

GaN RF MARKET: APPLICATIONS, PLAYERS, TECHNOLOGY, AND SUBSTRATES 2020

Market & Technology Report - May 2020

Driven by military applications and 5G telecom infrastructure, the GaN RF market continues growing.

WHAT'S NEW

- Updated packaged device and bare die market segmentation, from Yole Développement
- Extensive analysis of 5G wireless infrastructure and competitive analysis of GaN versus other existing technologies, such as GaAs and LDMOS
- Comprehensive analysis of the military GaN RF market, including a detailed overview of airborne, ground-borne, and ship-borne military radar, as well as geographical evolution
- Device segmentation by discrete HEMT, MMIC, front-end modules, and integration, as well as an advanced packaging technology roadmap
- Overview of GaN RF device technologies on different substrates - silicon, SiC and diamond - including analysis of landscape and market maturity

KEY FEATURES

- In-depth analysis of GaN's penetration in different applications, including 4G LTE and 5G wireless infrastructure, handset, military, satellite communication, RF energy, wired broadband, civil radar, and avionics
- Analysis of different players in different markets, along with their product ranges and technologies for each substrate platform
- Outline of market access and market-size evolution from 2019 - 2025, and technology split
- Exploration of the main technologies in GaN devices on silicon, SiC, and diamond substrates, and packaging in the different application markets

TELECOM AND DEFENSE ARE DRIVING THE GaN RF MARKET

In the past few years, Radio Frequency (RF) applications have received a boost from the implementation of GaN technology. The main GaN RF market drivers remain telecom and defense applications. The total GaN RF market will increase from \$740M to more than \$2B by 2025, with a CAGR of 12%.

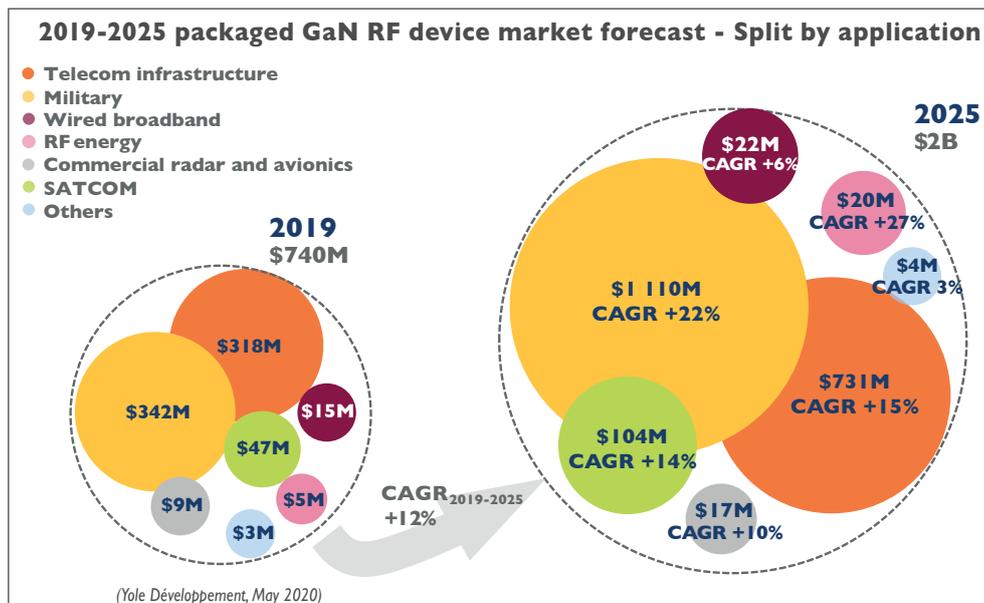
In telecom infrastructure, the aftermath of U.S. sanctions related to Huawei slowed the GaN-based Remote Radio Head (RRH) market in 2019 and pushed OEMs to restructure their supply chain for the coming years. Nevertheless, GaN deployment will remain the same for the long-term. In Active Antenna Systems (AAS), the increase in bandwidth will favor increasing GaN implementation. Also, small cells and backhaul connections will see an impressive deployment of GaN in the coming years.

In military applications, with investments from governments to improve their national security by replacing Travelling Wave Tube (TWT)-based systems, defense will remain one of the GaN RF market's main drivers. Radar is the main driver in

military applications, mainly due to the increase of T/R modules in new GaN based Active Electronically Scanned Array (AESA) systems and stringent requirements for lightweight devices for airborne systems. The total GaN RF military market will surpass \$1.1B in 2025, at a CAGR of 22%.

For handset, GaN's high performance and small form factor could attract OEMs. The adoption of GaN PA will depend on the evolution over the next five years of GaN's technology maturity, supply chain, and cost, as well as OEM strategies. What does the future hold for GaN PA in the handset market?

This report conveys Yole Développement's (Yole) understanding of GaN implementation in different market segments. It also includes an extensive overview of 5G's impact on the wireless infrastructure and RF Front Ends (FEs), along with the GaN-based military market. Furthermore, Yole shares its view of the market's current dynamics and future evolution.



IN THE 5G TELECOM MARKET, WHAT IS GaN'S POSITIONING COMPARED TO LDMOS?

Since its first commercial products appeared 20 years ago, GaN technology has become a serious competitor to LDMOS and GaAs in RF power applications, showing continuous

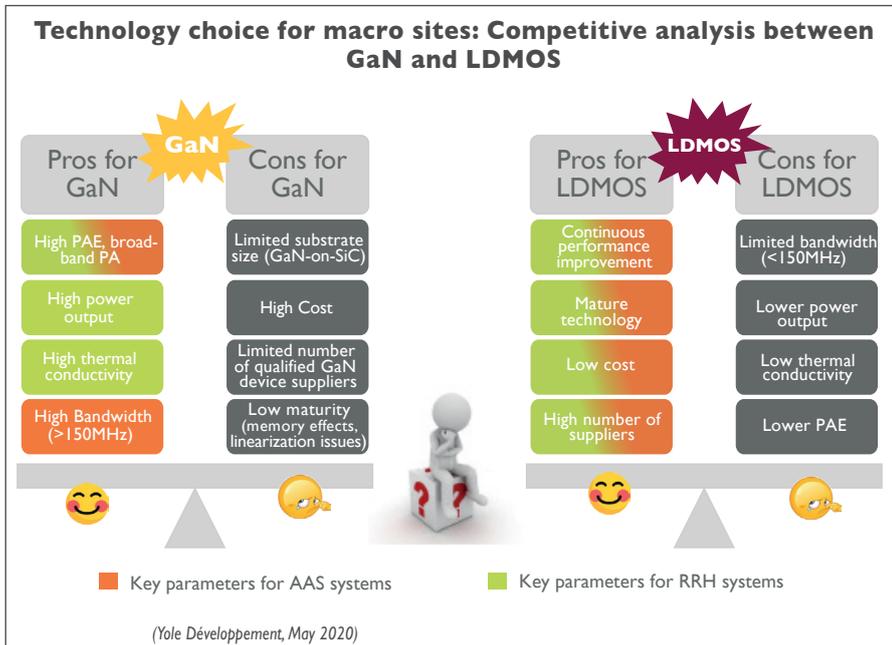
performance and reliability improvement at a lower cost. Following its penetration in the fourth generation (4G) Long-Term Evolution (LTE) telecom infrastructure market, GaN-on-

SiC is expected to maintain its strong position in 5G sub-6GHz RRH implementations. In the emerging segment of 5G sub-6GHz AAS, massive multiple input, and multiple output (MIMO) deployments, the rivalry between GaN and LDMOS continues. While cost-efficient LDMOS technology carries

on with noteworthy progress in high-frequency performance for sub6GHz, GaN-on-SiC offers remarkable bandwidth, PAE, and power output. Indeed, following the China Unicom and Telecom merger requiring >150MHz bandwidth, GaN has been a chosen technology in AAS. 5G telecom infrastructure is a very dynamic market requiring significant strategic decisions from OEMs, which could create new opportunities for GaN technology platforms.

In this context, GaN-on-Si stands as a potential challenger and promises cost-efficient, integrated solutions. Even though GaN-on-Si market volume remains tiny as of Q1/2020, technology developments at sub6GHz and mm-wave are closely followed and evaluated by telecom equipment vendors.

This report discusses GaN's positioning amongst other competing technologies such as GaAs and LDMOS in the emerging 5G telecom markets. Also provided is an extensive overview of the value chain for different substrate platforms: SiC, Si, diamond, and bulk GaN, as well as discrete transistors, Monolithic Microwave Integrated Circuits (MMICs), and Front-End Module (FEM) technologies - with a special focus on advanced packaging aspects.



HOW IS THE GaN RF LANDSCAPE EVOLVING?

GaN-based commercial products and prototypes currently exist on SiC, Si, and diamond substrates, showing different technological maturities and thus varying value chain maturity. Numerous actors are involved in the well-established GaN-on-SiC technology field with different business models. However, following America's sanctions related to Huawei in Q2/2019, a short supply situation occurred, mainly in the GaN-based telecom infrastructure market. As a result, it will be important to watch how various strategic partnerships and investments unfold during 2020 - 2021. At the RF component level, market leaders Sumitomo Electric Device Innovations (SEDI) and II-VI plan to ramp up their vertically integrated 6-inch GaN-on-SiC wafer platforms to address the increasing demand from 5G. Additionally,

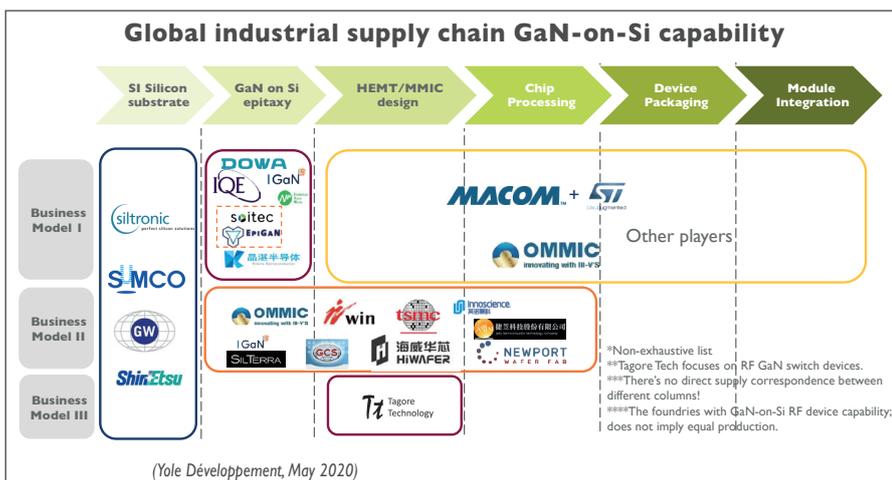
leading compound semiconductor foundry Win Semiconductors expects to double its GaN RF capacity during 2020 - 2021.

Regarding the military segment, each country and region is individually strengthening its GaN RF ecosystem. In the U.S., Northrop Grumman, Lockheed Martin, and Raytheon are driving GaN adoption. Meanwhile, UMS, SAAB, Airbus, Thales, and Leonardo are actively involved in Europe, while China Electronics Technology Group Corporation (CETC), a leading vertically integrated company, is boosting the Chinese GaN-based defense market.

In the GaN-on-Si business, while the MACOM-ST consortium's 6" fabrication line development is ongoing, French foundry OMMIC is offering GaN-on-Si MMIC technology for mm-wave markets. And that's not all: in 2019, following its acquisition of EpiGaN, Soitec is considering entry into the 5G infrastructure and handset market with its own innovative GaN-on-Si technology.

One of the most exciting GaN-on-Si markets is undoubtedly 5G handset. As of Q1/2020, several actors are seriously developing this technology. How and when can GaN enter handsets? What are the associated challenges? Which OEM(s) will shape its future?

This report examines the GaN RF industry playground, covering the value chain for epitaxy, device, and module design on SiC, Si, and diamond substrates. Yole also shares its understanding of the market's current dynamics and future evolution.



REPORT OBJECTIVES

- Overview of GaN RF markets: wireless infrastructure, handset, military, satellite communication, RF energy, wired broadband, civil radar, and avionics
- 2018 - 2024 market-size evolution and technology split
- Analysis of different players in different markets, along with their product ranges and technologies, for each substrate: Si, SiC, and diamond
- Summary of the main technologies in GaN devices on Si, SiC, and diamond substrates and packaging, in different application markets
- Explanation of the needs of different RF markets and the corresponding impact on the need for different technologies, along with geographic specifics

COMPANIES CITED IN THE REPORT (non exhaustive list)

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AUTHORS

As a Technology & Market Analyst, Compound Semiconductors, **Ezgi Dogmus**, PhD is member of the Power & Wireless division at Yole Développement (Yole). She is daily contributing to the development of these activities with a dedicated collection of market & technology reports as well as custom consulting projects. Prior Yole, Ezgi was deeply involved in the development of GaN-based solutions at IEMN (Lille, France). Ezgi also participated in numerous international conferences and has authored or co-authored more than 12 papers. Upon graduating from University of Augsburg (Germany) and Grenoble Institute of Technology (France), Ezgi received her PhD in Microelectronics at IEMN (France).



Ahmed Ben Slimane, PhD. is a Technology & Market Analyst, specialized in Compound Semiconductors at Yole Développement (Yole). As part of the Power & Wireless team, Ahmed is contributing to the development of dedicated collection of compound semiconductors market & technology reports and monitor. Previously, he worked as an epitaxy (MBE/MOCVD) & fabrication process engineer for GaAs-based photovoltaic applications at TOTAL and IPVF (Paris-Saclay, France). Ahmed also completed his PhD in Material Engineering from KAUST (Saudi Arabia), where his mission was focused on GaN-based microstructures for flexible solid state lighting. During this career, Ahmed Ben Slimane proposed lot of presentations towards an international audience. He authored/co-authored more than 20 publications in the semiconductor field, and submitted a patent on the III-V heterostructure for PV industry. Ahmed obtained his Master degree in Electronics Engineering from INPG (Grenoble, France).

RELATED REPORTS, MONITORS & TRACKS



- Active and Passive Antenna Systems for Telecom Infrastructure 2019
- 5G's Impact on RF Front-End Module and Connectivity for Cell phones 2019
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- Compound Semiconductor Quarterly Market Monitor
- MACOM NP1008 RF Power Amplifier with GaN-on-Si HEMT

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CONTACT



Western US & Canada

Steve Laferriere - steve.laferriere@yole.fr
+1 310 600-8267

Eastern US & Canada

Chris Youman – chris.youman@yole.fr
+1 919 607 9839

Europe and RoW

Lizzie Levenez – lizzie.levenez@yole.fr
+49 15 123 544 182

Benelux, UK & Spain

Marine Wybraniez - marine.wybraniez@yole.fr
+49 69 96 21 76 78

India and RoA

Takashi Onozawa – takashi.onozawa@yole.fr
+81-80-4371-4887

Korea

Peter Ok - peter.ok@yole.fr
+82 1040890233

Japan

Miho Ohtake – miho.ohtake@yole.fr
+81 34405-9204

Toru Hosaka – toru.hosaka@yole.fr
+81 90 1775 3866

Japan and Singapore

Itsuyo Oshiba – itsuyo.oshiba@yole.fr
+81-80-3577-3042

Greater China

Mavis Wang – mavis.wang@yole.fr
+886 979336809 +86 136 61566824

Sales Coordination & Customers Service

David Jourdan – david.jourdan@yole.fr
+33 472 83 01 90

Fayçal El Khamassi – faycal.khamassi@yole.fr
+33 472 83 01 95

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CONTACTS

For more information about :

- Consulting & Financial Services: Jean-Christophe Eloy (eloy@yole.fr)
- Reports & Monitors: David Jourdan (david.jourdan@yole.fr) & Fayçal Khamassi (faycal.khamassi@yole.fr)
- Marketing & Communication: Camille Veyrier (camille.veyrier@yole.fr)
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Bank code: 30056
Branch code: 00170
Account n°: 0170 200 1565 87
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If the Buyer cancels the order in whole or in part or postpones the date of mailing, the Buyer shall indemnify the Seller for the entire costs that have been incurred as at the date of notification by the Buyer of such delay or cancellation. This may also apply for any other direct or indirect consequential loss that may be incurred by the Seller, pursuant to such cancellation or postponement.

8. MISCELLANEOUS

8.1 All the provisions of these General Terms and Conditions of Sale are for the benefit of the Seller, but also for that of its licensors, resellers and agents. Each of them is entitled to assert and enforce these provisions against the Buyer.

Any notices under these Terms and Conditions shall be given in writing and shall be effective upon receipt by the other Party.

8.2 The Seller may, from time to time, update these General Terms and Conditions of Sale, and the Buyer, shall be deemed to have accepted the latest version of such General Terms and Conditions of Sale, once they have been duly communicated to the Buyer by the Seller.

9. GOVERNING LAW AND JURISDICTION

- 9.1 Any dispute arising out or linked to these General Terms and Conditions of Sale or to any Licenses or Products purchased in application thereof shall be submitted to the French Commercial Court of Lyon, which shall have exclusive jurisdiction upon such issues.
- 9.2 French law (without reference to any applicable conflict of law provisions) shall apply to these General Terms and Conditions of sale and any agreement between the Buyer and the Seller made pursuant thereto.