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A reliable manufacturing solution to enable normally-off recessed gate GaN MISHEMT by atomic layer etch and in-situ etch depth monitoring

Aileen O'Mahony

Product Manager

Agenda

- Oxford Instruments Company Overview
- Global Trends & Our Market Focus
- Cutting-edge Solutions for GaN Production Fabs
- Summary

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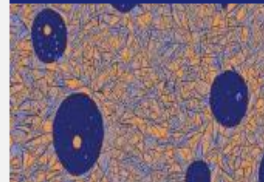
8 business units to meet the challenges of the most advanced technologies in the world

Materials & Characterisation

Products and solutions that enable the fabrication and characterisation of devices down to the atomic scale.

ASYLUM



Leader in development & manufacture of **Atomic Force Microscopy (AFMs)**

MAGNETIC RESONANCE

Offering a range of benchtop **Nuclear Magnetic Resonance (NMR)** instruments

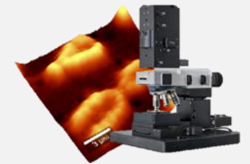
NANOANALYSIS

Enabling materials characterisation and **sample manipulation** at the nanometre scale

PLASMA TECHNOLOGY

Leading provider of **etch and deposition** processing solutions and recipes

WITec



Leader in d **Raman**, Atomic Force Microscopy, and Scanning **Near-field** Optical Microscopy

Research & Discovery

Provides advanced solutions that create unique environments and enable imaging and analytical measurements down to molecular and atomic levels.

ANDOR

Development & manufacture of high performance **scientific digital cameras** and light microscopes

NANOSCIENCE

Enabling **quantum** technologies, **nano** technology research, advanced materials & nano device development

X-RAY TECHNOLOGY

Leading manufacturer of **x-ray tubes**, power supplies & integrated x-ray sources

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Oxford Instruments Plasma Technology: Trusted and reliable partner in the CS community

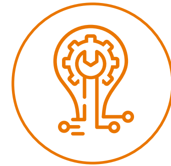
Atomic precision at HVM scale

Oxford Instruments thrives on innovation and provides **world-class plasma processing solutions** with **atomic precision**

Plasma processing solutions

Deposition	Etching
Atomfab plasma ALD	PlasmaPro 100 Cobra ICP & ALE

Knowledgeable & active member of the CS community

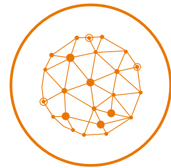


Years of expertise

- 37 years of experience in plasma processing captured in a comprehensive database with >6,000 references on various materials/technologies

Trusted partner in high-volume manufacturing

- Extensive experience in HVM with >3,000 installed systems including leading IDMs and foundries



Global network

- Global network for service, application engineering, and parts
- Worldwide support with locally positioned labs and engineers

Performance mindset

- Committed to ongoing performance, quality, and CoO improvements
- Delivered through application labs in UK and Taiwan (ITRI)

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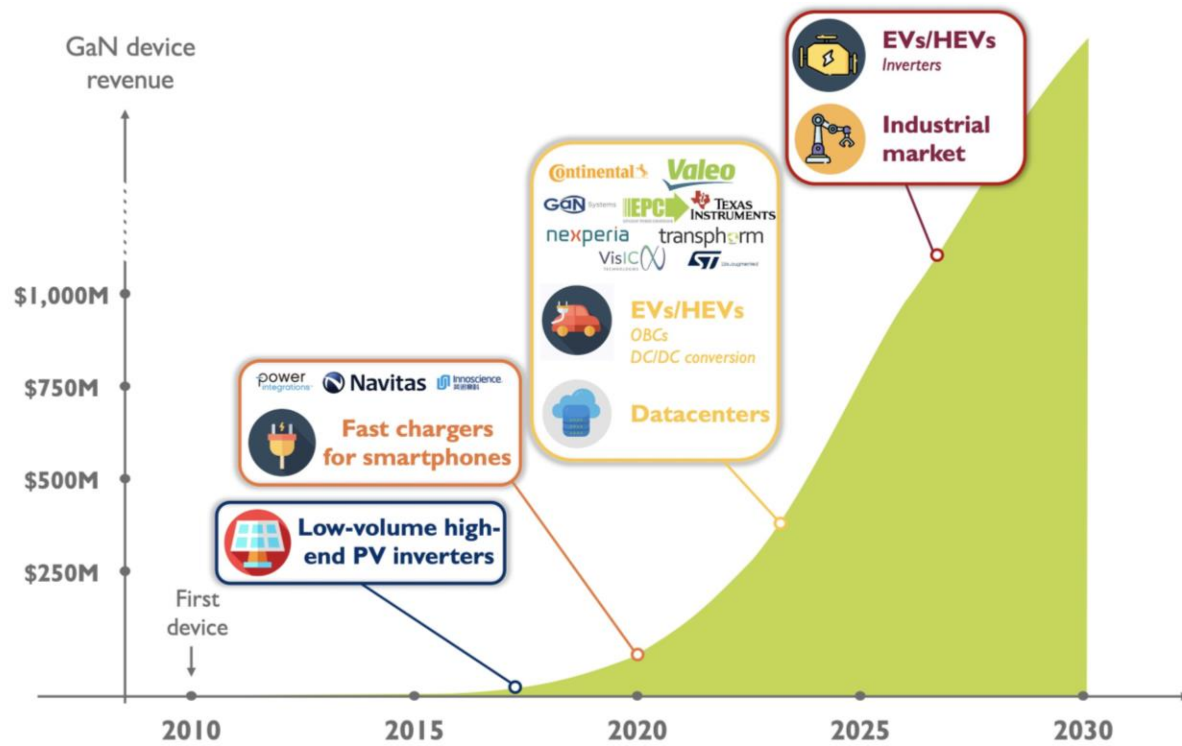
Market growth for GaN power devices

Significant predicted revenue growth for GaN devices in power electronics applications: >>$1B by 2030



(Source: GaN Power 2021: Epitaxy, Devices, Applications and Technology Trends report, Yole Développement, 2021)

Continued strong growth driven by adoption of GaN-based consumer electronics, telecoms/datacomms, automotive

Source: CAGR for total GaN power device market, Yole Développment, 2022

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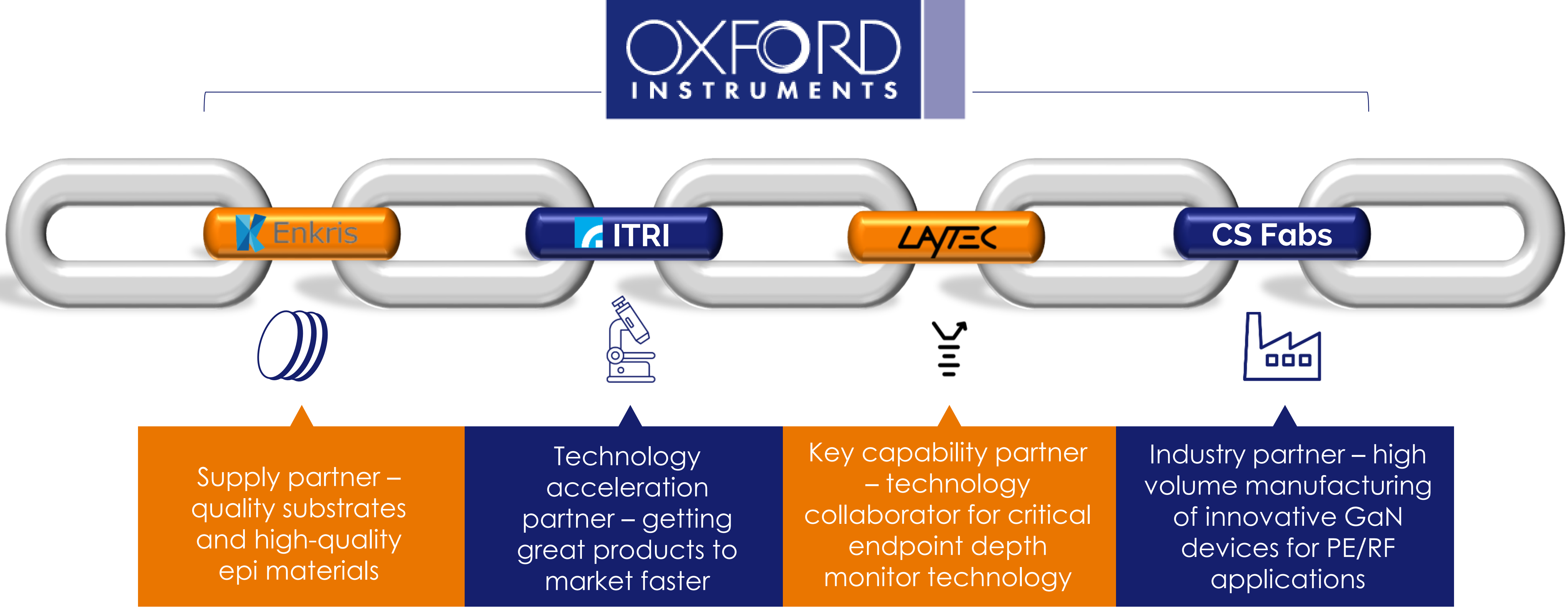
GaN Supply Chain Partners



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Focus on Power Electronics Solutions

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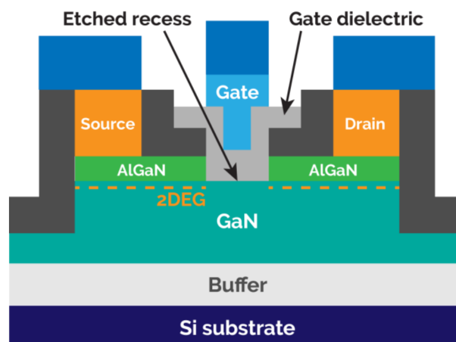
OUR MARKETS

OUR MATERIALS

Power Electronics: GaN, SiC

Opto electronics: GaAs, InP & GaN

Display & lighting: GaN & GaAs



Normally-off recessed gate MISHEMT:

- Lower leakage current
- Higher device breakdown
  - ➢ Atomic scale processing solutions enable ease of manufacturability of recessed gate MISHEMT

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Atomic Scale Processes Solutions: Enabling normally-off recessed gate MISHEMT

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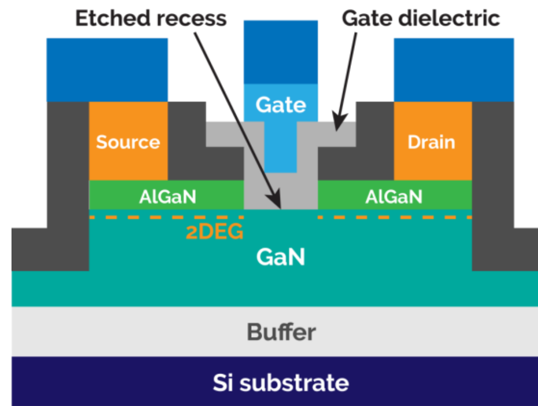
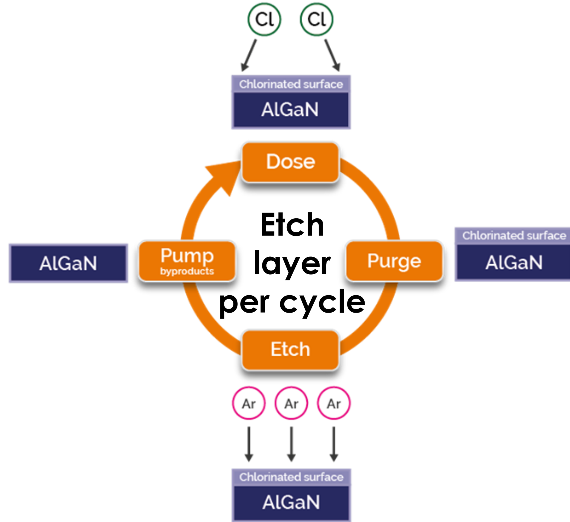
Atomic Layer Etch

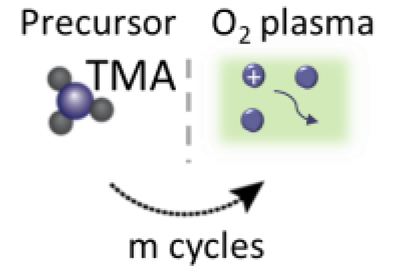
Low damage controlled etch of gate region for recessed MISHEMT



Atomic Layer Deposition

Low damage high quality GaN pre-treatment & passivation by plasma ALD





PP100 Cobra
Atomic Layer Etch

Atomfab
Atomic Layer Deposition

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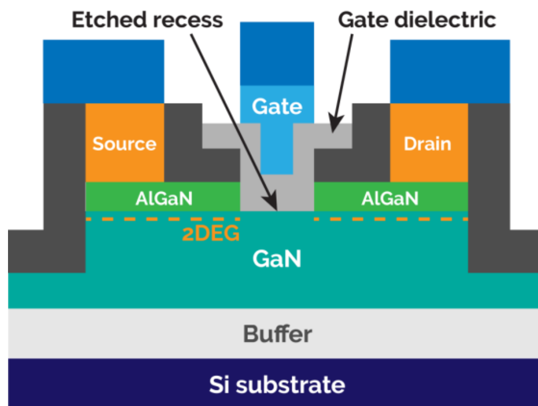
ALE with etch depth monitoring

Atomic Layer Etch:
Delivers low damage, accurate & repeatable etching for enhanced device reliability

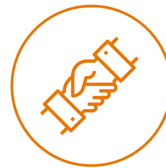
Recessed gate MISHEMT

- Needs low damage, low etch rate, accurate (±0.5 nm) control of AlGaN thickness
- **Solution**: Atomic layer etch and etch depth monitor



Advanced depth monitoring

- Patent-pending etch depth monitoring system
  - Designed and optimised for AlGaN etch thickness control
  - Fully integrated with ALE system hardware and software



Solution: ALE & etch depth monitor

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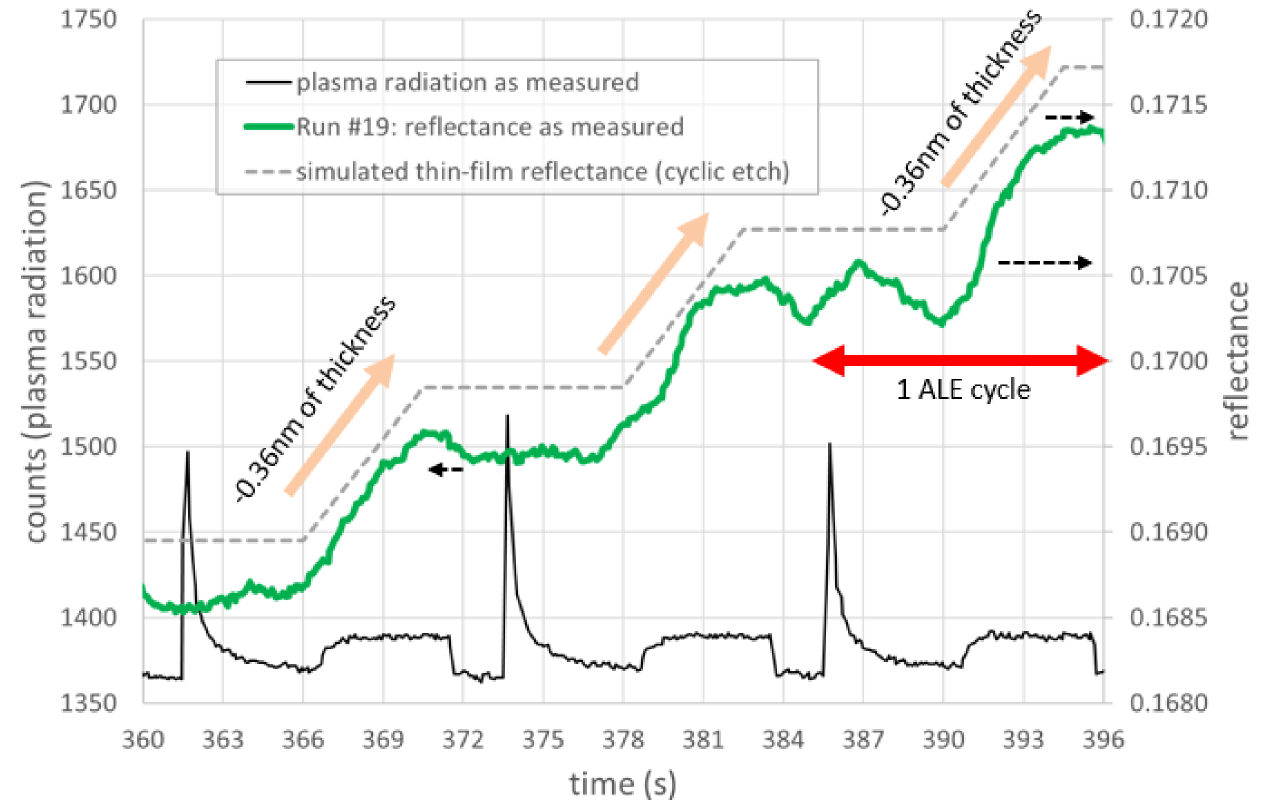
Optimised EPD for GaN HEMT etching

- Atomic layer etch for low, damage accurate etch control of AlGaN or GaN
- Optimised patent-pending UV wavelength endpoint control for ±0.5 nm accuracy

Fully-integrated LayTec EPD with Oxford Instruments PP100 Cobra ALE system

Cycle-by-cycle etch monitoring with EPD



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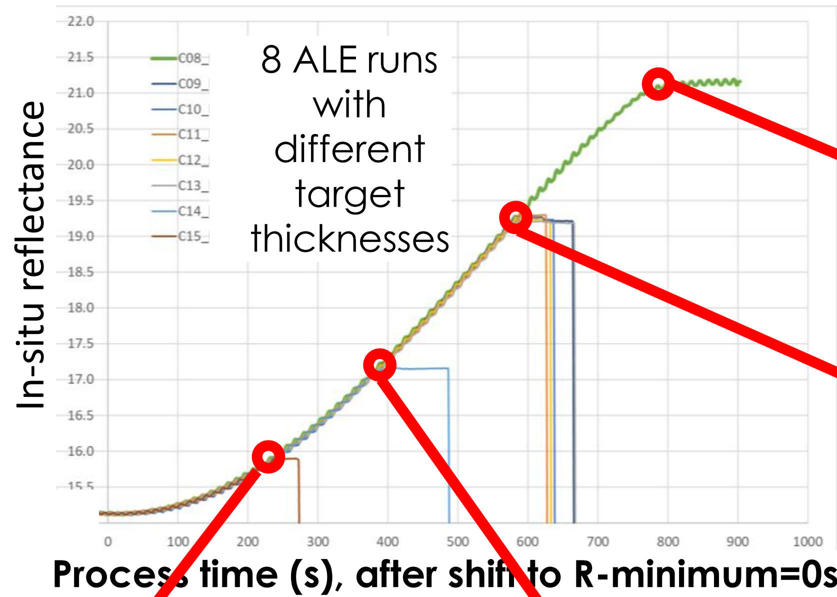
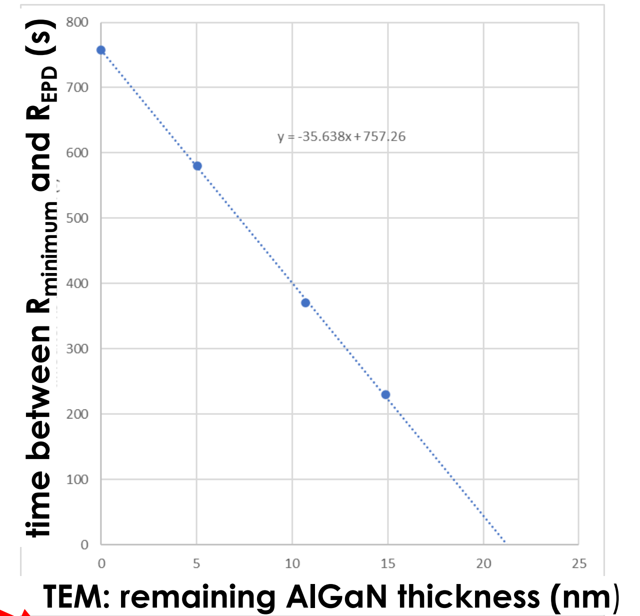
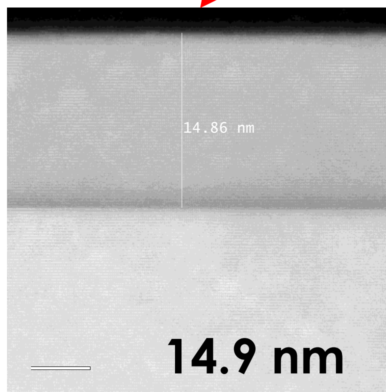
Delivering AlGaN target thickness with EPD

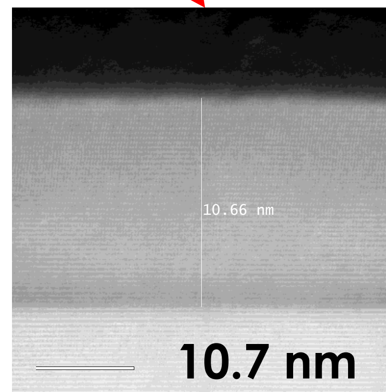


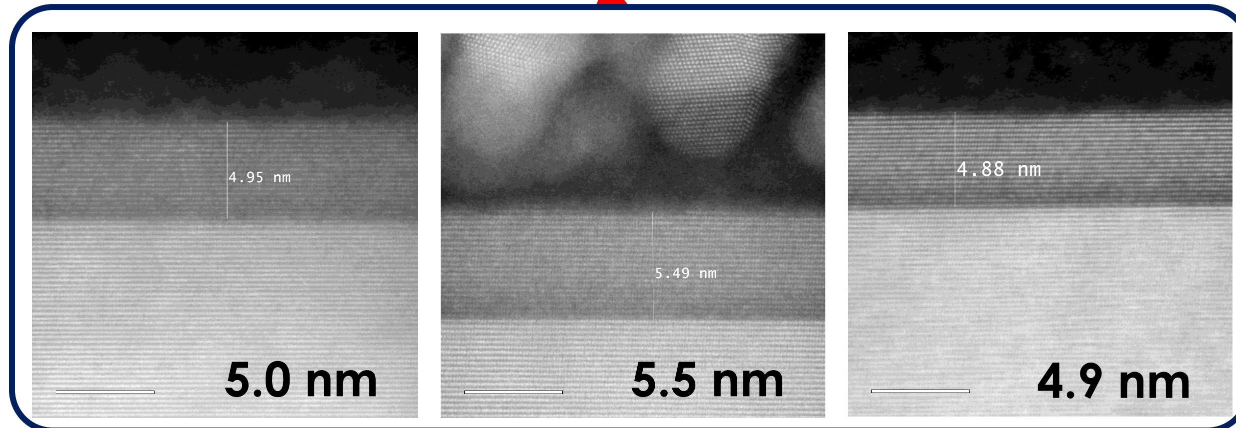
Fully removed AlGaN layer



TEM referencing of remaining AlGaN thickness







In-situ reflectance end-pointing perfectly correlates with TEM measurements!

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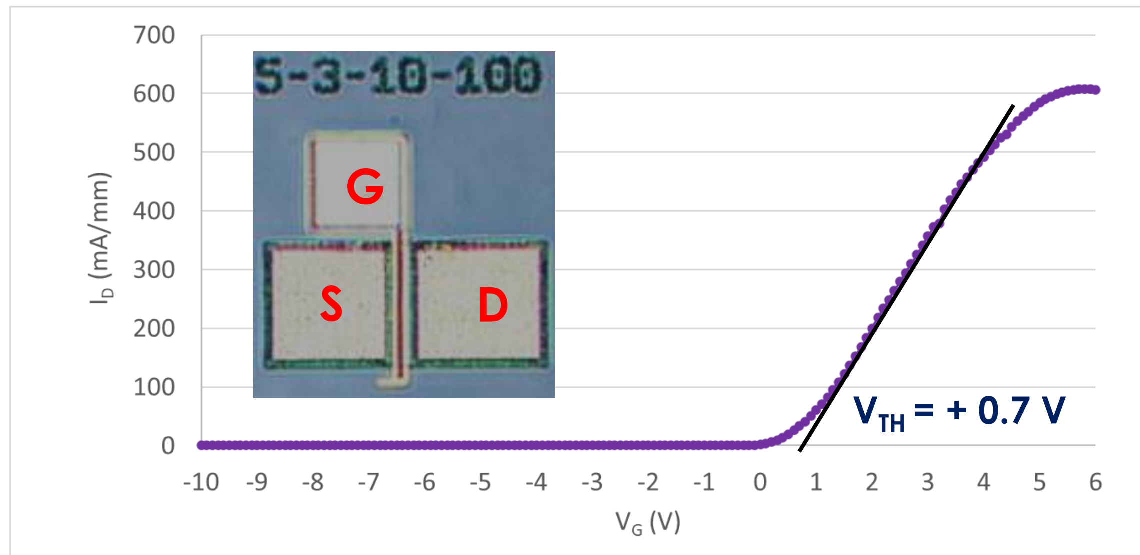
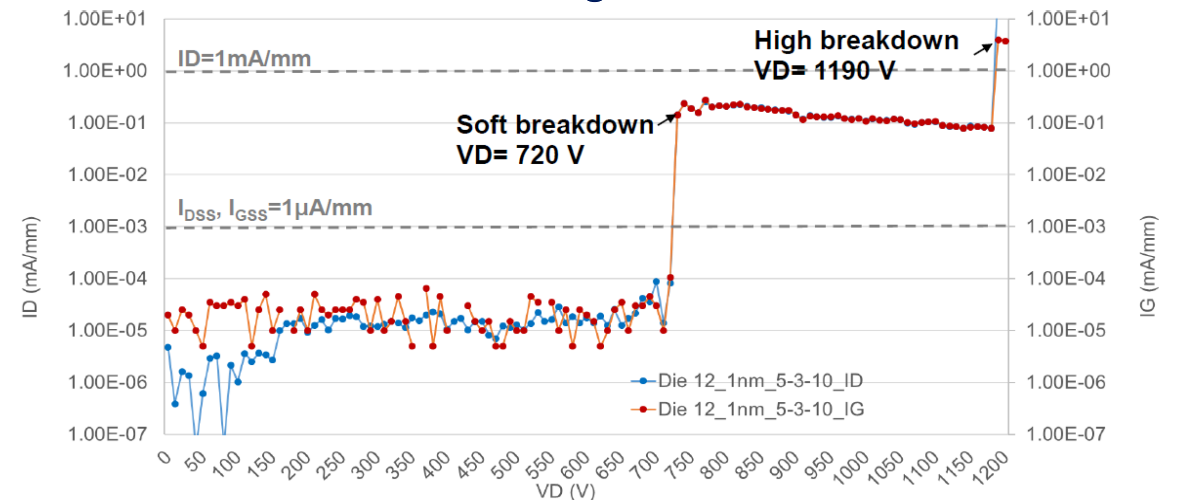
Normally-off recessed gate GaN MISHEMT

- Control of 1 nm of AlGaN remaining by ALE process with etch depth monitoring
- +0.7 V of turn-on voltage (**normally-off MISHEMT**)
- Low on resistance - 1.2 mΩ•cm^2
- 1190V of breakdown voltage



1 nm AlGaN remaining AlGaN/GaN MISHEMT



Plasma ALD in production for GaN HEMTs

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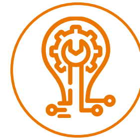
Atomfab qualified to >5k WPM in GaN PE market leader with plasma pre-treatment & Al_2O_3

USB-C fast chargers



Process of record for GaN HEMT device passivation

Atomfab market leader in HVM due to low damage plasma ALD for GaN HEMT **thin film passivation**

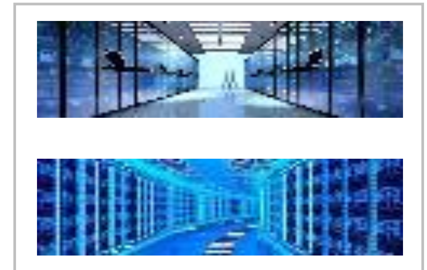
Qualified supplier to device manufacturers and foundries with dominant market share of consumer GaN PE modules e.g. Samsung, Apple, Huawei and Anker

HV/ EV

Wireless charging

Energy efficient white goods

Power efficiency for data centres



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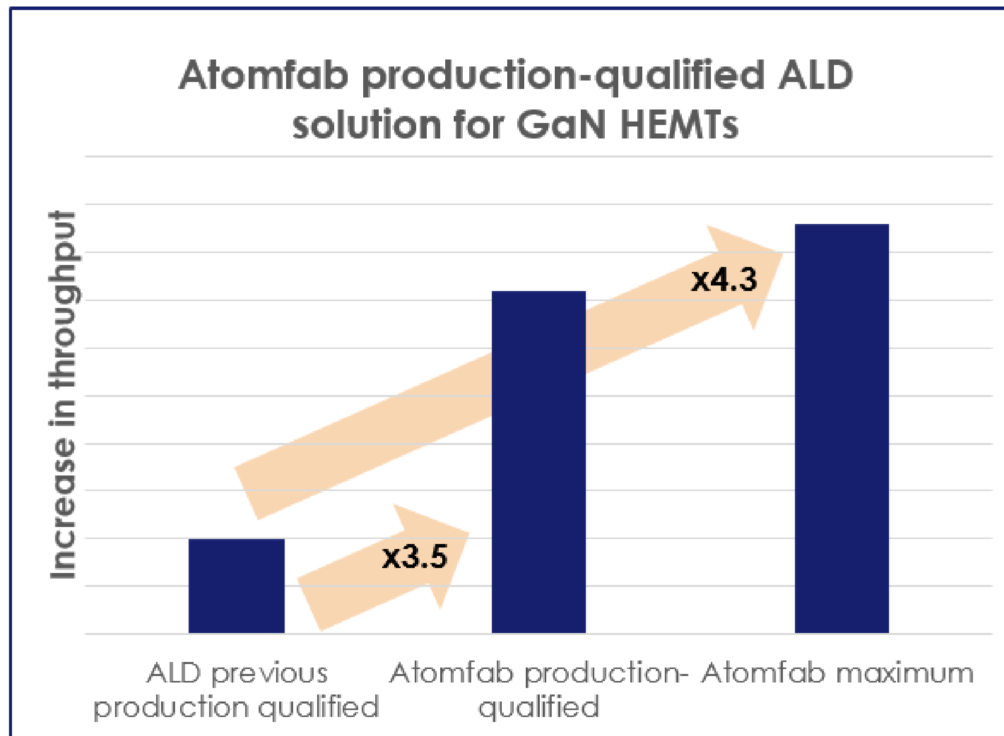
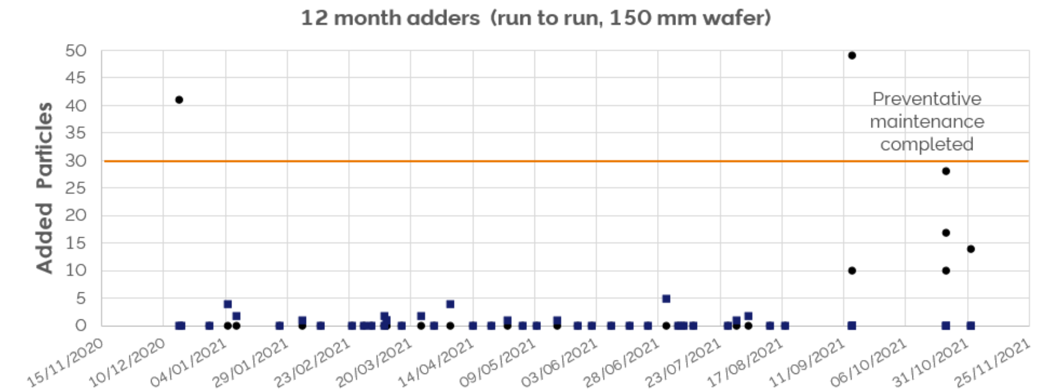
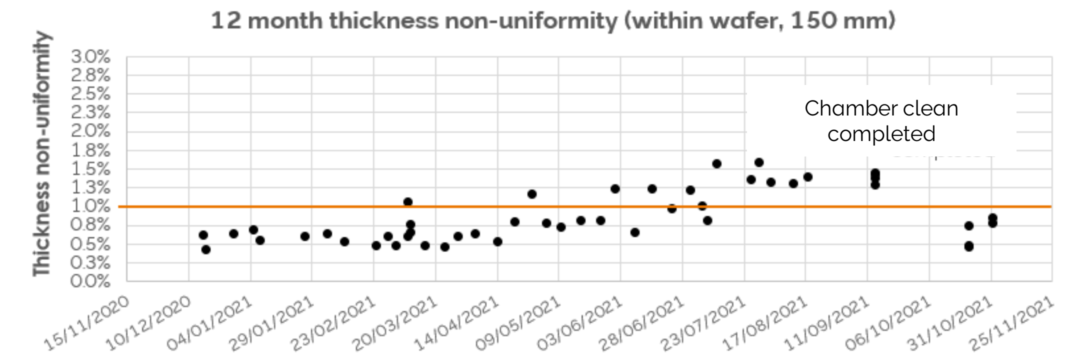
Atomfab: Production-qualified at leading GaN power electronics manufacturer

>4x increase in throughput, & reduction in CoO for ALD passivation of GaN HEMTs





Spec: ≤30 added particles/wafer: Production-qualified



Customer spec: ≤±1.0% thickness non-uniformity: Production-qualified

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Recent News

Oxford Instruments partnership with Rohm using ALE for next gen GaN power devices

23 March 2022

New Partnership for Reliable GaN Power Devices

Leading GaN device manufacturer Rohm Semiconductor partners with Oxford Instruments Plasma Technology for greener and more reliable GaN power electronics using ALE technology

Oxford Instruments Plasma Technology announced today that Rohm Semiconductor, a leading Japanese manufacturer of innovative GaN devices for automotive applications, has selected Oxford Instruments' PlasmaPro®100 Cobra® Atomic Layer Etch (ALE) system. The system will be implemented in Rohm's facility for the development of next generation highly efficient and reliable GaN power devices. Rohm will work closely with Oxford Instruments Plasma Technology to resolve challenges in GaN device manufacture, which will enable GaN technology to revolutionise key industries.

ROHM starts Production of 150V GaN HEMTs: Featuring Breakthrough 8V Withstand Gate Voltage

March 22nd, 2022

The first series of the new EcoGaN™ family contributes to lower power consumption and greater miniaturization in data centers and base stations

ROHM 150V GaN HEMTs, GNE10xxTB series (GNE1040TB) increase the gate withstand voltage (rated gate-source voltage) to an industry-leading 8V – ideally to be applied in power supply circuits for industrial equipment such as base stations and data centers along with IoT communication devices.

In recent years – due to the rising demand for server systems in response to the growing number of IoT devices – improving power conversion efficiency and reducing size have become important social issues that require further advancements in the power device sector.

As GaN devices generally provide higher switching characteristics and lower ON resistance than silicon devices, they are expected to contribute to lower power consumption of various power supplies and greater miniaturization of peripheral components.

Along with mass-producing industry-leading SiC devices and feature-rich silicon devices, ROHM has developed GaN devices that achieve superior high frequency operation in the medium voltage range, allowing us to provide power solutions for a wider variety of applications.

Breaking News: Recessed gate GaN MISHEMT & SiC Plasma Epi-prep alternative to CMP

29 August 2022

SiC Plasma Epi-Prep, Alternative to CMP, is Validated

Oxford Instruments Complete Feasibility Study at Tier 1 SiC Semi Fab

Following Oxford Instruments announcement of their plasma alternative to CMP product, being launched at the International Conference on Silicon Carbide and Related Materials (ICSCRM / ECSCRM) in Davos Switzerland on 11-16 September 2022, Oxford Instruments shares exciting news.

Oxford Instruments have developed a non-contact plasma etch method of preparing SiC substrates for epitaxy. The technique delivers comparable results to CMP but with lower OPEX, higher device yield and a process window capable of supporting the transition to thinner wafers and therefore increasing wafers per boule. Their feasibility project, carried out at a tier 1 SiC semiconductor manufacturing fab using whole wafers, found that performance of the new plasma substrate preparation technique is already equivalent to CMP for epitaxy readiness.

"This validation outcome is a significant milestone in our goal of creating a more cost-effective and sustainable technique for preparing SiC substrates for epitaxy" comments Klaas Wisniewski, Plasma Technology's Strategic Business Development Director, who also added: "Our Plasma epi-prep technology is hugely promising and currently compares favourably to existing alternatives, but has the potential to exponentially increase substrate production and meet the growing demand for SiC substrates in high growth markets."

22 September 2022

GaN HEMT device performance

Oxford Instruments and ITRI announce breakthrough development in GaN HEMT device performance

Oxford Instruments alongside its research partner Industrial Technology Research Institute (ITRI) can today share new and exciting technology developments that will significantly benefit key hyper-growth electric vehicle, datacentre and 5G markets. The technology developments allow critical transistor components to operate at higher voltages which increases performance and reliability, while also achieving a safer and more energy efficient (normally off 'E-mode') operation compared to existing devices. The new GaN (gallium nitride) HEMT device architecture is defined by a recessed and insulated gate junction into the AlGaN layer, and this device is referred to as GaN MISHEMT.

In September 2021, Oxford Instruments Plasma Technology and ITRI announced a cooperative research program for next-gen compound semiconductors. This latest breakthrough is an example of that collaboration delivering on its goal of accelerating technology to benefit the partners, their regions and wider global markets. Since that announcement, Oxford Instruments has also unveiled an exclusive supply deal with Laytec, who's endpoint technology is used to control the GaN MISHEMT recess gate depth. Recess depth accuracy and repeatability is critical to tune the device performance characteristics, and LayTec's technology is designed specifically for this application achieves target depth accuracy of ±0.5nm. ITRI provides pilot production and value-added services, including process verification and product development. ITRI's integration services, especially this GaN development project, have proved incredibly beneficial, which quickly proved out the higher performance of GaN MISHEMT and provided a lower risk and faster route to market for the device.

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Summary

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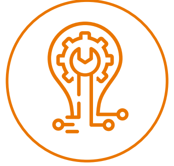

OI providing innovative & optimised, **production-proven solutions** for GaN HEMT manufacturing with strong growth predicted in consumer electronics, EV, data and telecoms

Trusted industry partner solving key technology challenges on the atomic-scale for next generation device fabrication with GaN HEMT collaborators and customers

Plasma processing expertise utilised to maximise device performance through low damage, high quality GaN

Successfully positioned our products with current device supply chains delivering **improved yields, throughput and reduced CoO**

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Thank you for your attention

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