively on the latest price estimate and first-level packaging value
- Manufacturer rankings for global sensor and actuator suppliers
- A specific chapter on MEMS packaging
- A MEMS foundry cost model
- MEMS market evolution compared to IC
- New major trends and evolutions for MEMS markets, players, and industry
- Updated MEMS market forecast to 2023 in value, units, and wafers
- Updated split by wafer size: from 4" and below, to 8"
- 2017 rankings for MEMS players/ MEMS foundries
- Updated information, by MEMS device and application

MEGATRENDS ARE DRIVING DEMAND FOR MORE MEMS AND SENSORS

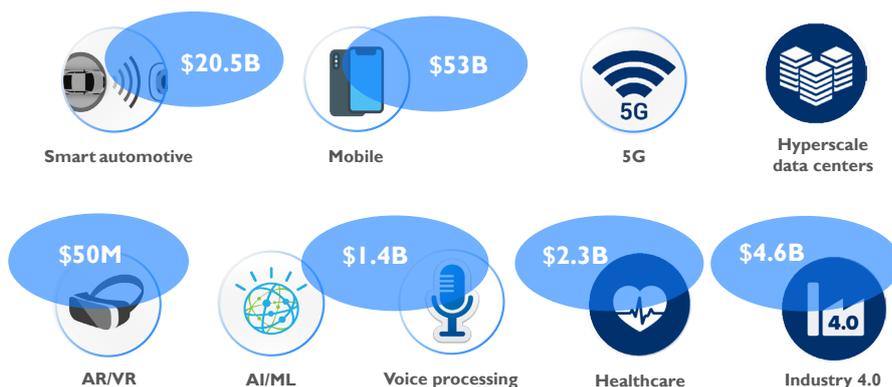
Global society is currently impacted by macro-economic megatrends that will shape our tomorrow, contributing to increased social interaction, a healthier lifestyle, and safer/low-pollution transports. These megatrends will rely on a rising demand for more semiconductor content in our everyday lives. Yole Développement has identified nine megatrends that will affect our present and future: smart automotive (electrification, autonomous driving, connected cars, etc.), mobile (i.e. for new and improved social interaction, augmented reality experience), 5G for increased bandwidth, hyper-scale data centers to cope with more and more data through the internet, AR/VR (augmented reality/virtual reality) for new immersive experiences, AI/ML (artificial intelligence/machine learning) for smart human-machine interfaces (smart homes, robotic cars, etc. with more voice processing intelligence), healthcare (for a healthier life), and industry 4.0 (connected factories with ubiquitous sensors for more efficient production). Megatrends offer huge opportunities for electronics, especially sensors and MEMS. We estimate that the total megatrends

business impact on the MEMS, sensors, and actuators market will be \$82B by 2023.

If we consider the mobile megatrend as an example, the drivers are: 5G's arrival (more bandwidth), improved displays (with higher resolution, better video quality, enhanced contrast/brightness), new design, augmented reality, and smaller form factor with more sensing capabilities. These megatrends facilitate a dramatic evolution for MEMS and sensors. At the smartphone level, there will be a profusion of new sensors: inertial sensors, 3D optical sensors, IR sensors, environmental sensors, fingerprint sensors, spectral sensors, and optical MEMS (such as autofocus and/or pico projection). Also, for reducing devices' form factor, wafer-level packaging (fan-out) will be increasingly used.

When 5G arrives, there will also be an increasing need for RF filters, and the MEMS sector with the largest growth will be RF MEMS (BAW filters). Besides MEMS and sensors, 5G's operating frequency will require new materials such as GaN on SiC, GaN on Si, SiGe (low noise amplifier), and GaAs (power amplifier).

Electronic megatrends: impact on the 2023 sensor & actuator markets per application



(Yole Développement, May 2018)

RF MEMS ARE BOOSTING THE GLOBAL MEMS MARKET

Yole Développement estimates the MEMS market will experience a 17.5% growth in value and a 26.7% growth in units, with consumer having the biggest share (more than 50% in value). The good news is that almost all MEMS devices will contribute to this growth.

Inkjet heads will grow, with the consumer market representing more than 70% of printhead market demand. This market recorded its first signs of recovery in the first half of 2017, a trend confirmed in the second half of the year. This recovery was noticed both in disposable and fixed printheads.

Most consumer players show discernable growth: for example, HP has recorded a 2% growth in consumer printer revenue since 2016, and Canon has confirmed a progression in sales for inkjet printers, with strong demand in Asia.

Numerous pressure sensor applications contribute to market expansion. It is interesting to see that, although it is one of the oldest MEMS technologies, pressure sensor keeps growing. In automotive, pressure sensors have the highest number of applications, with many advantages

such as, resistance to toxic exhaust gas and harsh environments, higher accuracy, and the development of intelligent tires that deliver more information on tire status (especially for future autonomous cars). For consumer, mobiles and smartphones still account for 90% of pressure sensor sales, and cost reduction is the priority vs. size reduction because size is already very small. Although there are no big “killer” applications expected in the future, new applications are emerging: smart homes, electronic cigarette, drones, and wearables, to name several.

MEMS microphones have been in the spotlight for a long time and have expressed one of the highest CAGRs of any MEMS technology over the last five years. In the range of \$105M in 2008, the MEMS microphone market was worth \$402M in 2012 and reached the \$1B milestone in 2016. Currently, almost 4.5B units are shipped annually.

Consumer is still inertial MEMS’ largest market, but price pressure is tough and competition is fierce. The smartphone and tablet market is still a difficult one for stand-alone accelerometer, competing with combo sensors (small size, low power, multi-purpose). Stand-alone accelerometers are used in low-end smartphones and can also be used with combo sensors to manage a few features (i.e. UI rotation/fluidity). Robotic cars are gyroscopes’ new application for dead reckoning function. High-end performance devices are needed,

but MEMS could take a share of the business. Lidar for autonomous vehicles is also an intriguing application for MEMS mirrors.

Step by step, the uncooled IR imager market keeps growing. This is due to a continuous price decrease over the last few years stemming from new technologies such as WLP and silicon lenses, as well as increasing acceptance from customers.

For microfluidics, many existing developments are fueling silicon’s development. In early 2018, Illumina released a new DNA sequencer, the iSeq 100. Unlike Illumina’s usual technology, this one works with a semiconductor (CMOS) chip.

Driven by the complexities associated with the move to 5G and the higher number of bands it brings, there is an increasing demand for RF filters in 4G/5G, making RF MEMS (BAW filters) the largest-growing MEMS segment. This market will soar from US\$2.3B in 2017 to US\$15B in 2023. Excluding RF, the MEMS market will grow at 9% over 2018 - 2023. With RF MEMS, the CAGR is 17.5%.

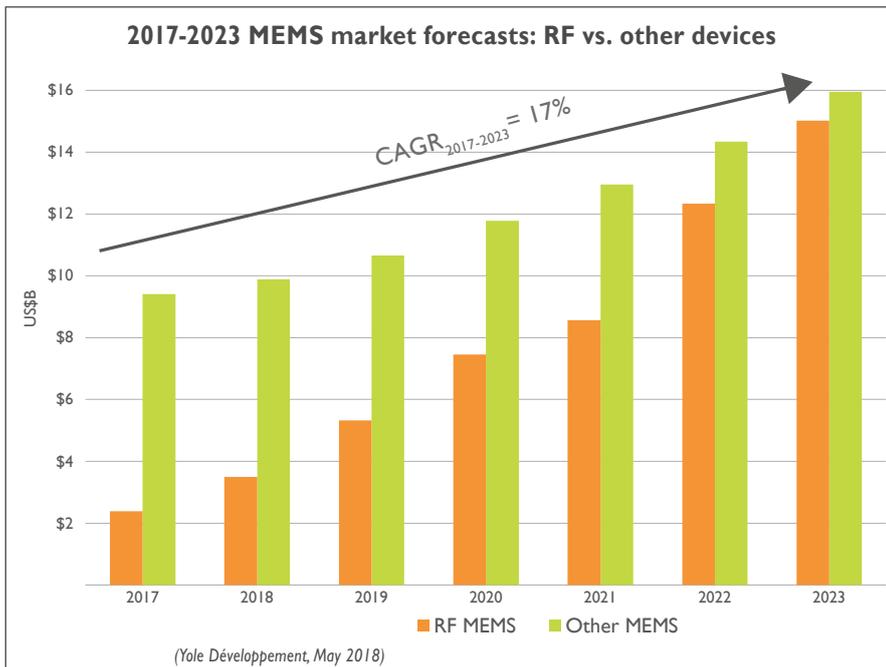
There are also plenty of new MEMS in development: piezo MEMS (auto-focus, inkjet heads), FTIR, portable electronic noses, ultrasound MEMS for medical imaging and industrial applications, micro switches, and more. These are several MEMS developments that will fuel this business’s.

In 2017, The biggest surprise (though not entirely unexpected) was Broadcom becoming the #1 MEMS player. As growth continues for RF, driven by an increasing number of filters/phones and by the front-end module’s increasing value, it is likely that RF players will still dominate the top 2018 rankings.

Most players showed positive growth in 2016 - 2017. Established players (Bosch, STMicroelectronics, TI, HP) were “shaken” by Broadcom’s growth but still performed well: for example, Bosch enjoyed growth of approximately \$100M. IJH players also had a good overall performance compared to previous years.

SiTime displayed the most impressive growth (exceeding 100%). Other MEMS players posting significant growth are: FormFactor, benefiting from the semiconductor business’s excellent health; and ULIS, with uncooled IR imaging still growing annually into multiple applications (consumer – thermography, firefighting, night vision, smartphones, drones, and military).

In 2016, the top 30 MEMS players totaled \$9.24B. In 2017, that number increased to \$9.88B.



FROM DETECTION TO ENVIRONMENT AWARENESS, MEMS WILL EVOLVE FROM A SENSING FUNCTION TO GLOBAL PERCEPTION CAPABILITIES

MEMS and sensors were first developed and used for “basic” physical sensing like shock and pressure. Next, acceleration and rotation sensors were developed, requiring a strong R&D effort in design.

As more effort was put into R&D, MEMS shifted from physical sensors to light management (i.e. micro-mirrors), and then to infrared sensing (microbolometers). This paved the way for the first sensor able to transcend human senses. From

physical/light, MEMS development has also been driven by sound with microphones.

Today, MEMS and sensors developments are aiming far beyond human limits, with sensing capabilities in ultrasonic, hyperspectral, and radiofrequency. We can even imagine a next generation of sensors used for emotion/empathy sensing.

This will be possible thanks to the evolution of sensors through three phases:

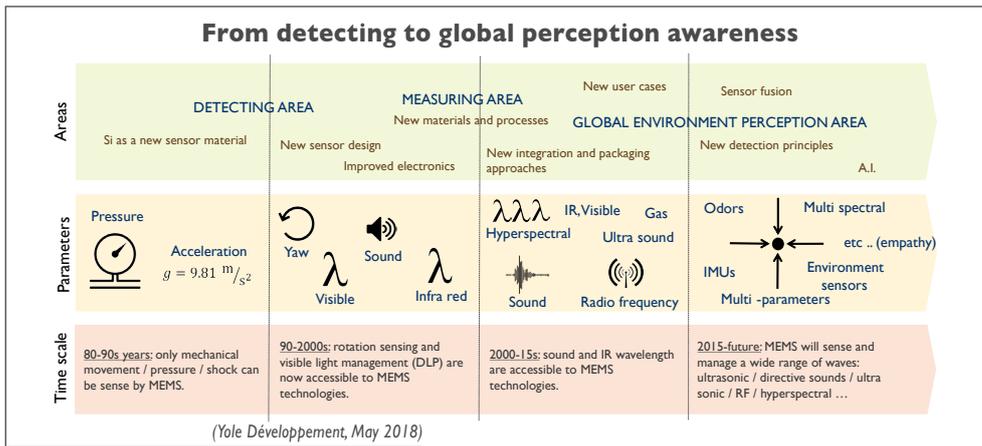
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1. In MEMS' early days, they were mainly detectors, with little ability to provide good accuracy
2. MEMS then evolved to measurement capabilities, with improved accuracy plus accessibility to additional measurable parameters (infrared, sound, etc.)
3. We believe the next step will be "global perception awareness". By this we mean sensors and MEMS that will provide global environment mapping (like lidar does for 3D, but this could also be possible for sound waves, hyper spectral waves, etc.). Multi-sensor fusion and AI will be critical building blocks towards achieving this milestone.

OBJECTIVES OF THE REPORT

- A view of future megatrends and their impact on sensors
- A global view concerning the future of MEMS, sensors, and actuators
- An understanding of the MEMS, sensor, and actuator markets and applications
- MEMS and sensor players' dynamics and rankings
- MEMS market data in \$M, units, and wafers for 2017 - 2023
- Information on future MEMS devices
- A presentation of MEMS game-changers and industry trends
- A MEMS applications overview: automotive, consumer, defense and aeronautics, medical, industrial, and telecommunications
- A MEMS financial analysis

COMPANIES CITED IN THE REPORT (non exhaustive list)

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AUTHOR

With almost 20 years of experience in MEMS, Sensors and Photonics applications, markets, and technology analyses, **Dr. Eric Mounier** provides deep industry insight into current and future trends. As a Principal Analyst, Technology & Market, MEMS & Photonics, in the Photonics, Sensing & Display division, he is a daily contributor to the development of MEMS and Photonics activities at Yole Développement (Yole), with a large collection of market and technology reports as well as multiple custom consulting projects: business strategy, identification of investments or acquisition targets, due diligences (buy/sell side), market and technology analysis, cost modelling, technology scouting, etc. Previously, Dr. Mounier held R&D and Marketing positions at CEA Leti (France). He has spoken in numerous international conferences and has authored or co-authored more than 100 papers. Eric has a Semiconductor Engineering Degree and a Ph.-D in Optoelectronics from the National Polytechnic Institute of Grenoble (France).



