Emerging Semiconductor Substrates: Market and Technology Trends 2019
GLOSSARY & ACRONYMS (1/2)

- **LDMOS**: Laterally Depleted Metal Oxide Semiconductor
- **AGR**: Annual Growth Rate
- **AlN**: Aluminum Nitride
- **APD**: Avalanche Photo Diode
- **AR**: Augmented Reality
- **ASP**: Average Selling Price
- **BAW**: Bulk Acoustic Wave
- **Bi-CMOS**: Bipolar and CMOS process technology
- **BICMOS**: Bipolar-CMOS
- **BIFET**: Bi Field Effect Transistor
- **BFM**: Baliga figure of merit
- **BOM**: Bill Of Materials
- **BTS**: Base Transceiver Station
- **CdTe**: Cadmium Tellurium
- **CIGS**: Copper-Indium-Gallium-Selenium
- **CMOS**: Complementary Metal-on silicon Oxide Semiconductor
- **CTE**: Coefficient of thermal expansion
- **CZ**: Czochralski
- **DBR**: Distributed Bragg Reflector
- **DFB**: Distributed Feedback Laser
- **DHBT**: Double Heterojunction Bipolar Transistor
- **DU**: Distributed Unit
- **EEL**: Edge Emitting Laser
- **EML**: Electro-absorption Modulated Laser
- **EPD**: Etch Pitch Density
- **EFG**: Edge defined film fed
- **FEM**: Front-End Module
- **FET**: Field Effect Transistor
- **FFT**: Fiber to the x
- **FIR**: Far Infrared
- **FM**: Frequency Modulation
- **F-P**: Fabry Pérot
- **FS**: Free Standing
- **FTIR**: Fourier-transform infrared spectroscopy
- **FTTH**: Fiber to the Home
- **FZ**: Floating Zone
- **GaAs**: Gallium Arsenide
- **GaN**: Gallium Nitride
- **Ga2O3**: Gallium Oxide
- **GaSb**: Gallium Antimonide
- **HB**: Horizontal Bridgman,
- **HBT**: Heterojunction Bipolar Transistor
- **HE**: High End
- **HEMT**: High Electron Mobility Transistor
- **HPHT**: High pressure high temperature
- **HVPE**: Hydride vapor phase epitaxy
- **IC**: Integrated Circuit
- **InSb**: Indium Antimonide
- **InP**: Indium Phosphide
- **InPOGaAs**: InP-on-GaAs
- **IR**: Infrared
- **JFM**: Johnson Figure of Merit
GLOSSARY & ACRONYMS (2/2)

- JFET: Junction field effect transistor
- KFM: Keyes figure of merit
- LD: Laser diode
- LEC: Liquid Encapsulated Czochralski
- LED: Light Emitting Diode
- LIDAR: Light Detection and Ranging
- LNA: Low Noise Amplifier
- LPE: Liquid Phase Epitaxy
- LWIR: Long Wave Infrared
- MBE: Molecular Beam Epitaxy
- MCM: Multi-Chip Module
- MEMS: Micro-Electro-Mechanical System
- MESFET: Metal Semiconductor Field Effect Transistor
- MEMOCVD: Migration-enhanced metal-organic chemical vapor deposition
- MIMO: Multiple Input, Multiple Output
- MMIC: Monolithic Microwave Integrated Circuit
- MOCVD: Metalorganic Chemical Vapor Deposition
- MOHVPE: Metal organic hydride vapor phase epitaxy
- MQW: Multiple Quantum Wells
- MWCVD: Microwave enhanced CVD
- MWIR: Medium Wave IR
- MLED: MicroLED
- NIR: Near IR
- ODM: Original Design Manufacturer
- OEM: Original Equipment Manufacturer
- PA: Power Amplifier
- PAE: Power Added Efficiency
- PD: Photodiode
- POI: Piezo on Insulator
- PVDNC: Plasma vapor deposition of nanocolumns
- RADAR: Radio Detection And Ranging
- RFFE: RF Front-End
- RWG: Ridge waveguide
- SC: Semi Conductive
- SBD: Schottky barrier diode
- SHBT: Single Heterojunction Bipolar Transistor
- SI: Semi Insulative
- SiC: Silicon Carbide
- SiGe: Silicon Germanium
- SiPH: Silicon Photonics
- SOL: Silicon-on-Insulator
- SWIR: Short Wave IR
- TD: Threading dislocation
- THz: Terahertz
- TIA: Transimpedance Amplifier
- T2SL: Type-2 Superlattice
- UPS: Uninterruptible power supply
- VB: Vertical Bridgman
- VCSEL: Vertically Cavity Surface Emitting Laser
- VGF: Vertical Gradient Freeze
- VISAR: Video Synthetic Aperture Radar
- VR: Virtual Reality
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OBJECTIVES OF THE REPORT

- To give an overview of different emerging semiconductor substrates other than Si, GaAs, InP and SiC
- Present the drivers and the barriers for each material
- Discuss the time to market
- Assess potential applications
- Identify the key players
ABOUT THE AUTHORS

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COMPANIES CITED IN THIS REPORT

TERMINOLOGY & DEFINITIONS

• **Blank, Bare or Raw wafer**
  • Un-polished wafer, as cut from the crystal.

• **Freestanding wafer**
  • Thick layer separated from a mother substrate (usually cheaper, such as Si or Sapphire).

• **Epi-ready wafer**
  • A raw wafer single- or double- side polished, ready to enter a MOCVD/MBE reactor. Clean-room compatible. No epitaxy layer.

• **Template**
  • Raw-wafer + nucleation + buffer layer with several µm of layer (GaN/AlN, etc..). Ready to enter a second phase of epitaxy to grow the active layer.

• **Epi-wafer**
  • [raw-wafer + nucleation + buffer layer + active layer] OR [Template + active layer]. An epi-wafer is ready to enter the Front-End line for deposition, etching, lithography, passivation… etc.… steps.

• **Engineered substrate**
  • Thin layer from crystalline wafer or epi layer bonded onto a carrier substrate. Ready to enter a second phase of epitaxy to grow the active layer.

---

**Raw wafer as cut**

**Free Standing wafer**

**Template**

**Engineered substrate**

Carrier substrate
WHAT IS IN THIS REPORT?

• In this report, we give an overview of the emerging crystalline semiconductor substrates, including GaSb, InSb, GaN, Ga2O3, AlN and diamond. Except for diamond, the materials are all compound semiconductors.

• We do NOT include some other compound semiconductors, such as SiC, GaAs and InP, which are well established and covered in various reports by Yole. We also do NOT include SiGe, which is manufactured on silicon wafers using conventional silicon processing toolsets.

• As these emerging wafers are costly, there have been numerous developments by academics and industry to develop low cost alternative solutions, such as templates or engineering substrates. In this context, we also include in this report the GaN template, AlN template and engineered substrates.

• We present our understanding on the developmental status/maturity of these materials and their application potential for both photonic and electronics applications, including laser diode, LED, sensor/detector, power electronics and RF. We do not look at PV applications, which is a very mature market.
The semiconductors address wavelengths according to their specific band gaps, which are intrinsic to each material.

While AlN and bulk GaN emit in the ultraviolet spectrum, GaSb and InSb related alloys emit in the infrared regime.
SCOPE OF THE REPORT

Semiconductor applications

This report covers the semiconductor applications of the materials in the previous slide.
Power applications (Baliga FOM)

Baliga Figure-of-Merit is a metric for how good a material is for uni-polar power device technology. It is a measure of the drift electron mobility and the critical electric field.

\[ R_{on} [\Omega \cdot cm^2] = \frac{4 \cdot Vbd \cdot 2}{\varepsilon \cdot \mu \cdot Ec^3} \]

Bulk GaN, Ga_2O_3, diamond and AlN have superior theoretical figures compared to Si and SiC due to intrinsic material properties.
There are very few bulk AlN players as of 2019. But according to our understanding, there could be several startups coming in 2019-2020.
# FREE STANDING AND BULK GaN

## Overview

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<th>Freestanding GaN</th>
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<tr>
<td>Description</td>
<td>300-500 µm thick GaN layer separated from a mother substrate.</td>
<td>GaN single crystals sliced into wafers</td>
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<td>TD density</td>
<td>$1 \times 10^4$ to $5 \times 10^7$ depending on growth method</td>
<td>$1 \times 10^1$ to $5 \times 10^4$ depending on growth method</td>
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Diamond is a dream material with high thermal conductivity, band gap, electrical isolation, high electron mobility and radiation hardness. Synthetic single crystal diamonds have been developed for a long time now, yet still faces limited size and high cost.

Diamond material development began more than 50 years ago. Besides traditional tooling applications (drilling, cutting, etc.), interest in diamonds continues to grow for both optical and thermal applications, as well as for new semiconductor device applications such as high-power, high-frequency devices able to work at elevated temperatures.

Diamond’s unique physical and electrical properties, which include the highest-known thermal conductivity, a wide band gap, excellent electrical insulator properties, very high breakdown voltage and very high carrier mobility, make diamond an excellent candidate for creating electronic devices with superior performance.

The availability of diamond materials such as high-quality, large-size single-crystal wafers and thick polycrystalline films, and the decrease of their still-high manufacturing costs, are crucial milestones for diamond electronic device development and detection / sensing applications.
Soitec has tried to develop engineered substrates for different compound semiconductors.

**Engineered Substrate**

**Case Study: Soitec’s Smart Cut™ or Smart Stacking™ (1/2)**

- **Smart Cut™** is Soitec’s proprietary technology for wafer bonding and layer splitting. It is a mature technology on materials like Silicon. Silicon On Insulator (SOI) wafers are used by AMD, Intel, Sony and others for the manufacturing of high performance semiconductors.

- **Smart Stacking™** is done through low-temperature direct wafer bonding and mechanical-chemical thinning to offer layer transfer capabilities for circuit transfer.

- Soitec has tried to adapt Smart Cut™ and/or Smart Stacking™ to compound semiconductor and claims that it is a generic technology for Si, GaN, SiC, GaAs, InP…
RELATED REPORTS

- Edge Emitting Laser (EEL) 2019 Market and Technology Trends
- Status of the Power Electronics Industry 2018
- Power SiC 2018: Materials, Devices and Applications
- GaN Power 2018: Epitaxy, Devices, Applications and Technology Trends
- 5G Impact on R.F Front End Modules & Connectivity for Cellphones 2018 report

From Technologies to Market
Silicon isn’t the perfect semiconductor, and with it currently being pushed to its limits, alternative platforms and compound semiconductors have emerged. The success stories include GaAs for RF and photonics applications, SiC for power and RF applications, GaN-on-sapphire for LEDs, and SOI for RF and CIS imaging sensors.

Fueled by a desire to push performance limits and reduce cost, new materials are being explored for different semiconductor applications. This report looks at the drivers involved.

Starting with RF applications, there are numerous market drivers, including 5G for infrastructure and handsets, defense applications and civil automotive radar, and more. For example, 5G deploys MIMO, which is used in high-end 4G LTE phones. MIMO is obligatory for handsets, and more filters will be needed. Plus, better performance is required, which implies a big market opportunity for new materials.

Regarding the power electronics market, which is currently driven by the electrification of transportation, renewable energy, motor drive, and numerous power supply applications, enhanced device performance to reduce power consumption is a general trend that has created market opportunities for wide band gap materials like SiC. Indeed, the SiC power device market is taking off, though the substrate remains expensive. Is there a place for other wide band gap and ultra-wide band gap semiconductors, like Ga$_2$O$_3$?

The photonics market, ranging from ultraviolet (UV) to the infrared (IR) spectrum, brings huge opportunities: from water purification and gas sensors, to infrared imagers. Since the wavelength is determined by the bandgap of the material (which is intrinsic to each material), different materials are being developed to push the wavelength towards shorter or longer regions.

Electronics and photonics applications are creating plenty of opportunities for emerging semiconductor substrates. Combined, Yole Développement (Yole) expects the emerging semiconductor substrate market to surpass $400M, growing at a 24% CAGR from 2018 - 2024. This report covers state-of-the-art crystalline semiconductor substrates, including GaSb, InSb, bulk GaN, Ga$_2$O$_3$, bulk AlN, diamond, GaN, AlN templates, and engineered substrates like piezo-on-insulator (POI) are also covered.

**EMERGING SEMICONDUCTOR SUBSTRATES: MARKET & TECHNOLOGY TRENDS 2019**

**Market & Technology Report - May 2019**

Emerging semiconductor substrates are expected to grow at a 24% CAGR from 2018 - 2024.

**REPORT KEY FEATURES**

- State-of-the-art technology development of GaSb, InSb, bulk GaN, Ga$_2$O$_3$, bulk AlN, diamond, GaN, AlN templates, and emerging engineered substrates
- Application potential for each material
- Key players/ecosystem for each material
- Materials market size (in $M) in 2018 and 2024
- Materials price in 2018 and 2024

**ELECTRONICS AND PHOTONICS APPLICATIONS ARE CREATING PLENTY OF OPPORTUNITIES FOR EMERGING SEMICONDUCTOR SUBSTRATES**

![2018-2024 emerging materials - Market revenue](image)

*Detailed market size forecast for 2024 available in the report.*

(Yole Développement, May 2019)
Researchers and engineers have plenty of ideas, and now the questions are, “Which emerging semiconductor substrate will be the next game-changer?” and “For which application?”

Starting with GaSb and InSb, laser diodes (LDs) and photodiodes (PDs) based on these materials are already deployed in performance-driven military applications. But this is not all. For example, IQE, a leading antimonide wafer and epiwafer supplier, is actively engaged with tier1 OEMs on new opportunities to migrate antimonide-based “see in the dark” IR technologies into consumer markets. Yole also sees that an emerging GaSb-based type-2-superlattice (T2SL) technology is being developed by several major detector players including FLIR, Semiconductor Devices, and IRnova. This technology is expected to penetrate into consumer applications, with ramp-up in the coming years.

Bulk GaN wafers have for many years been widely used for laser diode applications. Recently, researchers have explored their usage in power electronics and RF applications. We see a growing effort, led by Japanese players (ranging from materials suppliers to device suppliers like Toyoda Gosei), to make vertical GaN-on-GaN power devices happen. In the meantime, an ultra-wide band gap material (Ga$_2$O$_3$) is garnering increased attention. Wafers up to six inches have been demonstrated, with the promise of potentially lower cost than today’s SiC solutions. Future ramp-up will depend on technology/cost competition from other existing solutions.

Up to now we have considered bulk crystal materials, but they are not the whole story. Templates and engineered substrates are also being developed for either lower cost (i.e. SiC and poly SiC bonding) or better performance, such as piezo-on-insulator for filter applications.

This report conveys Yole understanding of these substrates’ application potential in RF, power electronics, photonics (including laser diodes), LEDs, sensors, and detectors.
REPORT OBJECTIVES

• Overview of different emerging semiconductor substrates other than Si, GaAs, InP and SiC
• Understanding of the driver and the barrier of each materials
• Time to market discussion
• Application potential assessment
• Identification of the key players

COMPANIES CITED IN THE REPORT (non exhaustive list)


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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 as 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)
More information on www.yole.fr

CONSEILLERIE ET ANALYSE
• Données de marché et recherche, analyse marketing
• Analyse technologique
• Conseil stratégie
• Ingénierie et coût inverse
• Analyse brevets
• Design et caractérisation de systèmes d’optique innovant
• Services financiers (due diligence, M&A avec notre partenaire)
Plus d’informations sur www.yole.fr

MEDIA & EVENTS
• i-Micronews.com website & related e-newsletter
• Communication & webcast services
• Events: TechDays, forums...
More information on www.i-micronews.com

RÉPONDS
• Rapports sur la technologie et les marchés
• Analyse investigation et risque de contrefaçon brevet
• Structure, processus et analyse coût
• Outil de simulation coût
Plus d’informations sur www.i-micronews.com/reports

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• Reports: David Jourdan (jourdan@yole.fr) Yole Group of Companies
• Press Relations & Corporate Communication: Sandrine Leroy (leroy@yole.fr)
**Life Sciences & Healthcare**
- Microfluidics
- BioMEMS & Medical Microsystems
- Inkjet and accurate dispensing
- Solid-State Medical Imaging & BioPhotonics
- BioTechnologies

**Power & Wireless**
- RF Devices & Technologies
- Compound Semiconductors & Emerging Materials
- Power Electronics
- Batteries & Energy Management

**Semiconductor & Software**
- Package, Assembly & Substrates
- Semiconductor Manufacturing
- Memory
- Software & Computing

**Photonics, Sensing & Display**
- Solid-State Lighting
- Display
- MEMS, Sensors & Actuators
- Imaging
- Photonics & Optoelectronics
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)

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  - Excel database covering supply, demand, and technology
  - Price, market, demand and production forecasts
  - Supplier market shares [www.i-Micronews.com/reports](http://www.i-Micronews.com/reports)

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6 COMPANIES TO SERVE YOUR BUSINESS

Yole Group of Companies

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.bmorpho.com

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**OUR GLOBAL ACTIVITY**

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About Yole Développement | www.yole.fr | ©2019
Our analysts provide market analysis, technology evaluation, and business plans along the entire supply chain.

SERVING THE ENTIRE SUPPLY CHAIN

Integrators, end-users and software developers

Device manufacturers

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

Financial investors, R&D centers
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 5,000 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 in-depth analysis. 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 Wireless Infrastructure 2019
  - 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
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 - Update
  - 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 – New

**INKJET AND ACCURATE DISPENSING**
- **MARKET AND TECHNOLOGY REPORT**
  - Inkjet Printheads - Dispensing Technologies & Market Landscape 2019 - Update
  - Emerging Printing Technologies for Microsystem Manufacturing 2019 - New
  - Piezoelectric Materials from Bulk to Thin Film 2019 - New
  - Inkjet Functional and Additive Manufacturing for Electronics 2018
- **STRUCTURE, PROCESS & COST REPORT**
  - Piezoelectric Materials from Bulk to Thin Film Comparison 2019

Update: 2018 version still available

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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
- **PATENT REPORT**
  - Personalized Medicine 2019 – New

**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
  - Nanopore Sequencing 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

**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
  - System in Package (SiP) Technology and Market Trends 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

- MARKET AND TECHNOLOGY REPORT
  - Nano Imprint Lithography 2019 - New
  - Equipment and Materials for Fan Out Packaging 2019 - Update
  - Equipment for More than Moore: Thin Film Deposition & Etching 2019 - New
  - Wafer Starts for More Than Moore Applications 2018
  - Polymeric Materials at Wafer-Level for Advanced Packaging 2018

- STRUCTURE, PROCESS & COST REPORT
  - Bonding and Lithography Equipment Market for More than Moore Devices 2018

- PATENT REPORT
  - Hybrid Bonding for 3D Stack 2019 – New

SOLID STATE LIGHTING

- MARKET AND TECHNOLOGY REPORT
  - Status of the Solid State Light Source Industry 2019 - New
  - Edge Emitting Lasers (EELS) 2019 - New
  - Light Shaping Technologies 2019 - New
  - Automotive Advanced Front Lighting Systems 2019 - New
  - VCSELs - Technology, Industry and Market Trends 2019 - Update

- STRUCTURE, PROCESS & COST REPORT
  - Wafer Bonding Comparison 2018

- PATENT REPORT
  - VCSEL Comparison 2019

DISPLAY

- MARKET AND TECHNOLOGY REPORT
  - Next Generation 3D Display 2019 - New
  - Next Generation Human Machine Interaction (HMI) in Displays 2019 - New
  - Micro- and Mini-LED Displays 2019 - Update

- PATENT REPORT
  - Technologies And Markets for Next Generation Televisions
  - Displays & Optical Vision Systems for VR, AR & MR 2018

- PATENT REPORT
  - MicroLED Displays : Intellectual Property Landscape 2018

Update : 2018 version still available

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OUR 2019 REPORTS COLLECTION (5/5)

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

POWER ELECTRONICS
- MARKET AND TECHNOLOGY REPORT
  - Power SiC: Materials, Devices and Applications 2019 - Update 📚
  - Power Electronics for EV/HEV and e-mobility: Market, Innovations and Trends 2019 - Update 📚
  - Status of the Power Electronics Industry 2019 - Update 📚
  - Discrete Power Packaging : Material Market and Technology Trends 2019 - New 📚
  - Status of the Power ICs Industry 2019 - Update 📚
  - Status of the Passive Components for the Power Electronics Industry 2019 - Update 📚
  - Status of the Inverter Industry 2019 - Update 📚
  - Status of the Power Module Packaging Industry 2019 - Update 📚
  - Wireless Charging Market Expectations and Technology Trends 2018 📚
  - Power GaN 2018: Epitaxy, Devices, Applications and Technology Trends 📚

- STRUCTURE, PROCESS & COST REPORT
  - Automotive Power Module Packaging Comparison 2018 📚
  - GaN-on-Silicon Transistor Comparison 2019 📚
  - SiC Transistor Comparison 2019 📚

- PATENT REPORT
  - Power SiC : Materials, Devices and Modules 2019 - New 📚
  - Power GaN : Materials, Devices and Modules 2019 – Update 📚

BATTERY & ENERGY MANAGEMENT
- MARKET AND TECHNOLOGY REPORT
  - Status of the Rechargeable Li-ion Battery Industry 2019 - New 📚
  - Li-ion Battery Packs for Automotive and Stationary Storage Applications 2019 - Update 📚

- PATENT REPORT
  - Battery Energy Density Increase: Materials and Emerging Technologies 2019 - New 📚
  - Solid-State Batteries 2019 - New 📚
  - Status of the Battery Patents 2018 📚

COMPOUND SEMI.
- MARKET AND TECHNOLOGY REPORT
  - Emerging Compound Semiconductor Market & Technology Trends 2019 - New 📚
  - Status of the Compound Semiconductor Industry 2019 - New 📚
  - InP Materials, Devices and Applications 2019 - New 📚
  - GaAs Wafer and Epiwafer Market: RF, Photonics, LED and PV Applications 2018 📚

- PATENT REPORT
  - GaN-on-Silicon Substrate: Materials, Devices and Applications 2019 - Update 📚
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**

**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.

**COMPUND 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.
OUR 2019 MONITORS COLLECTION (2/2)

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

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.

o 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.

o 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.

o 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 (LiNiM02), 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.

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

o 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.

o 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.

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

o RF Front-End Modules

o Microfluidics
  From components to chips and systems, including all applications.
I-MICRONEWS MEDIA

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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**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.

#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

**Contact:** Camille Veyrier (veyrier@yole.fr), Marketing & Communication Director
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