Tutorial Series

State-of-the-art architectures and future concepts in GaN technology for power electronics

Tuesday, 14th March
5pm-6pm GMT

CGD™
CAMBRIDGE GaN DEVICES

Presenter: Prof. Florin Udrea, Founder and Chief Technology Officer (CTO)
Moderator: Nare Gabrielyan, Product Marketing Manager

Ground Rules and Instructions

Please make sure
you are muted

Use the chat for comments
and questions

About the Host

- Florin Udrea is the CTO and the co-founder of Cambridge GaN Devices Ltd (CGD). In 2016, together with Dr. Giorgia Longobardi he founded CGD. CGD has now grown into a reputed power device company supplying Gallium Nitride products in the market.
- Florin has worked on power devices for over three decades with specific research on wide bandgap materials since 1997.
- Florin has published over 600 papers in journals and international conferences and is an inventor of 200 patents in power semiconductor devices and sensors.
- In 2015, Prof. Florin Udrea was elected a Fellow of Royal Academy of Engineering.

Tutorial Webinar Series Schedule

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Topic	Presenter	Live Date
Powering up the future with GaN	Andrea Bricconi, CCO	February 9th
GaN devices in power electronics	Florin Udrea, CTO	March 13th
ICeGaN: New steps towards Quality and Reliability	Zahid Ansari, VP Operations	April
ICeGaN vs GaN: the application focus	Peter Comiskey, Head of Applications Engineering	May

Cambridge GaN Devices at a Glance

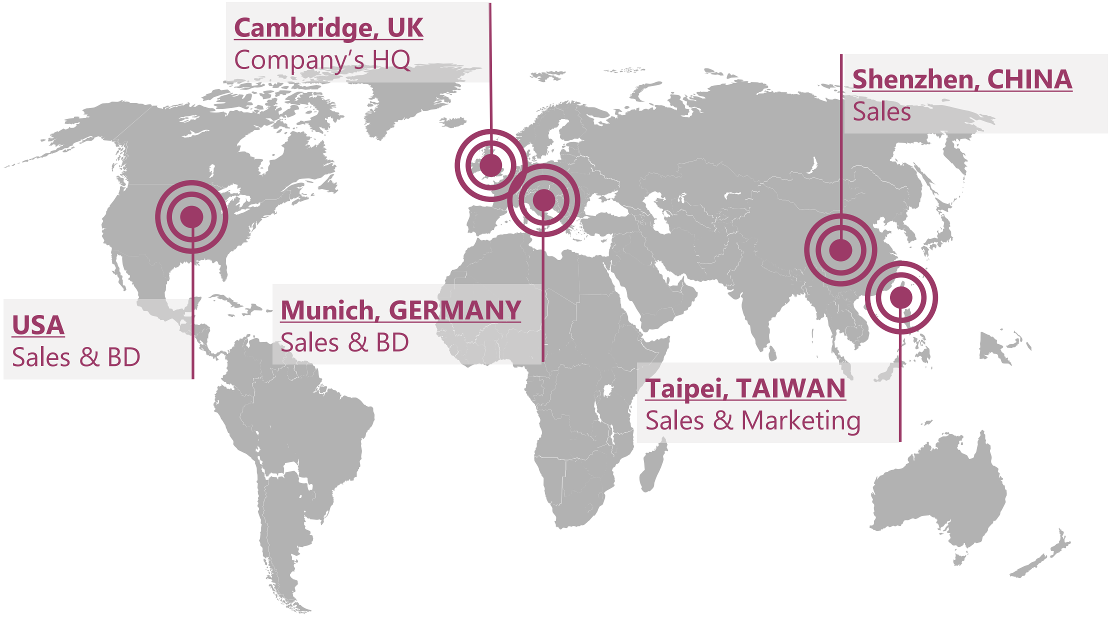
A Fast-growing CleanTech Pioneer spun-out from the Cambridge University

A fabless semiconductor company designing, developing and commercialising **energy-efficient GaN-based power devices and ICs**

Operating from
5
Locations

Supporting
20+
Leading customers

Employees
40+
> 300% growth (2019– 2022)



Knowledge

Academic excellence and industry expertise combined

Innovation

Innovative power solutions that help protect the environment

Sustainability

Eco-compatible business measures (**ESG**)

Responsability

Energy savings for reliable and sustainable electronics

Introduction

3 Areas Driving the Growth of Energy-Efficient Solutions

1. ELECTRIFICATION

The e-mobility disruption, energy efficiency regulations and CO_2 reduction emissions targets will drive change

2. RENEWABLE ENERGIES

Wind and **Solar** power expected to account for 50% of the power mix by 2030 and 85% by 2050

3. CONNECTIVITY

Big data, Cloud Computing and **5G** full deployment will continue a 3-digit growth

Power Semiconductors are the Core of Energy Conversion and Control

Sources: Yole Développement - Forecast for eBike, eScooters and EV/HEV for GaN and a subset of Wide Band Gap, McKinsey Center for Future Mobility, McKinsey Global Energy Perspective 2022 Executive Summary

Properties of Silicon, 4H SiC, GaN, Diamond and GaO

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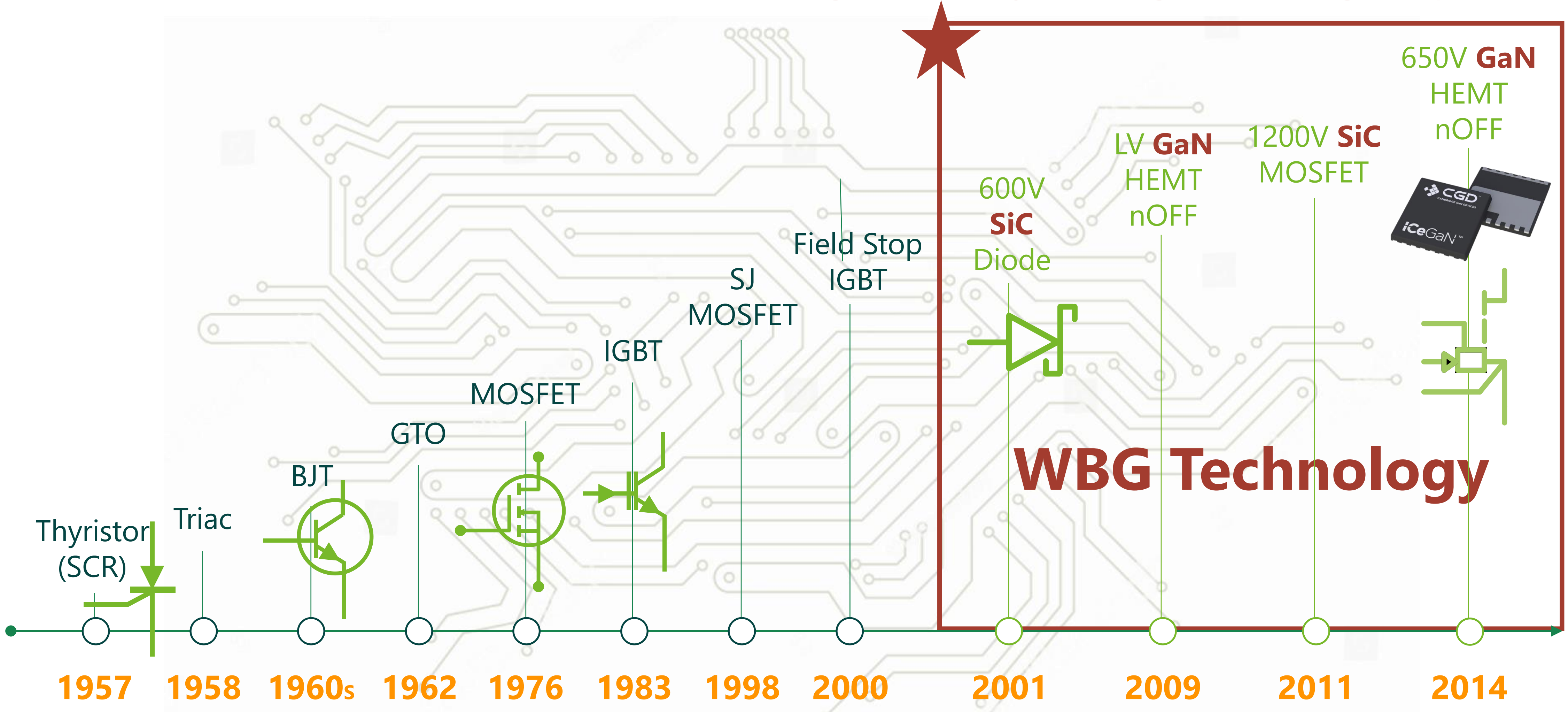
Physical Property	Si	4H-SiC	GaN	SC CVD Diamond	β-Ga_2O_3
Band gap (eV)	1.1	3.2	3.4	5.5	4.9
Relative permittivity	11.9	10	9.5	5.7	10
Breakdown field (MV/cm)	0.3	3	3.3	5	8
Thermal conductivity (W/K/cm)	1.48	3.30	1.30	24.00	0.13
Mobility ($cm^2/(Vs)$)	1350	700	1200 (bulk) 2000 (2DEG)	3800 for holes 4500 for electrons	200-300
Saturation velocity (10^7cm/s)	1	2	2.5	2	2

System and Technology key aspects for Silicon, SiC, GaN, GaO and Diamond

System and Technology key aspects	Si	4H-SiC	GaN	SC CVD Diamond	β-Ga_2O_3
Efficiency/Performance					
Size/Form factor					
Reliability					
Ease of manufacturing					
Infrastructure					
Cost					
Ease of use					
Diversity					

Timeline of the Introduction of Modern Power Devices

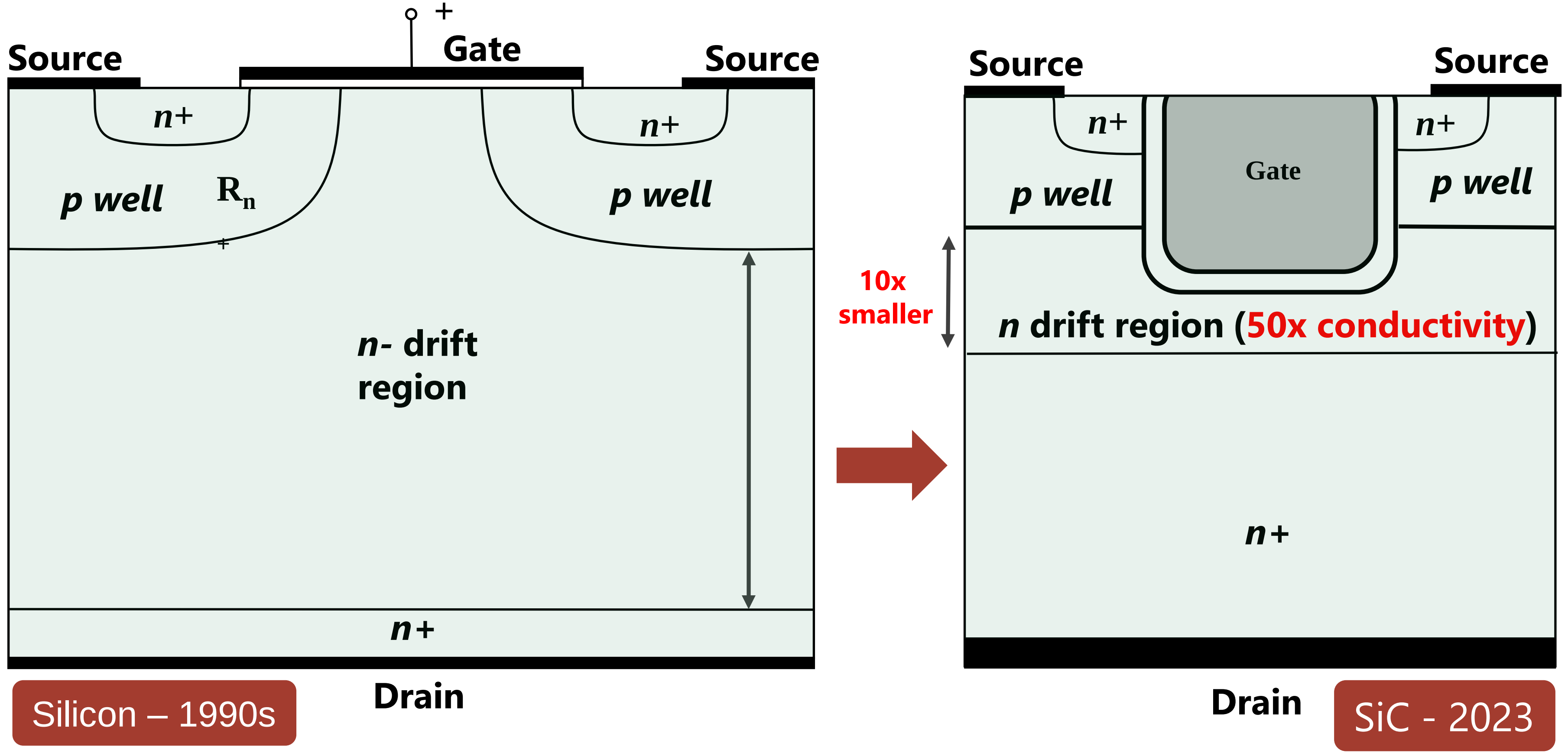
Novel Power Semiconductor Materials Enable High Efficiency and High Switching Frequencies



Sources: MDPI - Overview of Power Electronic Switches: A Summary of the Past – Dec. 2020

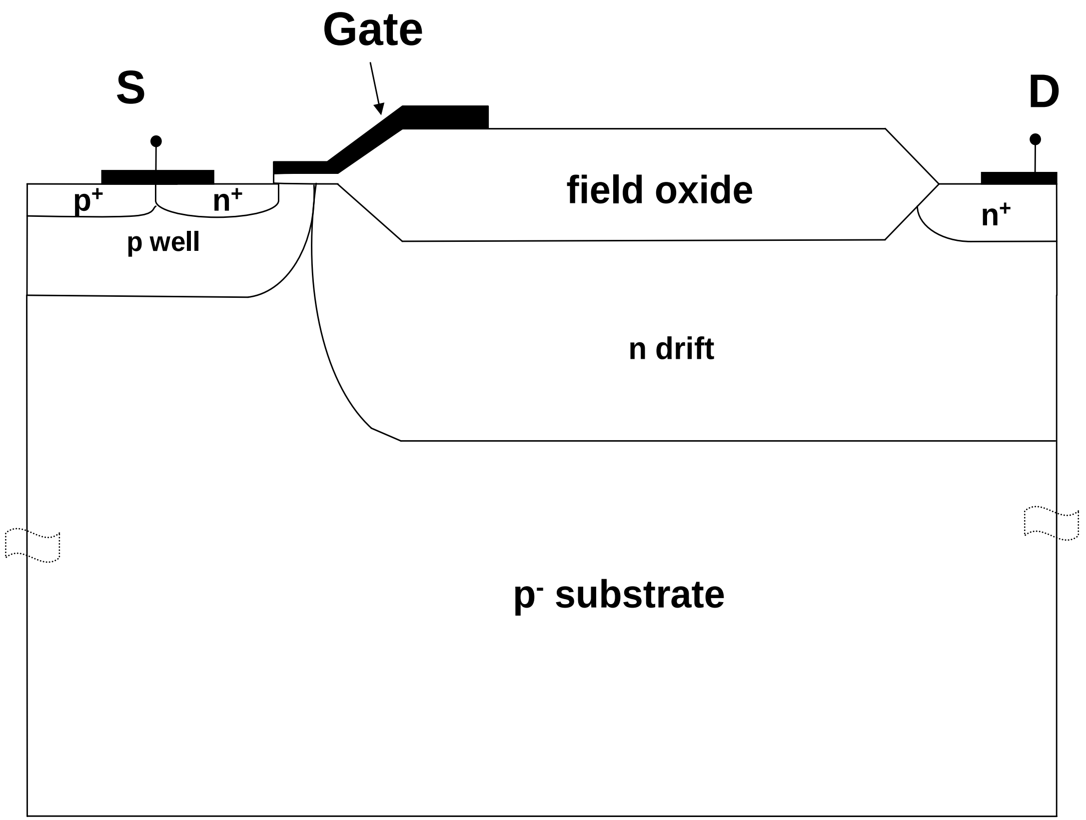
Evolution from vertical Si Power MOSFET to vertical SiC Power

10 x decrease in the depth of the drift region and **50x** increase in its conductivity – results in **approximately 200x reduction in the overall on-resistance**

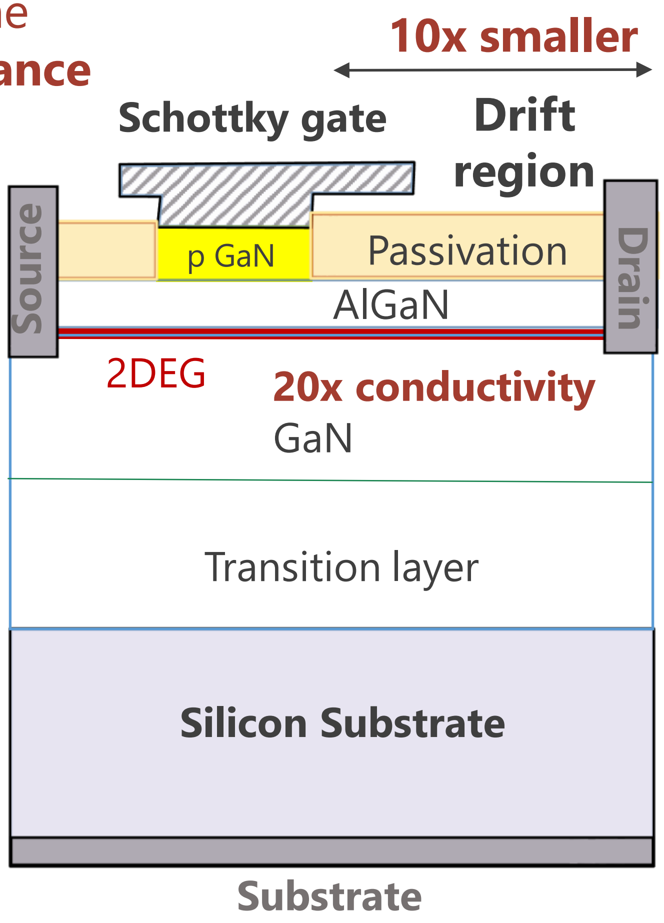


Evolution from lateral Si Power LDMOSFET to lateral GaN HEMT

10 x decrease in the length of the drift region and **20x** increase in the conductivity (due to 2DEG) – results in **200x reduction in on-resistance**



Silicon LDMOSFET – 2000s

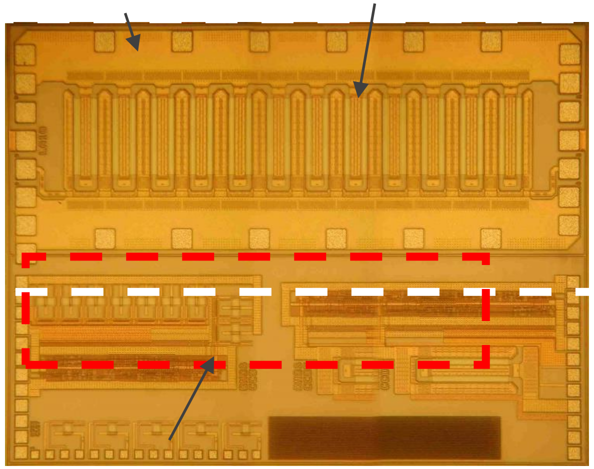


Normally off GaN HEMT - 2023

Advantages of lateral technology in Silicon and GaN

Lateral technology allows for monolithic integration of sensing and protection functions, slew rate control, driver and controller

Example of a Silicon 700V 10W power device (over 300-500 mohmcm^2 specific Ron)

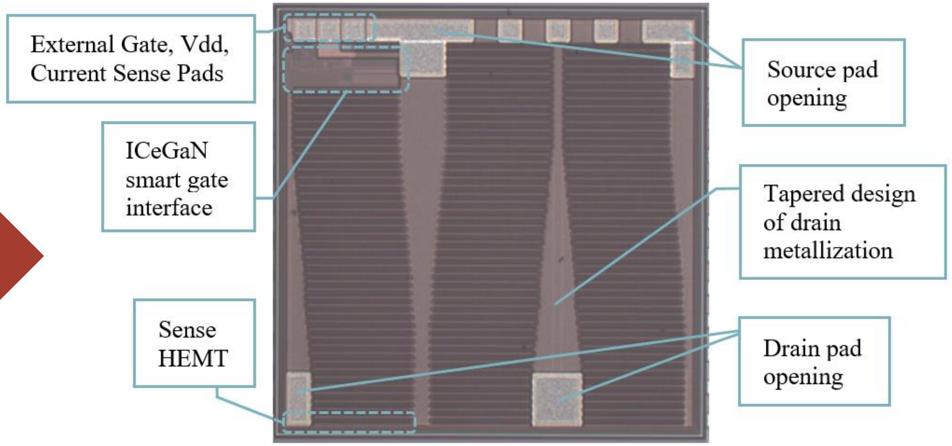


Integrated Analogue Controller containing:

- PWM controller
- Over temperature detector
- Over current protection

Silicon Power IC – 2000s

Example of a GaN 650V,500W HEMT (2-3 mohmcm^2)



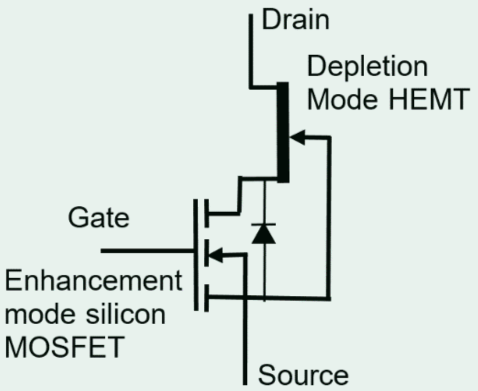
Integrated Analogue sensing and protection functions

- Current sensing
- Over gate voltage protection
- ESD circuits

GaN Power IC – 2023

From discrete to hybrid and monolithically integrated solutions

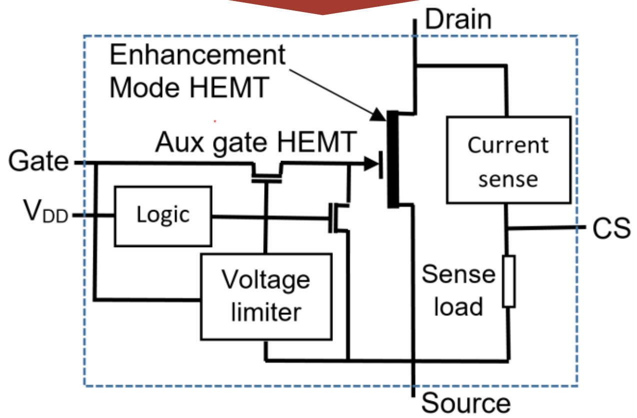
Cascode Si MOSFET + HEMT



HYBRID

Schottky gate depletion mode HEMT in a hybrid integration with a silicon low-voltage MOSFET

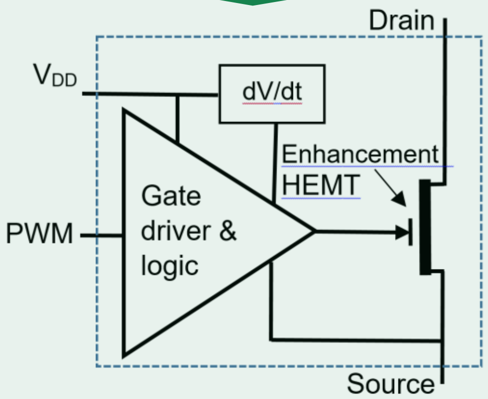
Smart HEMT (ICeGaN™ HEMT)



Power IC – Level 1 monolithic integration

- Enhancement mode HEMT
- Smart interface for higher threshold voltage and higher reliability of the gate
- Gate voltage protection
- Current sensing

HEMT with integrated drive



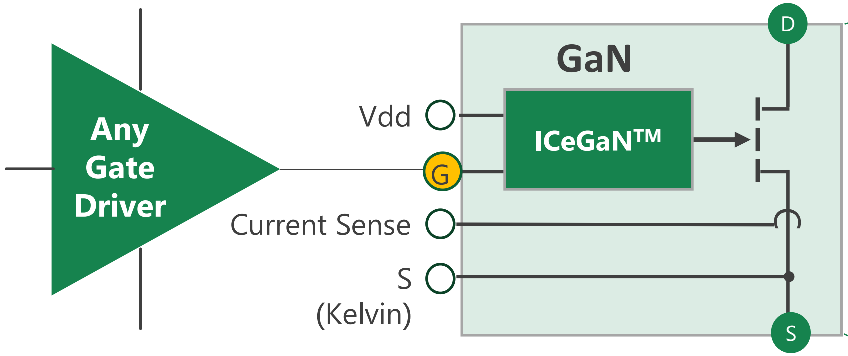
Power IC – Level 2 monolithic integration

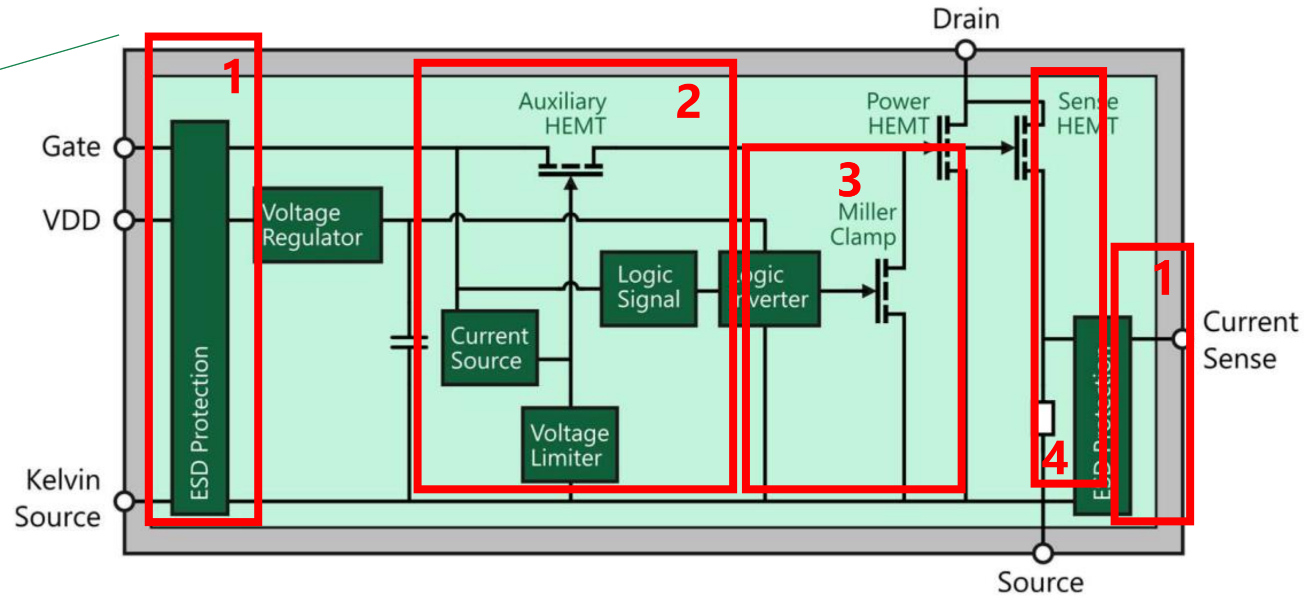
- Enhancement mode HEMT
- Gate driver integrated
- dV/dt slew rate adjustment

ICeGaN™ technology

Decades of Research Led to ICEGAN™

Combined System Performance, Enhanced Robustness and Ease-of-Use





Ease-of-use ✓

System cost ✓

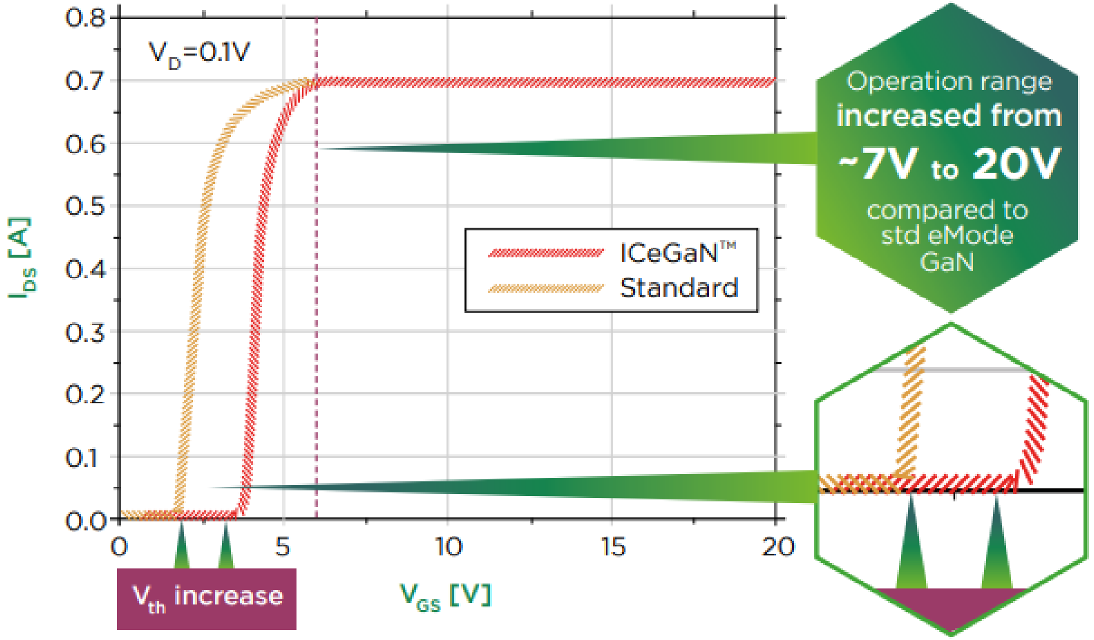
Scalability ✓

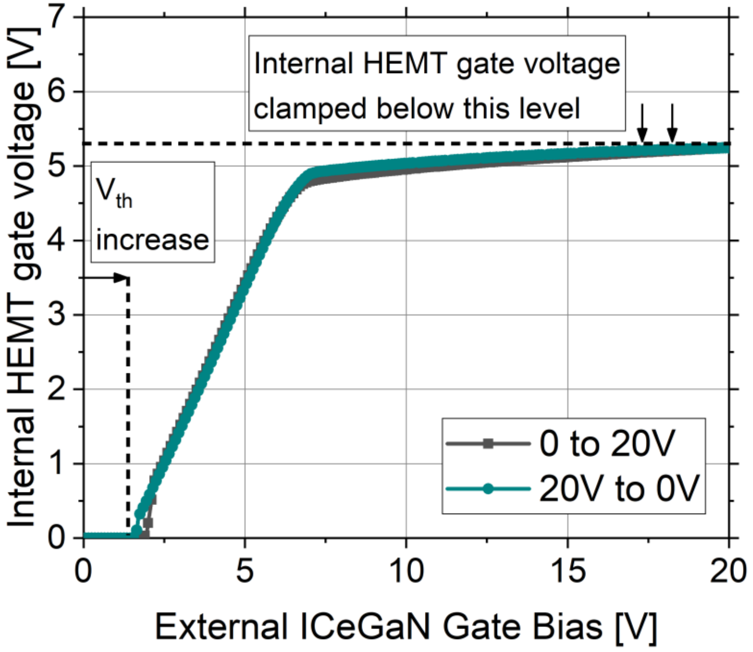
Gate robustness ✓

System performance ✓

1. ESD protection
2. Gate voltage clamping , higher threshold voltage and extended static (0-20 V) and dynamic voltage range (0-70 V)
3. Miller clamp and logic to ensure high dV/dt, fast switching and avoid negative voltages on the gate
4. High efficiency current source solution

Ease of use





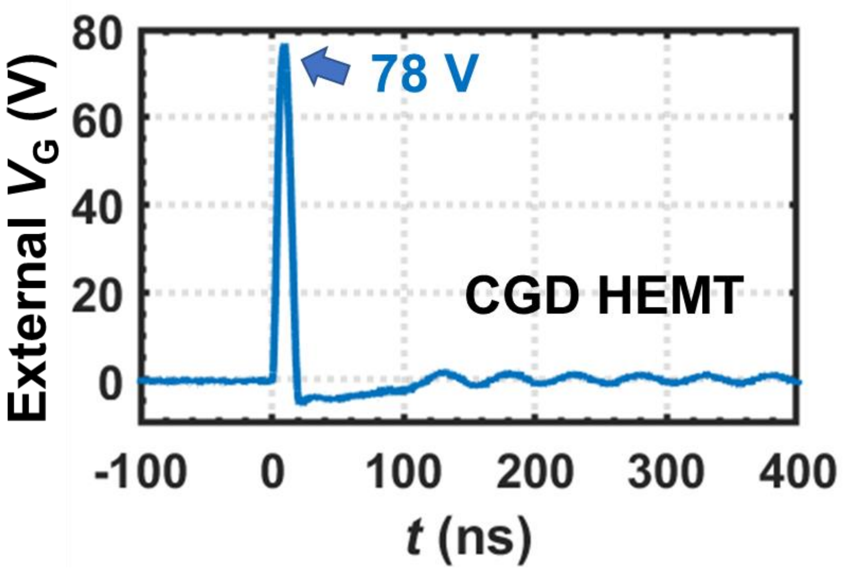
The threshold voltage, V_{th}, of an ICeGaN™ device is around 2.8 V compared to 1.6 V for the conventional counterpart.

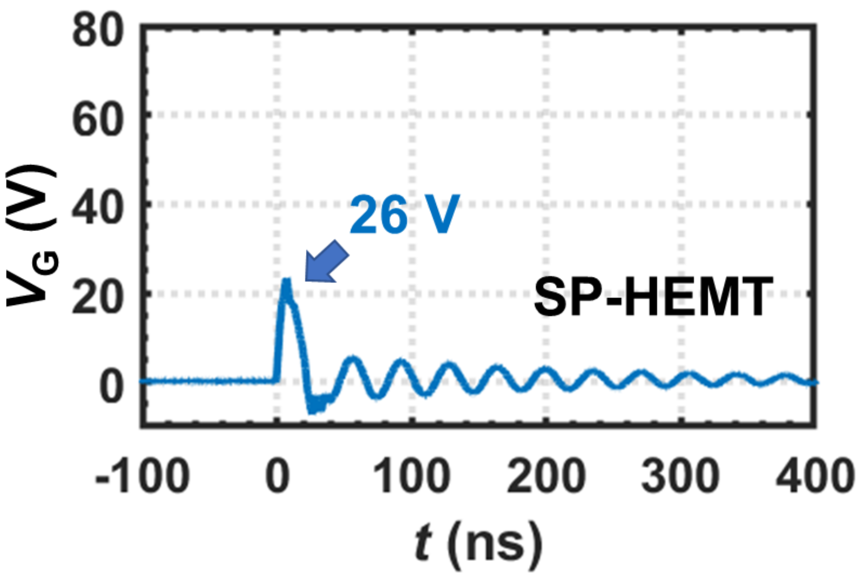
One can also note that the maximum gate voltage is extended to 20 V, allowing direct connection to standard silicon MOSFET drivers.

The internal gate of the transistor is clamped to 6 V even when the external gate voltage is increased to 20 V.

The extra voltage is absorbed by the auxiliary HEMT, which in turn is controlled by the voltage limiter and the current source.

Smart gate robustness



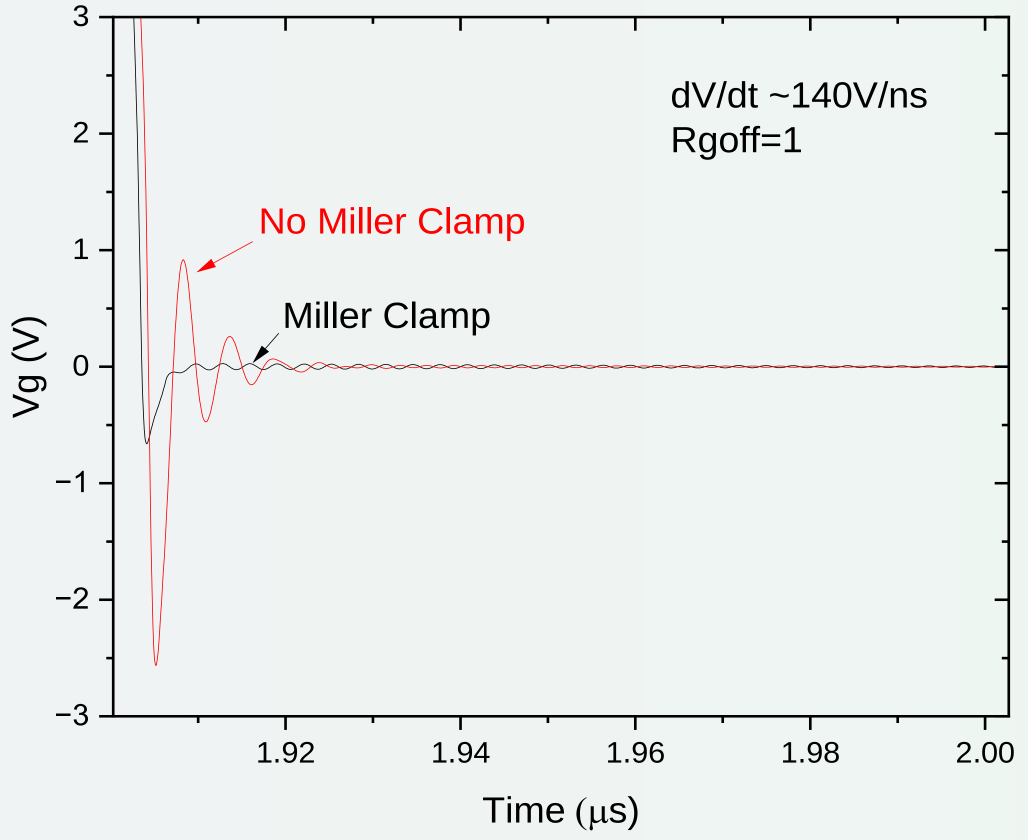


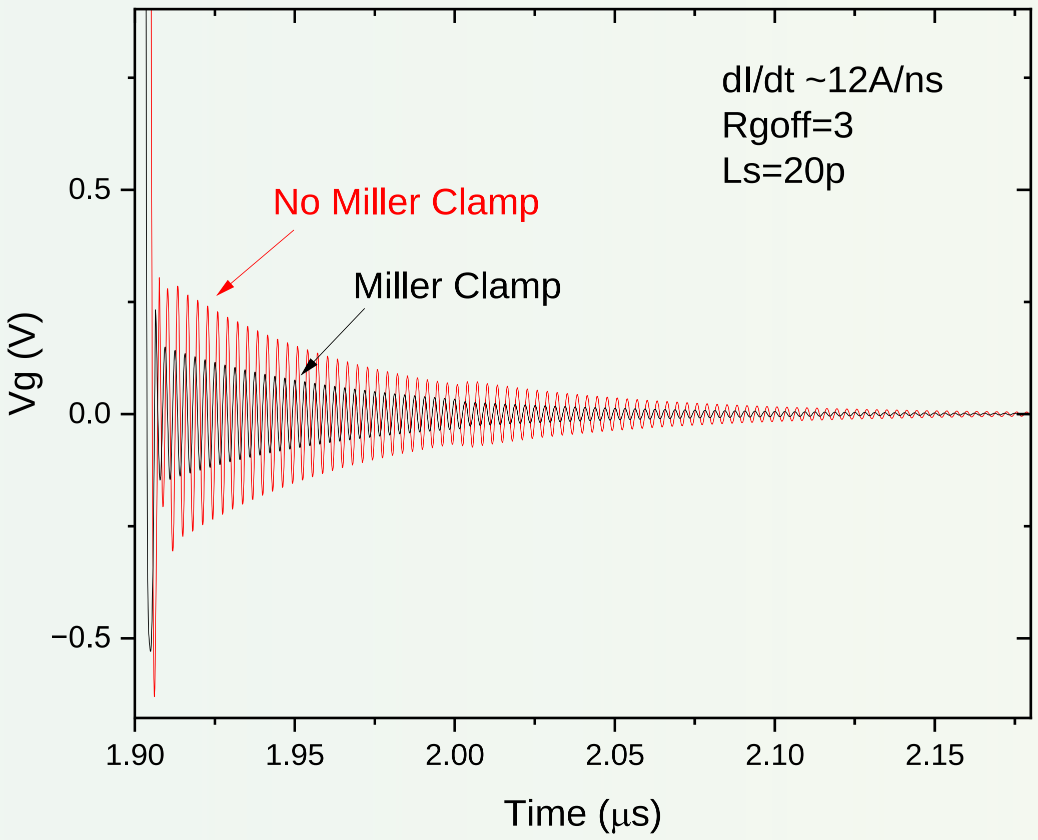
Dynamic gate voltage
ICeGaN offers "extreme robustness" against dynamic voltage overshoots on the gate terminal [1].

[1] B. Wang etal, A GaN HEMT with **Exceptional Gate** Overvoltage Robustness, APEC, March 2023

V_G Pulse Width	CGD HEMT	SP-HEMT
20ns	66V	24 V
16ns	78V	26 V

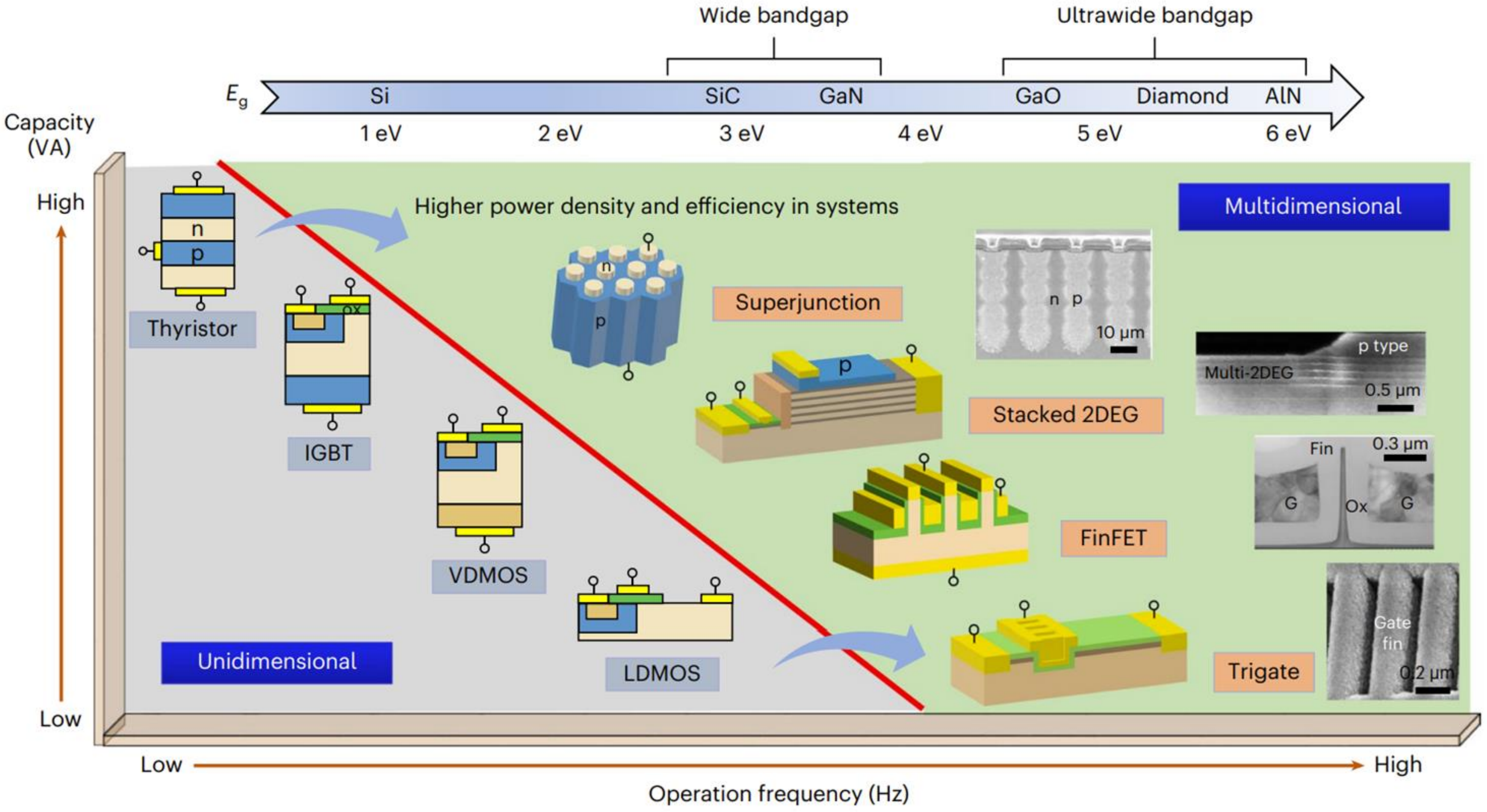
Higher dV/dt and dI/dt immunity





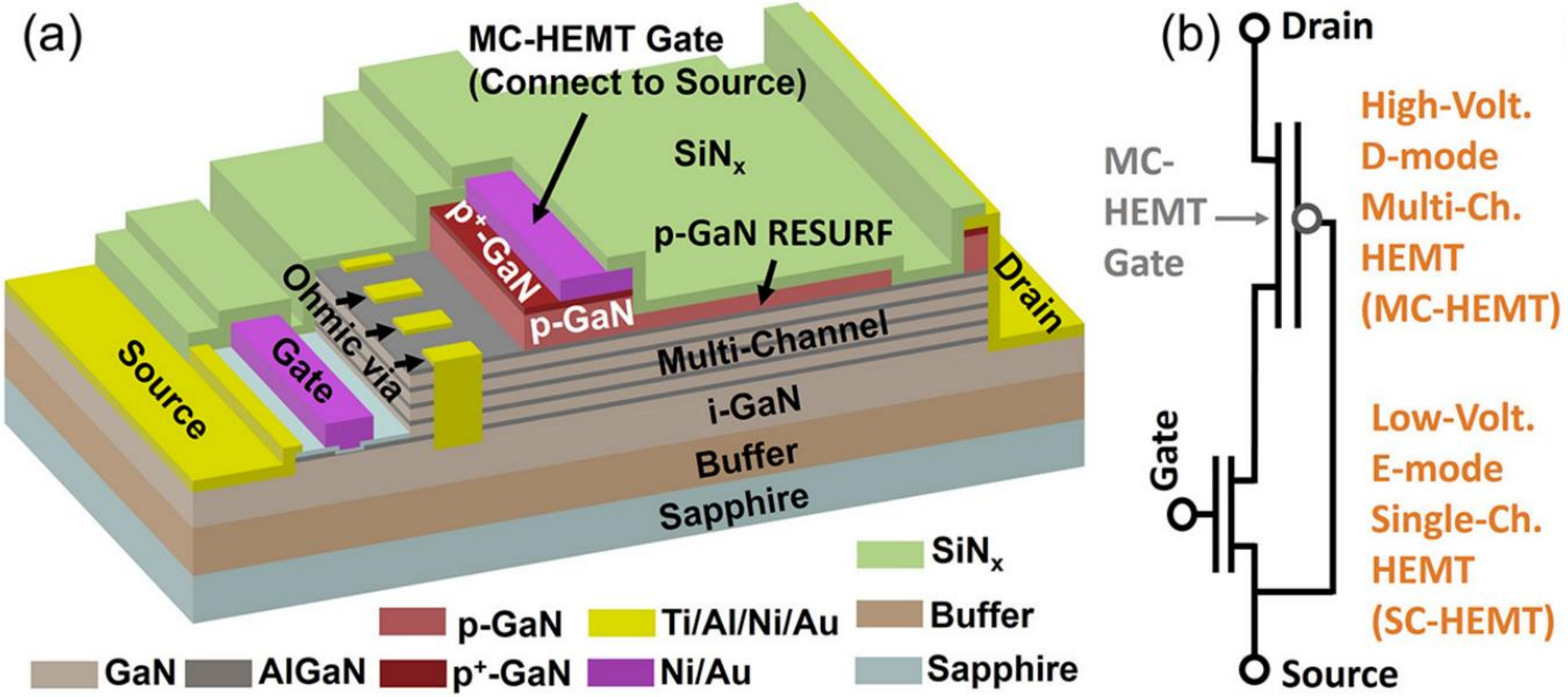
A window to the future of GaN technology in power electronics

Multidimensional architectures in Power Devices



[5] *Zhang, Yuhao, Florin Udrea, and Han Wang. "Multidimensional device architectures for efficient power electronics." Nature Electronics (2022): 1-12.*

Multi-channel Normally-off GaN HEMT with world record Performance



[6] M. Xiao, Y. Ma, Z. Du, V. Pathirana, K. Cheng, A. Xie, E. Beam, Y. Cao, F. Udrea, H. Wang. Y. Zhang, "Multi-channel monolithic-Cascode HEMT (MC 2 -HEMT): A new GaN power switch up to 10 kV ", *IEDM Tech. Dig*, Dec. 2021"

Back to the present:
What CGD can offer now?

CGD Product Portfolio

A Targeted Offering Entering the Market with 2 SMD Packages, 3 $R_{DS(on)}$ Classes and a Voltage Rate

CGD's H1 series are SINGLE CHIP eMode HEMT, with 3V threshold voltage, with real 0V turnOFF and with a revolutionary gate concept that can be operated up to 20V.

No Cascode, no complex multi-chip configurations or no thermally complex integrated solutions, but a single chip with embedded proprietary logic which enables the coupling with std gate drivers or controllers.

PN	Type	$R_{DS(on)}$	Voltage Rating	DC Current rating	Peak Gate Voltage	Package	Features	Preferred gate driver
CGD65A055S2	Single eMode	55 mOhm	650 V (750 V*)	27 A	20 V	DFN 8x8	ICeGaN™**, Current Sense ***	Any MOSFET driver
CGD65A130S2		130 mOhm		12 A				
CGD65B130S2						DFN 5x6		
CGD65B200S2		200 mOhm		8.5 A				

APPLICATIONS

CGD Supports Customers Throughout Their design-in

A Solution for Each Step

PURPOSE:
INITIAL DEVICE CHARACTERIZATION

Samples: Available at the factory or through CGDs distributors

DFN8x8

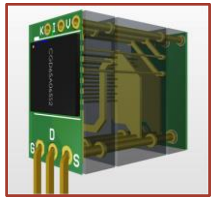
55mOhm & 130mOhm
650V

DFN5x6

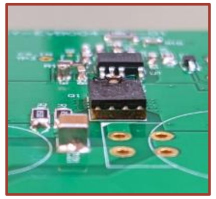
130mOhm & 200mOhm
650V

PURPOSE:
FUNCTIONAL TESTS in existing PCBs *(not efficiency optimized)*

Application Interface Boards (AIB) : Mimic all popular Si and GaN footprints to plug-in ICeGaN™ in existing PCBs



AIB concept:
CGD's GaN on competitor's footprint



AIB mounted on a recipient PCB

AIB UserGuide: CGD-UG 2201

PURPOSE:
CUSTOMISED PCBs for highest efficiency and/or high frequency

Design Tips and Support Material:

- White Papers (5)
- Application Notes (4)
- Design Guides (4)
- User Guides (4)
- info@camgandevices.com


GaN
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Stay tuned with us!