Piezoelectric Devices - from Bulk to Thin-Film 2019
About the Author

Biography & contact

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Jérôme Mouly serves as a Senior Technology & Market Analyst & 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 Physics from the University of Lyon (France).

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**Executive summary**

- Executive summary

**Context**

- Context
  - Introduction to piezoelectricity
  - Piezoelectric materials
  - Application markets for sensors, actuators, and transducers

**Market forecasts**

- Market forecasts
  - Piezoelectric device market 2018 - 2024 for sensors, actuators, and transducers, by type (bulk vs. thin-film)
  - Piezoelectric device market 2018 - 2024 for sensors, actuators, and transducers, by application
  - Penetration of thin-film vs. bulk-based devices
  - Market dynamics, per application

**Market trends**

- Market trends
  - Speakers
  - Microphones

**Market share and supply chain**

- Market share and supply chain
  - Bulk device players
  - Thin-film device players
  - Thin-film device players - market share
  - Focus on foundry players

**Technology trends for thin-film-based technologies**

- Technology trends for thin-film-based technologies
  - Thin-film materials
  - Equipment and process flow
  - Deposition process analysis and comparison

**Conclusions**

- Conclusions
COMPANIES CITED IN THIS REPORT

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And many more…
OBJECTIVES OF THE REPORT

• We have decided to perform a technology and market report on piezoelectric devices to analyze transition from bulk to thin film for the following reasons:
  • What kind of applications are concerned by bulk to thin-film transition (Past and future)
  • What kind of applications remain Bulk
  • What kind of applications are created thanks to thin film piezo deposition
  • Time of development (analysis of current products like microspeakers, autofocus, Inkjet)

• The objectives of the reports are:
  • Provide an overview of piezo devices and related applications:
    • Description of the key piezo applications for sensors, actuators, and transducers
    • Analysis of the transition from bulk to thin-film piezo devices
  • Analyze deposition trends:
    • Global manufacturing techniques and material trends
    • Focus on deposition techniques used for thin-film piezo devices
  • Describe each player’s product roadmap and expected year of market entry
    • Supply chain analysis
    • Foundry players and technology choice
  • Furnish market data and forecasts for piezo-based sensors, actuators, and transducers
    • Piezo device production forecast 2018 - 2024 in units, value, and wafers, by application
    • Market share for main thin-film device manufacturers
SCOPE OF THE REPORT

Properties covered

- Piezoelectric effect
- Pyroelectric effect
- Ferroelectric properties

Material types

- Bulk piezoelectric devices
- Thin-film piezoelectric devices

Legend:

- Covered
- Not covered

Yours needs are out of the report’ scope?
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Yole’s market forecast model is based on the matching of several sources:

Comparison with existing data
Comparison with prior Yole reports
Monitoring of corporate communication
Recursive improvement of dataset
Using other market research data
Customer feedback

Yole analysis (consensus or not)
Preexisting information

Top-to-bottom approach
Aggregate of market forecasts
@ System level

Bottom-up approach
Ecosystem analysis
Aggregate of all players’ revenue
@ System level

Top-to-bottom approach
Aggregate of market forecast
@ Semiconductor device level

Bottom-up approach
Ecosystem analysis
Aggregate of key players’ revenues
@ Semiconductor device level

Market
Volume (in Munits)
ASP (in $)
Revenue (in $M)

Semiconductor foundry activity
Capacity investments and equipment needs

Primary data
• Reverse costing
• Patent analysis
• Annual reports
• Direct interviews

Secondary data
• Press releases
• Industry organization reports
• Conferences

Information Aggregation

Information Aggregation

Preexisting information
WHY THIS REPORT?

• Piezoelectricity has been exploited during the world war for military applications (Sonar), using its ultrasound capabilities.

• More than ultrasound, piezoelectricity has a double effect of sensing and actuating, representing a high number of possible applications from industrial to consumer, through automotive and medical.

• Most of the piezoelectric devices are bulky and expensive devices, used for specific high end applications. Moreover, their manufacturing process is not serial, avoiding possibility to reach high volume markets and possible cost reduction.

• New development on piezoelectric materials and formulation allows thin film deposition of piezoelectric materials. It gives opportunity to integrate thin film deposition in a MEMS / CMOS process.

• This report is presenting how which kind of devices are turning to thin film technologies, what are the challenges linked to the changes, what are the business opportunities.

• It describes the market and technology trends, and is giving insights on players and related interconnections, collaboration and competition.
WHAT IS PIEZOELECTRICITY?

Definition

- Piezoelectricity is the ability of some materials to generate an electric charge in response to applied mechanical stress.
- A piezoelectric effect is reversible.
PIEZOELECTRIC CERAMIC

Format and applications

Sensor elements

- Distance detection
- Flow level detection
- Park assist
- Medical doppler

Actuator elements

- Autofocus
- Micro-nano-positioning
- Speakers

Devices

Distance detection
Flow level detection
Park assist
Medical doppler

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Piezoelectric Bulk Players

Business models

• In the bulk piezoelectric industry, the piezo material is a key part of the final system and the business models are numerous. From monocrystal to piezo ceramics, and from piezo element to final systems, the players are finding where is their key added value from externalizing or manufacturing internally.

Monocrystal makers

Example of Kistler: the company has developed its PiezoStar Crystals using a Czochralsky process. The company is controlling all the processes from the quartz production to the sensor device.

Courtesy of Kistler

Piezoelectric ceramic makers

Raw materials
• From powders to calcination, mixing and ball milling

Green parts
• Shaped and pressed

Sintered ceramics
• The piezo ceramic is sintered at 1250°C to 1350°C

Poling process
• Final sensor / actuator

Interest of some players at this stage (ex: Automotive industry)

No specific interest at that stage

Most of the interest

Interest of some players at this stage performing electrode deposition

No specific interest at that stage
### The Different MEMS Sensors, and Actuators, and Where They Can Combine

#### Sensors

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<td><strong>piezoMEMS</strong></td>
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**“Closed” package 6 to 9+ DOF combos**

Possible integration with environmental combos

- Bosch BME680
- ST pressure sensor
- Infineon microphone
- InvenSense MPU9250

#### Optical combos

| FLIR Lepton One | Apple dot projector |

#### Optical MEMS

- Micromirrors
- Optical benches

#### Microfluidics

- Drug delivery
- Biochips

#### RF

- Switch
- Filter
- Resonator

#### Micro structures

- Micro tips
- Probes
- Wafers components

#### Actuators

- Debiotech micro pump
- Avago-Broadcom FBAR Filter
- Spiromax Patek Philippe
- Texas Instruments DLP
- pLight AF
- Audio Pixels MEMS-based speaker

Possible integration with piezo combos

- PoLight AF
- Debiotech micro pump
- Texas Instruments DLP
- pLight AF
- Audio Pixels MEMS-based speaker

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PIEZOELECTRIC APPLICATIONS: COEXISTENCE OF BOTH TECHNOLOGIES, BULK & THIN-FILM

Bulk piezoelectric technologies

- Shock sensors
- Acoustic emission sensors
- Flow level sensors
- Force & strain sensors
- Braille cells
- Linear motor positioning
- Scalpels
- Dental scalers
- Flow meters
- Distance detection
- Weldings

Thin-Film piezoelectric technologies

- Microphones
- Accelerometers
- RF Filters
- Inkjet printheads
- Microspeakers
- Ultrasound transducers
- Gyrosopes
- MEMS Micromirrors
- Micropumps
- Sensors
- Actuators
- Transducers

Legend:
PIEZOELECTRIC BASED DEVICES MARKET: THIN FILM & BULK

CAGR 2018-2024: 15.3%
CAGR 2018-2024: 12.2%

$0 $10,000 $20,000 $30,000 $40,000 $50,000 $60,000

2018 2019 2020 2021 2022 2023 2024

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A 12.6% CAGR is expected in the next 6 years with BAW Filters as the main driver.
SPEAKERS AND MICROSPKAKERS

MEMS piezo-based speakers – Technology highlights

• USound technology is based on Piezoelectric actuation. A PZT thin film is deposited on silicon substrates. The PZT material is extending or shrinking when a current is applied.

• Based on this piezo effect, multiple cantilevers are produced and create a translation of a piston up and down. Compare to a coil based speaker, cantilevers replace the magnet.

• Mounting a membrane on the top of the piston, a sound could be generated by the displacement of air created.
SPEAKERS AND MICROSPKAKERS

MEMS speakers size and performance

Performance and Value

- Audio output for phones
- Integrated by phone manufacturers

Final system footprint (diameter)

- 5mm
- < 1cm
- 1cm – 5 cm
- 10cm – 20cm

Coil based speakers

Balanced armature speakers

Dynamic speakers

Minispeakers

Speakers
INKJET PRINTHEADS

Applications

- **Functional printing**
- **Ceramic tiles**
- **Bulk PZT domain**
- **Thin film PZT printheads for high resolution**
- **Drop volumes (pL)**
  - 100
  - 10
  - 10

- **Document / mail printing**
- **Textile**
- **Labels**
- **Consumer & office printing**
- **Graphics - posters**
- **Photo**
- **Resolution (dpi)**
  - 300
  - 600
  - 1200

Thin film PZT printheads for high volume
INKJET PRINTHEADS

Still resistance in the conventional printhead

• Kyocera is leading the high-end printhead market for industrial applications.

• The company has a long history with piezoelectric ceramics and is not investigating into thin film PZT deposition. The company is strengthening efforts in bulk PZT capability with high accuracy positioning of actuators over nozzles and a proprietary process to form PZT actuators and electrodes. They are producing ceramic based actuator sheets.

• The company is able to produce a 4.2" printhead with 5300 nozzles and reaching 1200 dpi. Thickness of the ceramic sheet is 0.5mm

Kyocera actuator sheet – state of the art. Integrated in 4.2" printhead; Credits: Kyocera
INERTIAL SENSORS

Thin film based gyroscope

- Panasonic is the only player having commercialized an inertial sensor (Gyroscope) using thin film PZT technology.
- Oscillating forks are coated with the piezoelectric material. Forks are moving in the X-axis and detection is done on the Z-axis when movement occurred.
- The main application for Panasonic piezo based Gyro is automotive rollover detection.
**MICROPHONES**

**VESPER MEMS**

**New piezoelectric MEMS** are disrupting the traditional capacitive microphone approach. This could have huge implications for noise-canceling technology.

For now, capacitive technology is widely used in the mobile phone market but the preferred high-end technology remains ECMs.

**Features**

- Small size: 3.76mm x 2.65mm x 0.96mm package
- Ultra-low noise, bottom-port
- Low part-to-part variation
- High dynamic range
- Durable piezoelectric MEMS construction
- Drop-in replacement for existing capacitive MEMS microphones

Vesper is now selling parts on Digikey and other online distributors.

*Courtesy of Vesper MEMS*
RF FILTERS

Thin film piezoelectric material for BAW Filters

![Diagram showing Thin Film Bulk Acoustic Resonator (FBAR) and Solidly Mounted Resonator (SMR) with AIN piezo material, electrodes, air gap, and Bragg reflector stack.]

- BAW Filters are using AlN piezo material (between electrodes) deposited on a cavity (FBAR) or a substrate with bragg reflector stack.

Credits: SPTS – Orbotech group
STMicroelectronics is using Sol-Gel technology for deposition of thin film PZT.
- The company is achieving final thickness by repeating each step "n" times.
- STMicroelectronics obtains a very dense film structure. An example is shown above with cross section and detailed view. The film is flat with very small grain.
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YOLE GROUP RELATED REPORTS
Yole Développement

Ultrasound Sensing Technologies for Medical, Industrial and Consumer Applications 2018

5G’s Impact on RF Front-End Module and Connectivity for Cell Phones 2018
RF Front-End Module Comparison 2018

Epson PrecisionCore Printhead with MicroTFP Inkjet Dies

Xaar 1201 GS2p5 PZT Printhead
This is definitely a bright period for piezoelectric devices! Telecommunication and 5G’s imminent arrival, personal assistants, consumer wearables, fingerprint and medical devices are all candidates for using the piezo effect. Since the beginning of the 20th century, when quartz was a material of choice for sonar in military applications, piezoelectricity has evolved into several usage types with a diversity of applications. Today, piezoelectric properties offer great opportunities to be used in three device types: sensor, actuator, and transducer.

Bulk piezo devices are made of a structured piece of quartz or ceramic and are integrated in products ranging from very common to high-end. On the other side, advanced materials and techniques have only been developed since the early 2000s, i.e. those which use semiconductor processes to meet the twin challenges of miniaturization and high integration required for mobile phones, consumer products, and inkjet printheads. Thin-film piezoelectric deposition techniques are gaining increasing importance within the MEMS industry, with different materials being used (i.e. lead zirconate titanate (PZT) and aluminium nitride (AlN)) - each with particular specifications that differentiate their performance as more suitable for sensors or actuators. For example, Epson completed construction of its new MEMS printhead factory in order to triple production of its PrecisionCore printheads: a full MEMS printhead using a thin-film PZT deposition process.

While several devices have begun transitioning from bulk to thin-film piezo materials, the specific use-case still influences the choice of bulk or thin-film types. Piezoelectric micromachined ultrasound transducers (PMUT) are a perfect example of the transition from bulk to thin-film piezo method, and PMUT devices have recently been well-publicized for fingerprint and gesture recognition applications. Another promising sector is medical imaging, in which bulk and thin-film-based devices (for imaging probes) will co-exist depending on the usage and performance required. Considering advancements for bulk piezo materials, TDK recently unveiled speakers with a thickness of 0.45mm - 0.7mm, demonstrating another approach for obtaining the thinnest-possible layer from bulk piezo material. Overall, it’s important to understand that transition is not competition: thin-film and bulk methods are two complementary approaches.

Yole Développement’s report describes this transition and the most promising applications, from microspeakers to MEMS autofocus, through Film Bulk Acoustic Resonator (FBAR), complete with a status report and product availability roadmap. Also included is a deep dive into the performance associated with usage in sensors, actuators, and transducers, describing the market trends and technology choices.
The piezoelectric market for sensors, actuators, and transducers is expected to reach $48.5B in 2024, with a 12.6% CAGR from 2018 - 2024 on comparable devices. Thin-film piezo-based devices are driving the piezoelectric market’s growth, though market share is still in favour of bulk-based devices, which remains a strong technology in the piezo market. In both the bulk and thin-film device markets, RF filters lead with surface acoustic waves (SAW) and bulk acoustic waves (BAW), respectively. Broadcom and Qorvo are the major thin-film players in the RF filters arena, with 5G as well as an increasing number of frequencies are strongly boosting the market.

The recent fundraising efforts of consumer players like Amazon in thin-film-based companies to support the development of piezo microspeakers and MEMS piezo microphones confirm mainstream interest in technologies that are able to work with ultra-low power. Bulk piezo devices offer the high actuation performance that is expected in a number of applications, from inkjet printheads to linear motors achieving very precise movements.

This report forecasts the growth of bulk and thin-film piezo devices over the next five years, illustrating the trends and dynamics of these two methods, with a market focus on thin-film-based devices, by application.

Specific to thin-film techniques, several MEMS foundries have internalized a piezo process in their fab. AlIn requires extensive knowledge for piezo layer deposition, since PZT is an exotic material for integration in a semiconductor fab. In terms of deposition, two technologies are competing: Sol-Gel and PVD (sputtering or pulsed laser deposition - PLD). Sol-Gel offers better intrinsic film properties, with good uniformity and higher breakdown voltages. But when considering high-volume production, throughput becomes a major consideration and this is where Sol-Gel exhibits limitations.

Most MEMS IDMs and foundries have already made their process choices. Fujifilm Dimatix and Bosch have chosen sputtering, while STMicroelectronics and Rohm Semiconductor will pursue Sol-Gel techniques. Equipment manufacturers play an important role in developing the right process: for example, SolMAteS, a Netherlands-based equipment manufacturer, recently announced that its PLD technology has entered the next 5G base-station.
and receiver market through a production site located in the USA.

This report covers the piezoelectric device supply chain from R&D to major end-users, with a focused analysis on equipment and device manufacturers, describing their process flows and technology choices.

REPORT OBJECTIVES
Provide an overview of piezo devices and related applications:
- Description of the key piezo applications for sensors, actuators, and transducers
- Analysis of the transition from bulk to thin-film piezo devices

Analyze deposition trends:
- Global manufacturing techniques and material trends
- Focus on deposition techniques used for thin-film piezo devices

Describe each player’s product roadmap and expected year of market entry:
- Supply chain analysis
- Foundry players and technology choice

Furnish market data and forecasts for piezo-based sensors, actuators, and transducers:
- Piezo device production forecast 2018 - 2024 in units, value, and wafers, by application
- Market share for main thin-film device manufacturers

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- Epson PrecisionCore Printhead with MicroTFP Injet Die

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• Press Relations & Corporate Communication: Sandrine Leroy (leroy@yole.fr)
4 BUSINESS MODELS

○ 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)

○ Syndicated reports
  • Market & technology reports
  • Patent investigation and patent infringement risk analysis
  • Teardowns & reverse costing analysis
  • Cost simulation tool
    www.i-Micronews.com/reports

○ Monitors
  • Monthly and quarterly update
  • Excel database covering supply, demand, and technology
  • Price, market, demand and production forecasts
  • Supplier market shares
    www.i-Micronews.com/reports

○ Media
  • i-Micronews.com website
  • i-Micronews e-newsletter
  • Communication & webcast services
  • Events: TechDays, forums, …
    www.i-Micronews.com
6 COMPANIES TO SERVE YOUR BUSINESS

Yole Group of Companies

[Company Logos and Descriptions]

- Market, technology and strategy consulting
  www.yole.fr

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

- IP analysis
  Patent assessment
  www.knowmade.fr

- Design and characterization of innovative optical systems
  www.piseo.fr

- Innovation and business maker
  www.blumorpho.com

- Due diligence
  www.yole.fr
OUR GLOBAL ACTIVITY

40% of our business
Yole Deutschland
Frankfurt

30% of our business
Yole Korea
Seoul
Greater China office
Hsinchu

30% of our business
Yole Japan
Tokyo

About Yole Développement | www.yole.fr | ©2019
SERVING THE ENTIRE SUPPLY CHAIN

Integrators, end-users and software developers

Device manufacturers

Suppliers: material, equipment, OSAT, foundries...

Financial investors, R&D centers

Our analysts provide market analysis, technology evaluation, and business plans along the entire supply chain.
We work across multiple industries to understand the impact of More-than-Moore technologies from device to system.
Over the course of more than 20 years, Yole Développement has grown to become a group of companies. Together with System Plus Consulting and KnowMade, we now provide marketing, technology and strategy consulting, media and corporate finance services, reverse costing, structure, process and cost analysis services and well as intellectual property (IP) and patent analysis. Together, our group of companies is collaborating ever closer and therefore will offer, in 2019, a collection of over 125 reports, 10 new monitors and 120 teardowns. Combining respective expertise and methodologies from the three companies, they cover:

- MEMS & Sensors
- RF devices & technologies
- Medical technologies
- Semiconductor Manufacturing
- Advanced packaging
- Memory
- Batteries and energy management
- Power electronics
- Compound semiconductors
- Solid state lighting
- Displays
- Software
- Imaging
- Photonics

If you are looking for:
- An analysis of your product market and technology
- A review of how your competitors are evolving
- An understanding of your manufacturing and production costs
- An understanding of your industry’s technology roadmap and related IPs
- A clear view supply chain evolution

Our reports and monitors are for you!

Our team of over 70 analysts, including PhD and MBA qualified industry veterans from Yole Développement, System Plus Consulting and KnowMade, collect information, identify trends, challenges, emerging markets, and competitive environments. They turn that information into results and give you a complete picture of your industry’s landscape. In the past 20 years, we have worked on more than 2,000 projects, interacting with technology professionals and high-level opinion makers from the main players of their industries and realized more than 3,000 interviews per year.

What to expect in 2019?
In 2019 we will extend our offering with a new ‘monitor’ product which provides more updates on your industry during the year. The Yole Group of Companies is also building on and expanding its investigations of the memory industry. Moreover, in parallel, the Yole Group reaffirms its commitment to a new collection of reports mixing software and hardware and is increasing its involvement in displays, radio-frequency (RF) technology, advanced substrates, batteries and compound semiconductors. Last but not least, System Plus Consulting is developing its teardowns service providing 120+ offers related to phones, smart home, wearables and connected devices. Discover our 2019 program right now, and ensure you get a true vision of the industry. Stay tuned!
18 fields of excellence combined with six markets to provide a complete picture of your industry landscape

**Market – Technology – Strategy – by Yole Développement**
Yole Développement (Yole) offers market reports including quantitative market forecasts, technology trends, company strategy evaluation and indepth application analyses. Yole will publish more than 55 reports in 2019, with our partner PISEO contributing to some of the lighting reports.

The Reverse Costing® report developed by System Plus Consulting provides full teardowns, including detailed photos, precise measurements, material analyses, manufacturing process flows, supply chain evaluations, manufacturing cost analyses and selling price estimations. The reports listed below are comparisons of several analyzed components from System Plus Consulting. More reports are however available, and over 60 reports will be released in 2019. The complete list is available at www.systemplus.fr.

**Patent Reports – by KnowMade**
More than describing the status of the IP situation, these analyses provide a missing link between patented technologies and market, technological and business trends. They offer an understanding of the competitive landscape and technology developments from a patent perspective. They include key insights into key IP players, key patents and future technology trends. For 2019 KnowMade will release over 15 reports.

**The markets targeted are:**

- Mobile & Consumer
- Automotive & Transportation
- Medical
- Industrial
- Telecom & Infrastructure
- Defense & Aerospace

Linked reports are dealing with the same topic to provide a more detailed analysis.
OUR 2019 REPORTS COLLECTION (1/5)

18 fields of excellence combined with six markets to provide a complete picture of your industry landscape

MEMS & SENSORS
- MARKET AND TECHNOLOGY REPORT
  - Status of the MEMS Industry 2019 - Update
  - Status of the Audio Industry 2019 - New
  - Uncooled Infrared Imagers and Detectors 2019 – Update
  - Consumer Biometrics: Technologies and Market Trends 2018
  - MEMS Pressure Sensor Market and Technologies 2018
  - Gas & Particle Sensors 2018
- STRUCTURE, PROCESS & COST REPORT
  - MEMS & Sensors Comparison 2019
  - MEMS Pressure Sensor Comparison 2018
  - Particle Sensors Comparison 2019
  - Miniaturized Gas Sensors Comparison 2018
- PATENT REPORT
  - MEMS Foundry Business Portfolio 2019 - New
  - Miniaturized Gas Sensors 2019 - New

PHOTONIC AND OPTOELECTRONICS
- MARKET AND TECHNOLOGY REPORT
  - Silicon Photonics and Photonic Integrated Circuits 2019
  - LiDARs for Automotive and Industrial Applications 2019 - Update
- PATENT REPORT
  - Silicon Photonics for Data Centers: Optical Transceiver 2019 - New
  - LiDAR for Automotive 2018

RF DEVICES AND TECHNOLOGIES
- MARKET AND TECHNOLOGY REPORT
  - 5G’s Impact on RF Front-End Module and Connectivity for Cell Phones 2019 – Update
  - 5G Impact on Telecom Infrastructure 2019 - New
  - Radar and Wireless for Automotive: Market and Technology Trends 2019 - Update
  - Advanced RF Antenna Market & Technology 2019 - New
  - RF Standards and Technologies for Connected Objects 2018
- STRUCTURE, PROCESS & COST REPORT
  - RF Front-End Module Comparison 2019 - Update
  - Automotive Radar RF Chipset Comparison 2018
- PATENT REPORT
  - Antenna for 5G Wireless Communications 2019 - New
  - RF Front End Modules for Cellphones 2018
  - RF Filter for 5G Wireless Communications: Materials and Technologies 2019
  - RF GaN 2019 – Patent Landscape Analysis

Update: 2018 version still available

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OUR 2019 REPORTS COLLECTION (2/5)

18 fields of excellence combined with six markets to provide a complete picture of your industry landscape

IMAGING
- MARKET AND TECHNOLOGY REPORT
  - Status of the CIS Industry 2019: Technology and Foundry Business - Update
  - Imaging for Automotive 2019 - Update
  - Neuromorphic Technologies for Sensing 2019 - Update
  - Status of the CCM and WLO Industry 2019 – Update
  - 3D Imaging & Sensing 2018
  - Machine Vision for Industry and Automation 2018
  - Sensors for Robotic Vehicles 2018

- STRUCTURE, PROCESS & COST REPORT
  - Compact Camera Modules Comparison 2019
  - CMOS Image Sensors Comparison 2019

- PATENT REPORT
  - Facial & Gesture Recognition Technologies in Mobile Devices 2019 - New
  - Apple iPhone X Proximity Sensor & Flood Illuminator 2018

MEDICAL IMAGING AND BIOPHOTONICS
- MARKET AND TECHNOLOGY REPORT
  - X-Ray Detectors for Medical, Industrial and Security Applications 2019 - New
  - Microscopy Life Science Cameras: Market and Technology Analysis 2019
  - Ultrasound technologies for Medical, Industrial and Consumer Applications 2018

- PATENT REPORT
  - Optical Coherence Tomography Medical Imaging 2018

MICROFLUIDICS
- MARKET AND TECHNOLOGY REPORT
  - Status of the Microfluidics Industry 2019 - Update
  - Organ-on-a-Chip Market & Technology Landscape 2019 - New
  - Point-of-Need Testing Application of Microfluidic Technologies 2018
  - Liquid Biopsy: from Isolation to Downstream Applications 2018
  - Chinese Microfluidics Industry 2018

- PATENT REPORT
  - Microfluidic Manufacturing Technologies 2019
  - Nanopore Sequencing 2019

INKJET AND ACCURATE DISPENSING
- MARKET AND TECHNOLOGY REPORT
  - Inkjet Printheads - Dispensing Technologies & Market Landscape 2019 - Update
  - Emerging Printing Technologies for Microsystem Manufacturing 2019 - New
  - Inkjet Functional and Additive Manufacturing for Electronics 2018

- STRUCTURE, PROCESS & COST REPORT
  - Piezoelectric Devices from Bulk to Thin Film 2019 - New
  - Piezoelectric Materials from Bulk to Thin Film Comparison 2019
OUR 2019 REPORTS COLLECTION (3/5)

18 fields of excellence combined with six markets to provide a complete picture of your industry landscape

BIOTECHNOLOGIES

- MARKET AND TECHNOLOGY REPORT
  - CRISPR-Cas9 Technology: From Lab to Industries 2018
  - Personalized Medicine 2019 – New

- PATENT REPORT
  - Neurotechnologies and Brain Computer Interface 2018

BIOMEMS & MEDICAL MICROSYSTEMS

- MARKET AND TECHNOLOGY REPORT
  - Medical Wearables: Market & Technology Analysis 2019 - New
  - Neurotechnologies and Brain Computer Interface 2018
  - BioMEMS & Non-Invasive Sensors: Microsystems for Life Sciences & Healthcare 2018

- PATENT REPORT
  - 3D Cell Printing 2019 - New
  - Circulating Tumor Cells Isolation 2019 - New

SOFTWARE AND COMPUTING

- MARKET AND TECHNOLOGY REPORT
  - Artificial Intelligence Computing For Automotive 2019 - New
  - Hardware and Software for Artificial Intelligence (AI) in Consumer Applications 2019 - Update
  - Image Signal Processor and Vision Processor Market and Technology Trends 2019
  - xPU (Processing Units) for Cryptocurrency, Blockchain, HPC and Gaming 2019 – New

- PATENT REPORT
  - Artificial Intelligence for Medical Diagnostics - New

MEMORY

- MARKET AND TECHNOLOGY REPORT
  - Status of the Memory Industry 2019 - New
  - MRAM Technology and Business 2019 - New
  - Emerging Non-Volatile Memory 2018

- STRUCTURE, PROCESS & COST REPORT
  - Memory Comparison 2019

- PATENT REPORT
  - Magnetoresistive Random-Access Memory (MRAM) 2019 - New
    - 3D Non-Volatile Memory 2018

ADVANCED PACKAGING

- MARKET AND TECHNOLOGY REPORT
  - Fan Out Packaging Technologies and Market Trends 2019 - Update
  - 3D TSV Integration and Monolithic Business Update 2019 - Update
  - Advanced RF SiP for Cellphones 2019 - Update
  - Status of Advanced Packaging Industry 2019 - Update
  - Status of Advanced Substrates 2019 - Update
  - Panel Level Packaging Trends 2019 - Update
  - Automotive Packaging 2019 - New
  - Trends in Automotive Packaging 2018
  - Thin-Film Integrated Passive Devices 2018

- STRUCTURE, PROCESS & COST REPORT
  - Advanced RF SiP for Cellphones Comparison 2019

Update: 2018 version still available

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## OUR 2019 REPORTS COLLECTION (4/5)

18 fields of excellence combined with six markets to provide a complete picture of your industry landscape

### SEMICONDUCTOR MANUFACTURING

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<td>Nano Imprint Lithography 2019 - New</td>
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<td>Equipment and Materials for Fan Out Packaging 2019 - Update</td>
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<td>Equipment for More than Moore: Thin Film Deposition &amp; Etching 2019 - New</td>
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<td>Wafer Starts for More Than Moore Applications 2018</td>
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<td>Polymeric Materials at Wafer-Level for Advanced Packaging 2018 Bonding and Lithography Equipment Market for More than Moore Devices 2018</td>
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### DISPLAY

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<td>Displays &amp; Optical Vision Systems for VR, AR &amp; MR 2018</td>
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Update: 2018 version still available
OUR 2019 REPORTS COLLECTION (5/5)

18 fields of excellence combined with six markets to provide a complete picture of your industry landscape

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Update: 2018 version still available
OUR 2019 MONITORS COLLECTION (1/2)

Get the most updated overview of your market to monitor your strategy

Yole Développement, System Plus Consulting and KnowMade, all part of the Yole Group of Companies, are launching a collection of 10 monitors in 2019. The monitors aim to provide updated market, technology and patent data as well dedicated quarterly analyses of the evolution in your industry over the previous 12 months. Furthermore, you can benefit from direct access to the analyst for an on-demand Q&A and discussion session regarding trend analyses, forecasts and breaking news.

Topics covered will be compact camera modules (CCMs), advanced packaging, compound semiconductors, microfluidics, batteries, RF and memory.

MARKET MONITOR by Yole Développement

A FULL PACKAGE:
The monitors will provide the evolution of the market in units, wafer area and revenues. They will also offer insights into what is driving the business and a close look at what is happening will also be covered in it.

The following deliverables will be included in the monitors:
- An Excel database with all historical and forecast data
- A PDF slide deck with graphs and comments/analyses covering the expected evolutions

- ADVANCED PACKAGING – NEW
  This monitor will provide the evolution of the advanced packaging platforms. It will cover Fan-Out Wafer Level Packaging (WLP), Fan-Out Panel Level Packaging (PLP), Wafer-Level Chip Scale Packaging (WLCSP), Flip Chip packaging platforms, and 2.5D and 3D Through Silicon Via (TSV) integration. Frequency: Quarterly, starting from Q3 2019

- COMPOUND SEMI. – NEW
  This monitor will describe how the compound semiconductor industry is evolving. It will offer a close look at GaAs, InP, SiC, GaN and other compounds of interest providing wafer volumes, revenues, application breakdowns and momentum. Frequency: Quarterly, starting from Q3 2019

- CAMERA MODULE – NEW
  This monitor will provide the evolution of the imaging industry, with a close look at image sensor, camera module, lens and VCM. Volumes, revenues and momentum of companies like Sony, Samsung, Omnivision and OnSemi will thus be analysed. Frequency: Quarterly, starting from Q3 2019

- MEMORY – UPDATE
  For the memory industry you can have access to a quarterly monitor, as well as an additional service, a monthly pricing. Both services can be bought separately:
  - DRAM Service: Including a quarterly monitor and monthly pricing.
  - NAND Service: Including a quarterly monitor and monthly pricing.

REVERSE TECHNOLOGY MONITOR by System Plus Consulting

- SMARTPHONES – NEW
  To stay updated on the latest components, packaging and silicon chip choices of the smartphone makers, System Plus Consulting has created its first Smartphone Reverse Technology monitor. This year, get access to the packaging and silicon content database of at least 20 different flagship smartphones — more than five per quarter. Starting at the beginning of 2019, the monitor will include an Excel database report for each phone and a quarterly comparison.
PATENT MONITOR by KnowMade

A FULL PACKAGE:
Starting at the beginning of the year, the KnowMade monitors include the following deliverables:

- An Excel file including the monthly IP database of:
  - New patent applications
  - Newly granted patents
  - Expired or abandoned patents
  - Transfer of IP rights through re-assignment and licensing
  - Patent litigation and opposition
- Quarterly report including a PDF slide deck with the key facts & figures of the quarter: IP trends over the three last months, with a close look to key IP players and key patented technologies.

- GaN for Power & RF Electronics
  Wafers and epiwafers, GaN-on-SiC, silicon, sapphire or diamond, semiconductor devices such as transistors, and diodes, devices and applications including converters, rectifiers, switches, amplifiers, filters, and Monolithic Microwave Integrated Circuits (MMICs), packaging, modules and systems.

- GaN for Optoelectronics & Photonics
  Wafers and epiwafers, GaN-on-sapphire, SiC or silicon; semiconductor devices such as LEDs and lasers; and applications including lighting, display, visible communication, photonics, packaging, modules and systems.

- Li-ion Batteries
  Anodes made of lithium metal, silicon, and lithium titanate (LTO); cathodes made of Lithium Iron Phosphate (LFP), Nickel-Manganese-Cobalt (NMC), Lithium Nickel Cobalt Aluminium Oxide (NCA), Lithium Nickel Metal Dioxide (LiNiMO2), Lithium Metal Phosphate (LiMPO4), and Lithium Metal Tetroxide (LiMO4); electrolytes including liquid, polymer/gel, and solid inorganics; ceramic and other separators; battery cells including thin film/microbattery, flexible, cylindrical and prismatic; and battery packs and systems.

- Post Li-ion Batteries
  Battery technologies including redox-flow batteries, sodium-ion, lithiiumsulfur, lithium-air, and magnesium-ion, and their supply chains, including electrodes, electrolytes, battery cells and battery packs/systems.

- Solid-State Batteries
  Supply chain including electrodes, battery cells, battery packs/systems and electrolytes, including polymer, inorganic and inorganic/polymer, inorganic materials, including argyrodites, Lithium Super Ionic CONductor, (LISICONs), Thio-LISICONs, sulfide glasses, oxide glasses, perovskites, anti-perovskites and garnets.

- RF Acoustic Wave Filters
  Including Surface Acoustic Wave (SAW), Temperature Compensated (TC)- SAW, Bulk Acoustic Wave- Free-standing Bulk Acoustic Resonator (BAWFBAR), BAW-Solidly-Mounted Resonator (BAW-SMR), and Packaging.

- RF Power Amplifiers
  Including Low Noise Amplifiers, Doherty Amplifiers, Packaging, and Millimeter-Wave technology.

- RF Front-End Modules

- Microfluidics
  From components to chips and systems, including all applications.
To meet the growing demand for market, technological and business information, i-Micronews Media integrates several tools able to reach each individual contact within its network.

We will ensure your company benefits from this

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**ONLINE**

i-Micronews e-newsletter  
i-Micronews.com  
FreeFullPDF.com

**ONSITE**

Events

**INPERSON**

Webcasts

---

Unique, cost-effective ways to reach global audiences.  
Online display advertising campaigns are great strategies for improving your product/brand visibility. They are also an efficient way to adapt with the demands of the times and to evolve an effective marketing plan and strategy.

Brand visibility, networking opportunities  
Today’s technology makes it easy for us to communicate regularly, quickly, and inexpensively – but when understanding each other is critical, there is no substitute for meeting in-person. Events are the best way to exchange ideas with your customers, partners, prospects while increasing your brand/product visibility.

Targeted audience involvement equals clear, concise perception of your company’s message.  
Webcasts are a smart, innovative way of communicating to a wider targeted audience. Webcasts create very useful, dynamic reference material for attendees and also for absentees, thanks to the recording technology.

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#15,800+ monthly unique visitors on i-Micronews.com  
#10,900+ weekly readers of i-Micronews e-newsletter

#110 attendees on average  
#7+ key events planned for 2019 on different topics

#380 registrants per webcast on average to gain new leads for your business

---

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