GaN Technology for Power Electronics Applications

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Brussels
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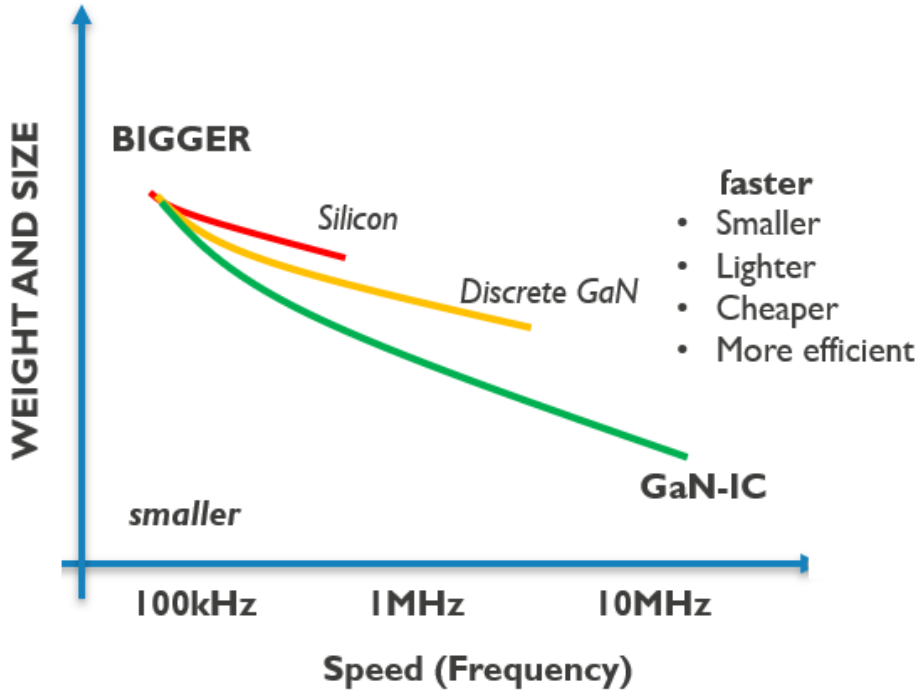
Introduction

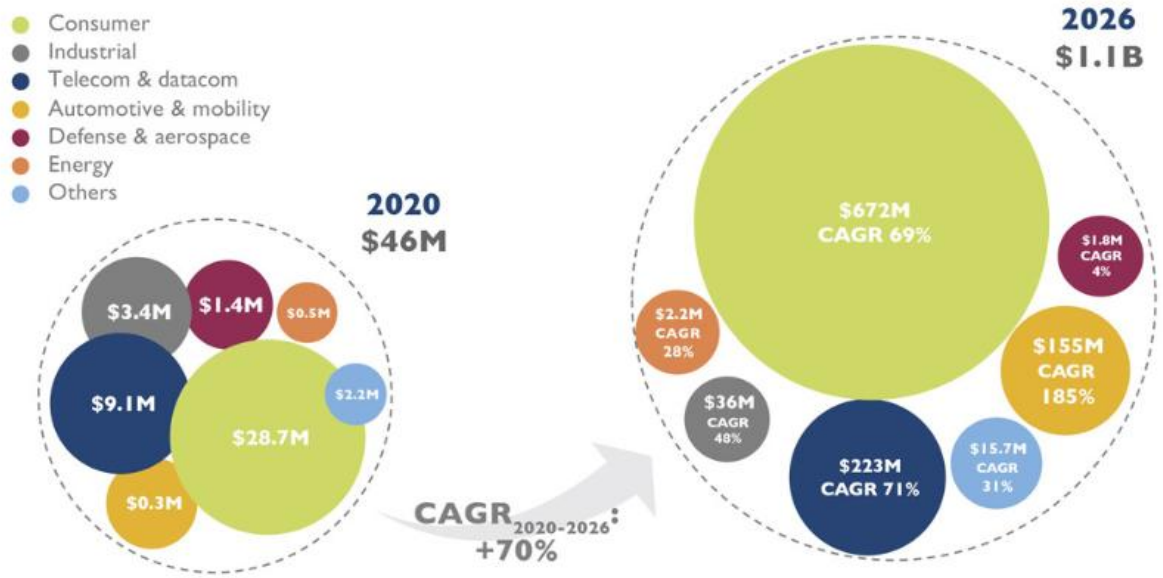
GaN Technology: A breakthrough for PE Application

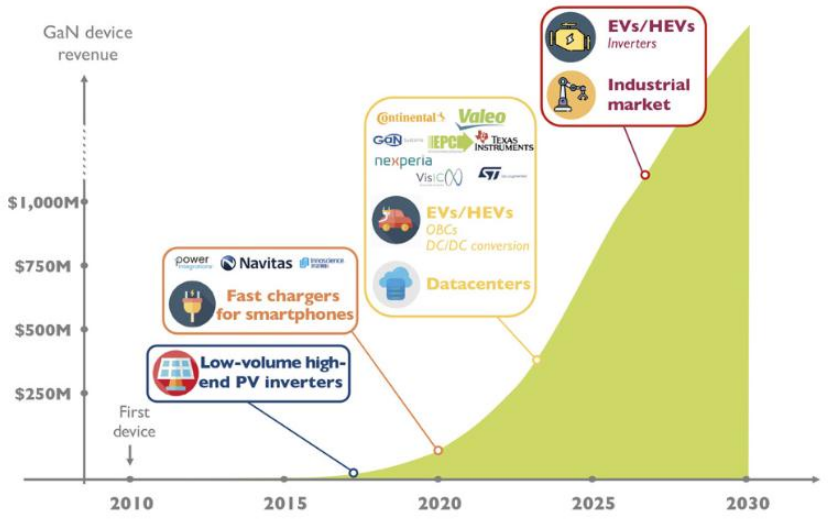


Higher integration	•Enables higher frequency operation •Integrate higher power
More efficient	•Less parasitic reduces gate ringing & switching loss
Compact & cost-effective	•Higher frequency, higher power density •Further reduction in filter size & cost
Easy to control	•Reduce gate overshoot undershoot •Easier control due to reduced ringing

Introduction

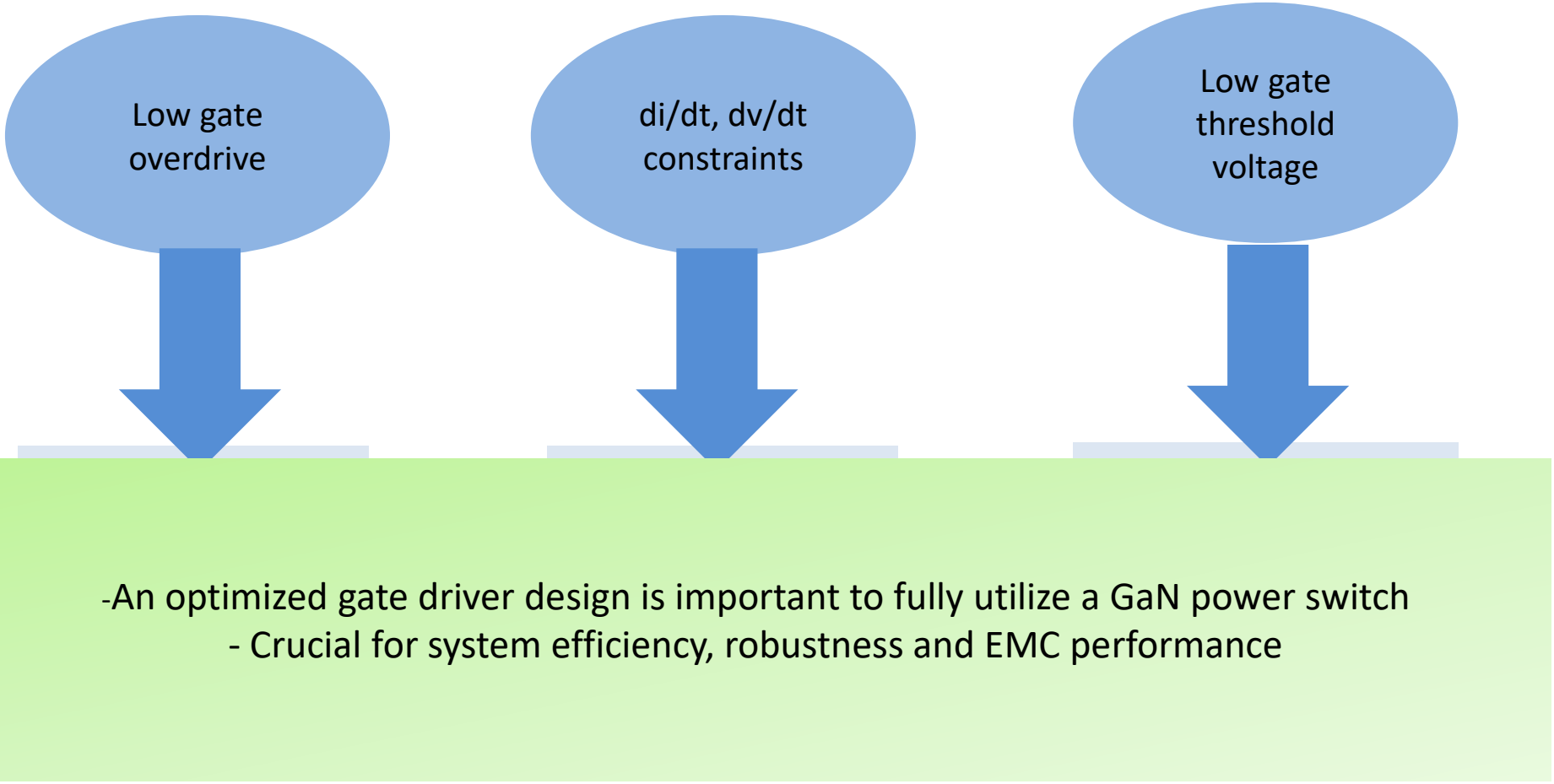
GaN Market Share





Source:: GaN power 2021, Yole Development, 2021

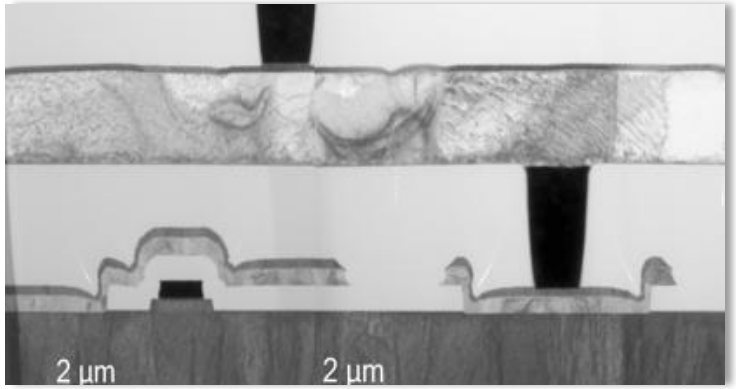
Operating a GaN Power Device



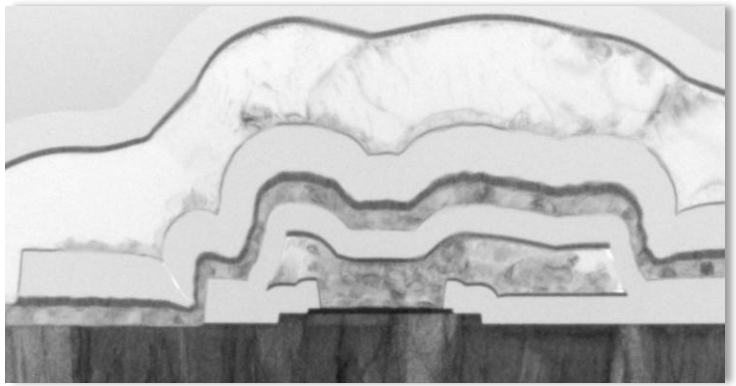
-An optimized gate driver design is important to fully utilize a GaN power switch
- Crucial for system efficiency, robustness and EMC performance

IMEC GaN Power Technology Overview

40V/100V p-GaN HEMT

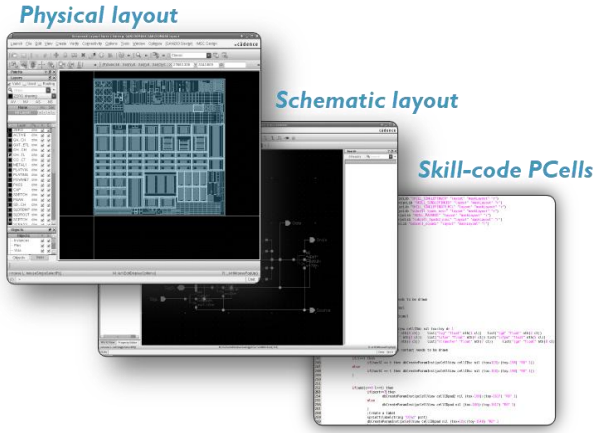


200V/650V p-GaN HEMT



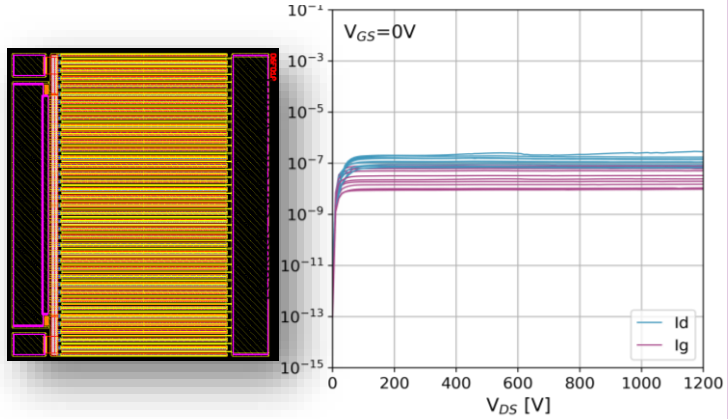
Monolithic integration (GaN-IC)

J. Thone, PWR SOC 2021

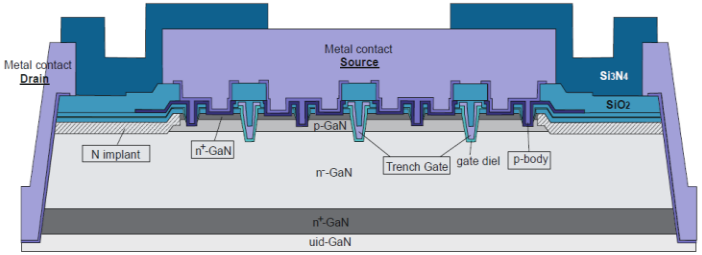


1200V GaN under development

Lateral p-GaN HEMT



Vertical GaN FET



Outline

- Discrete Power Devices & more
- Towards Integration: GAN Power ICs
  - Monolithic integration
  - GANIC demonstrator
  - Extended GANIC platform

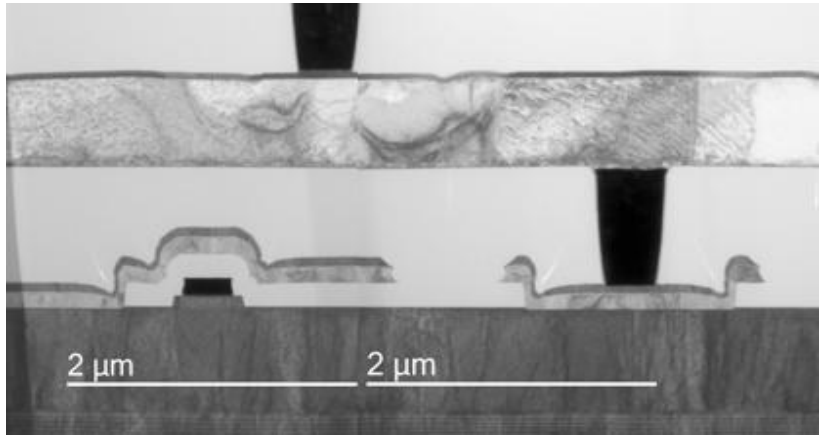
Discrete Power Devices & More

Discrete Device Development

Low Voltage Platform 40V/100V

P-GaN gate with Schottky contact
TiN/W gate
No gate field plate
Planarized back-end :

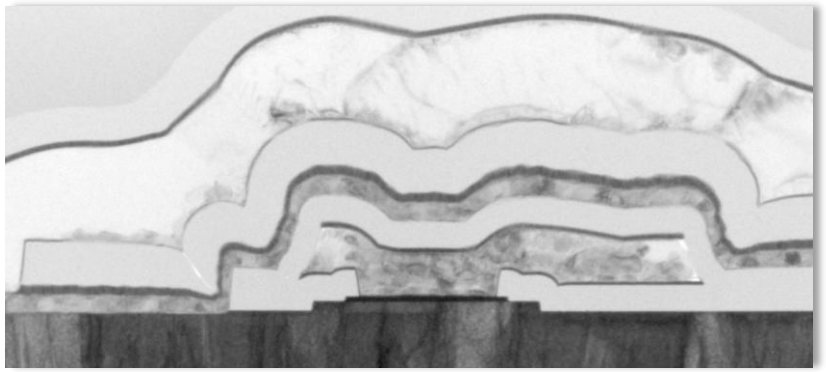
- Oxide CMP
- W-plugs



High Voltage Platform 200V/650V

P-GaN gate with Schottky contact
TiN electrode and Al-base gate metal
Gate field plate
Conformal back-end:

- Field plates closer to 2DEG
- Low-cost

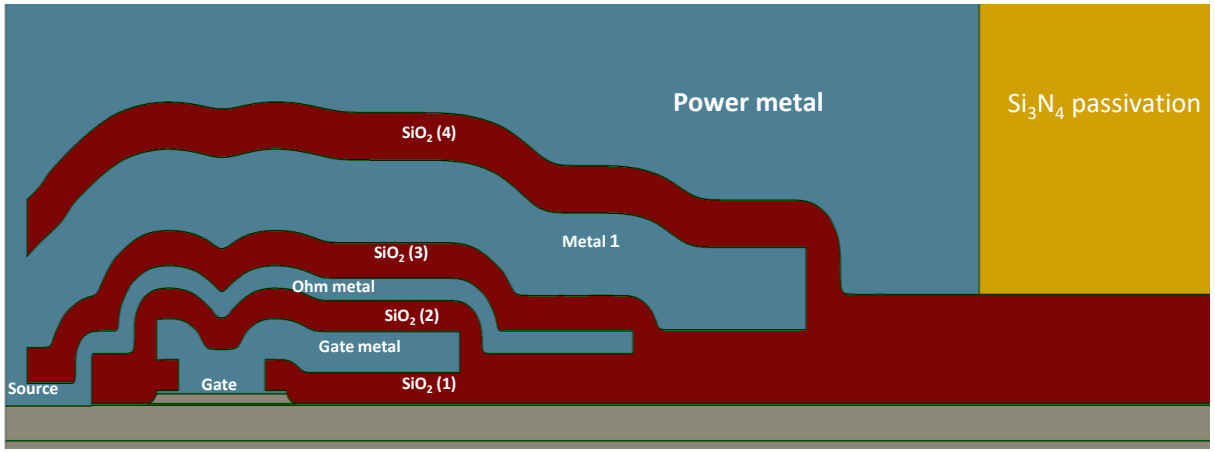


*N. Posthuma, *et al*, An ind-ready..pow tech, *ISPSD 2018, doi: 10.1109/ISPSD.2018.8393658*

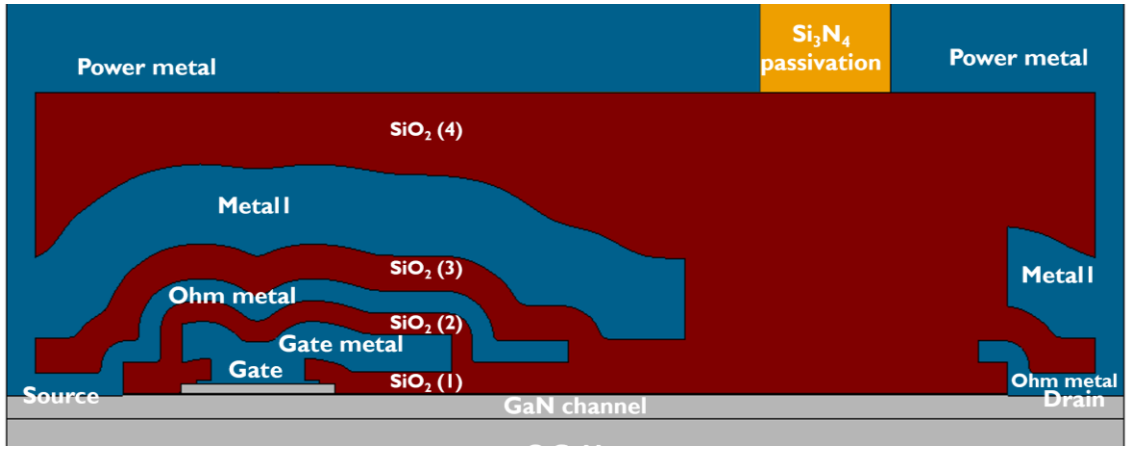
Device Architecture

Discrete & IC Technology Platform

Discrete devices on Si

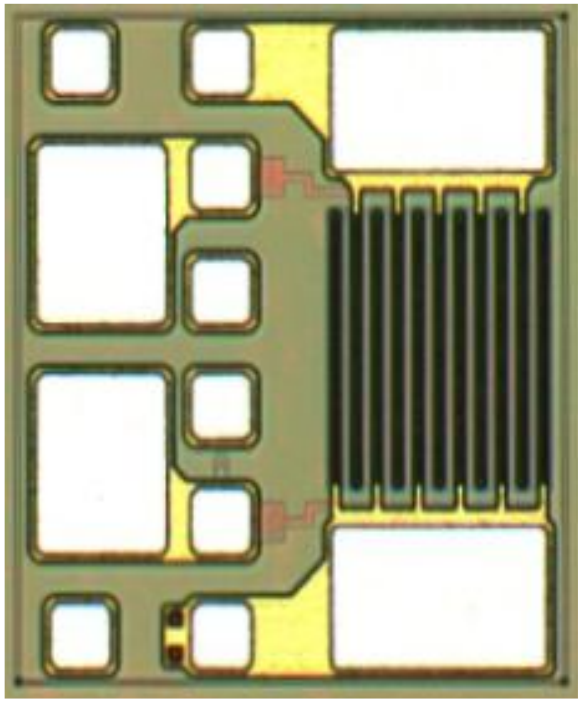


GaN-IC devices



- Basic device architecture is based on a pGaN gate type E-mode HEMT
- Same field plate configurations
- During deep trench isolation, an additional IMD planarization after Metal1 is done in GaN-IC platform
  - Difference SiO_2 thickness between Metal1 and Metal2

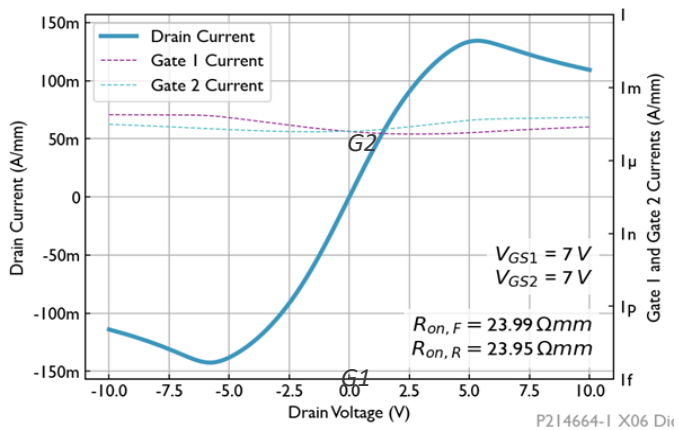
GaN Bidirectional Switch



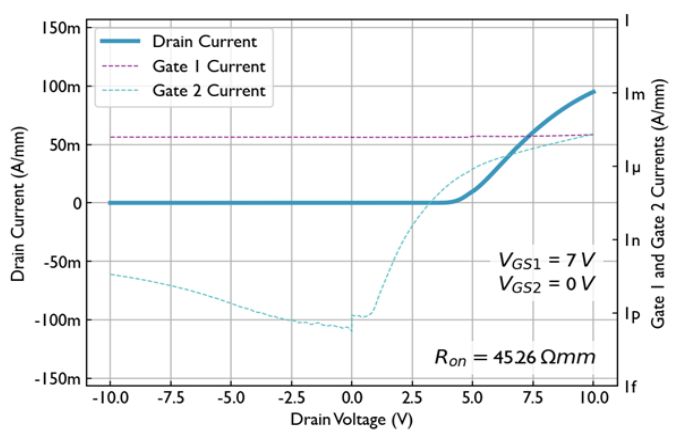
Microscopic image of a dual gate bidirectional switch

*G. Baratella, U. Chatterjee *et al*, "Monolithic 650V dual gate p-GaN bidirectional switch" IEEE TED, 10.1109/TED.2024.3456077.

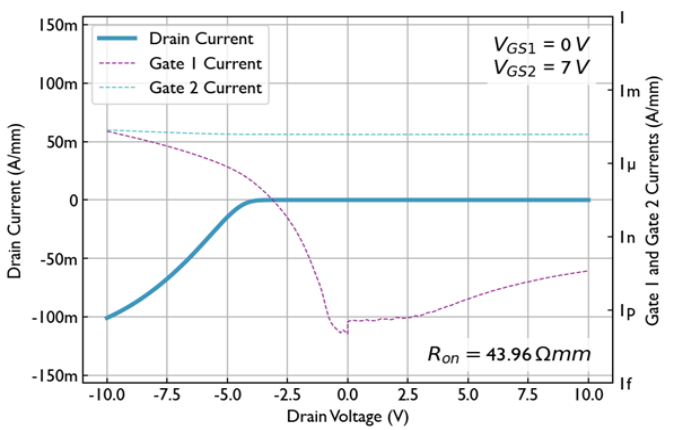
ON state (bidirectional mode)



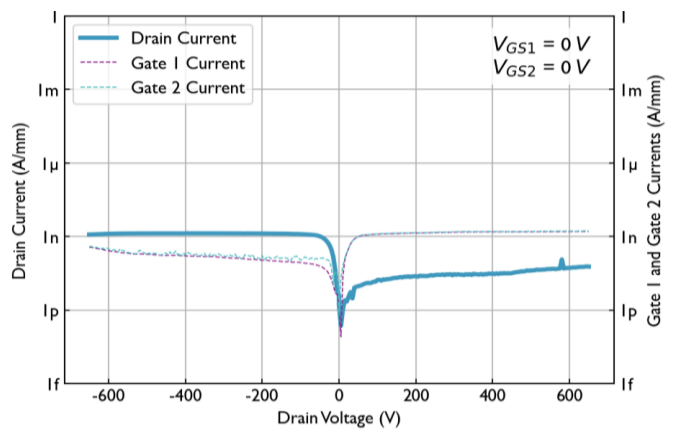
Forward diode mode



Reverse diode mode

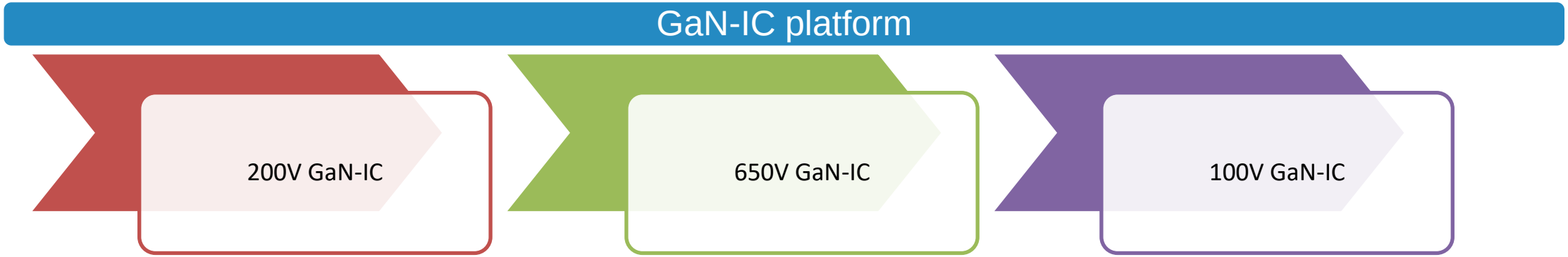


OFF state (blocking mode)

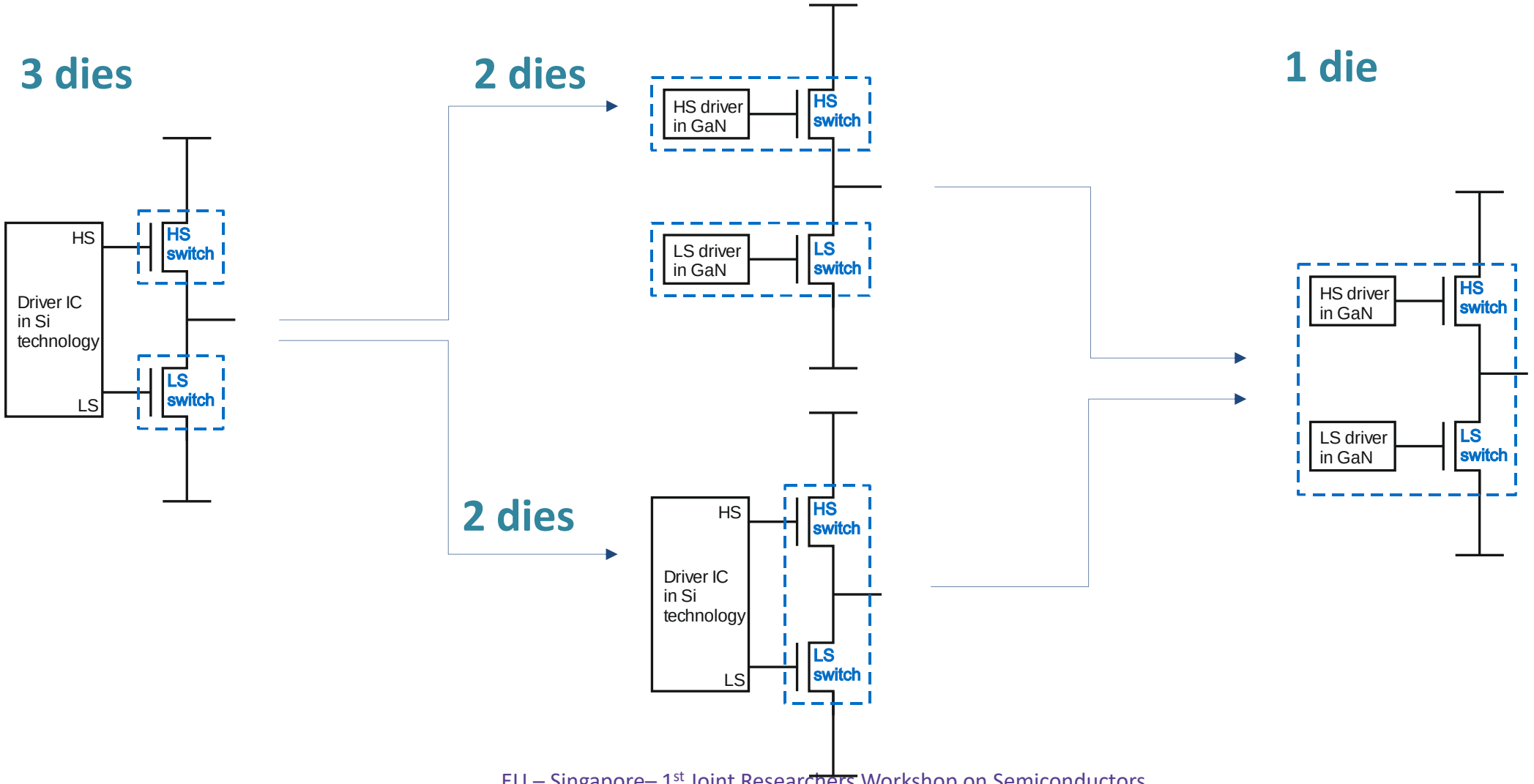


Towards Integration: GaN Power ICs

MPW April 2025

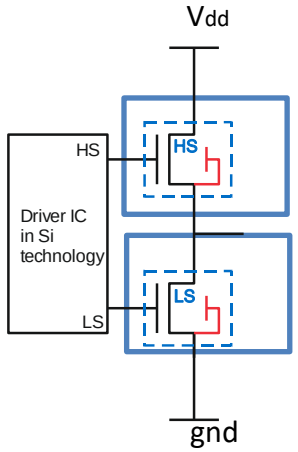


Discrete components to GaN-ICs

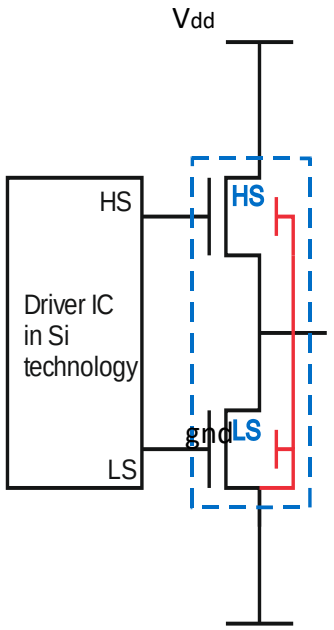


Monolithic Integration

Technological Challenges



Discrete devices : V_{SB} = 0 Volt



Example for Vin = 400 Volt.
When HS switch is ON, and
LS switch is OFF :

VS_LS = 0 Volt
VSB_LS = 0 Volt
VS_HS ~ 399 Volt

- Current in substrate
  - Disconnect substrate from Source_HS, then VSB = 399 Volt

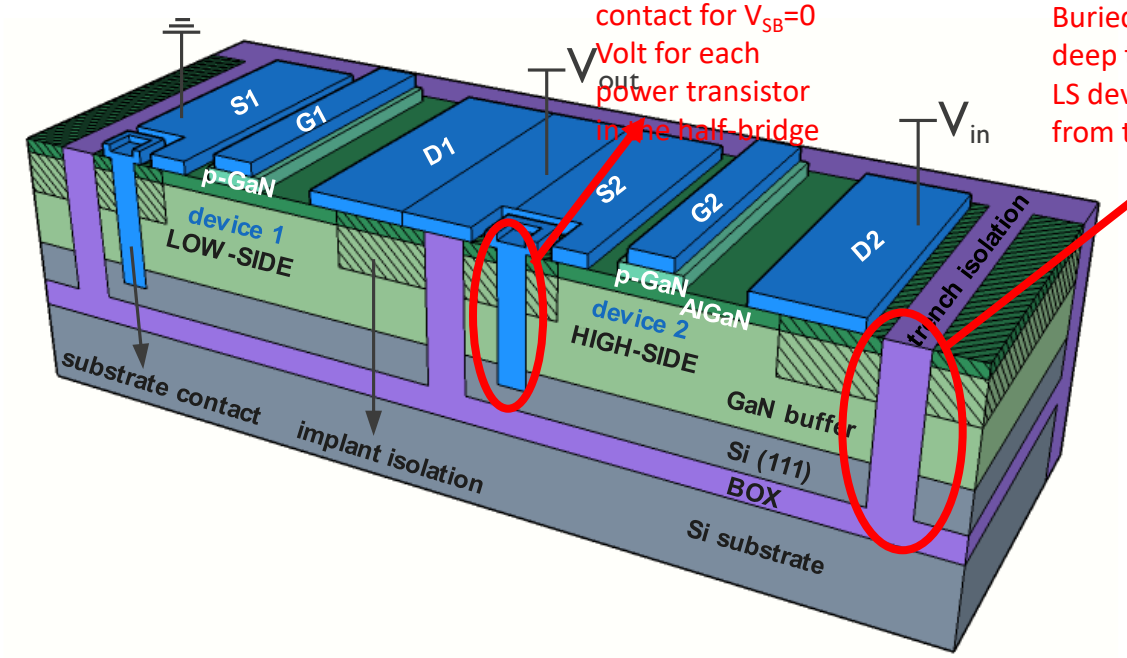
- Back-gating effects
- Low-voltage analog circuits that integrates with device
- Suitable passive components

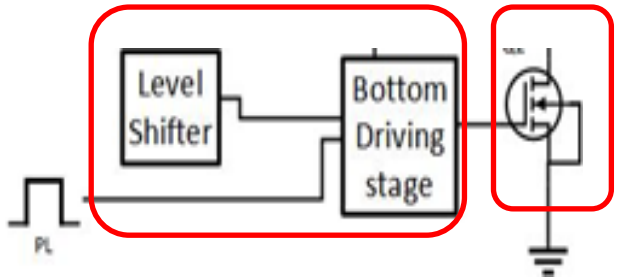
GANIC Solution

SOI substrate for isolation

Deep silicon contact for V_{SB}=0 Volt for each power transistor in the half-bridge

Buried oxide and oxide filled deep trench isolate the HS and LS devices from each other and from the silicon substrate.

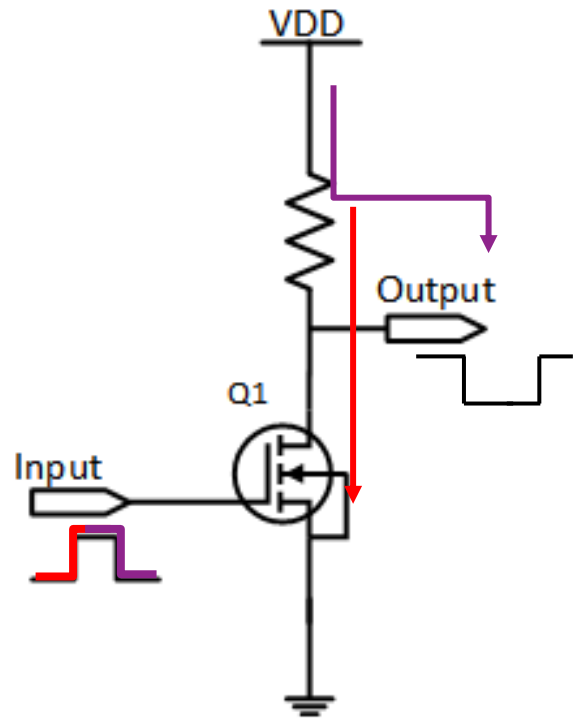




*X. Li, *et al*, "200V enh..integration" IEDM,38.7 (2017): 918-921.

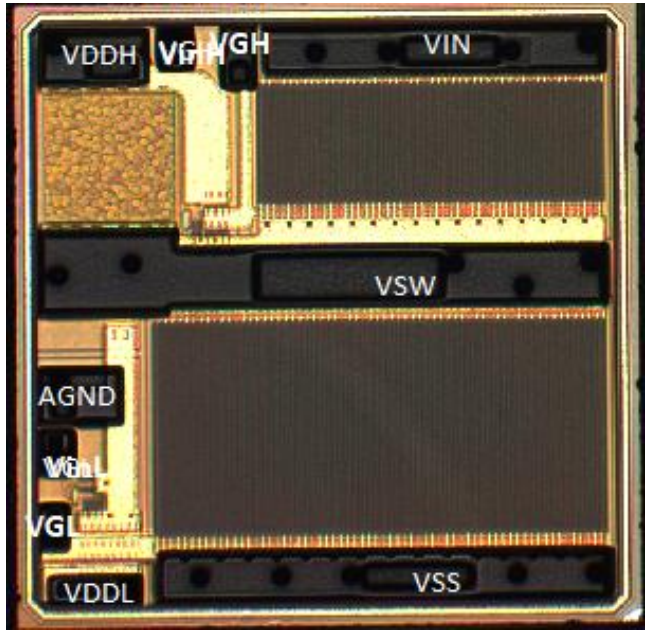
Monolithic Integration:
Circuit level challenges

- No complementary device
  - Use RTL based design
  - Trade-off between switching speed and power dissipation in dimensioning the resistors
- Difficulties in driver design
- Difficulties in logic gates/analog sub-circuits



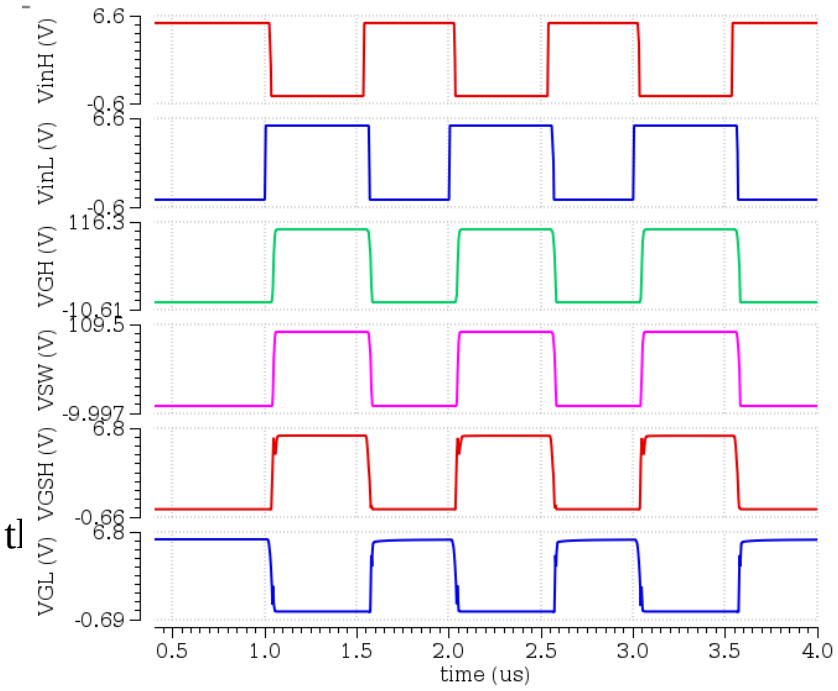
- RL increases => gain & transition delay increases
- RL increases => V_{OL} & power dissipation decreases

GANIC Demonstrator:200V GANIC



GaNIC sample

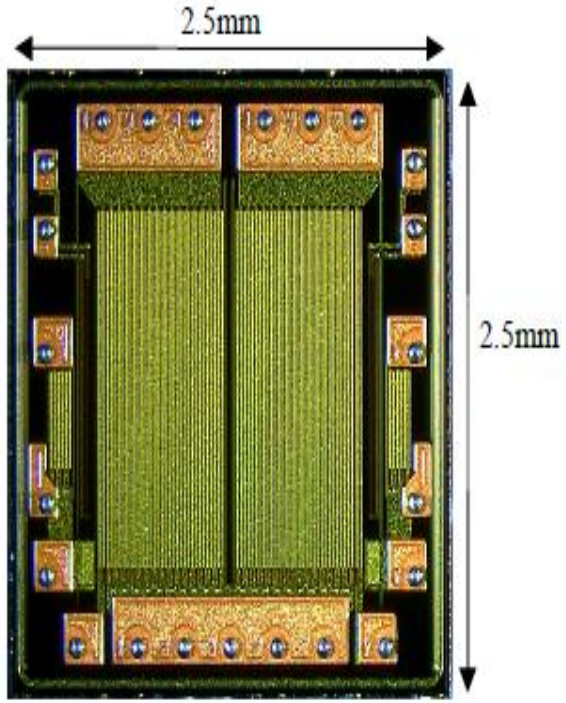
Thermal vias and metal on tl back



200V Asymmetric Half-Bridge switch with integrated driver for synchronous power converters

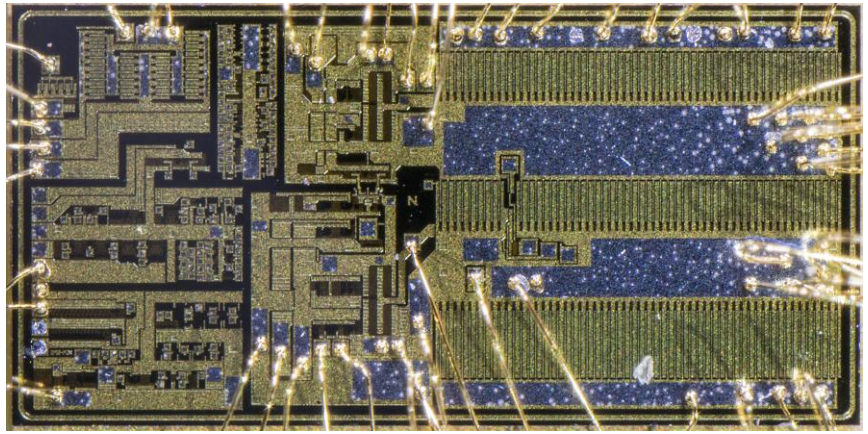
*U. Chatterjee, *et al*, Elsevier SSE, https://doi.org/10.1016/j.sse.2023.108707

GANIC Demonstrator:650V GANIC



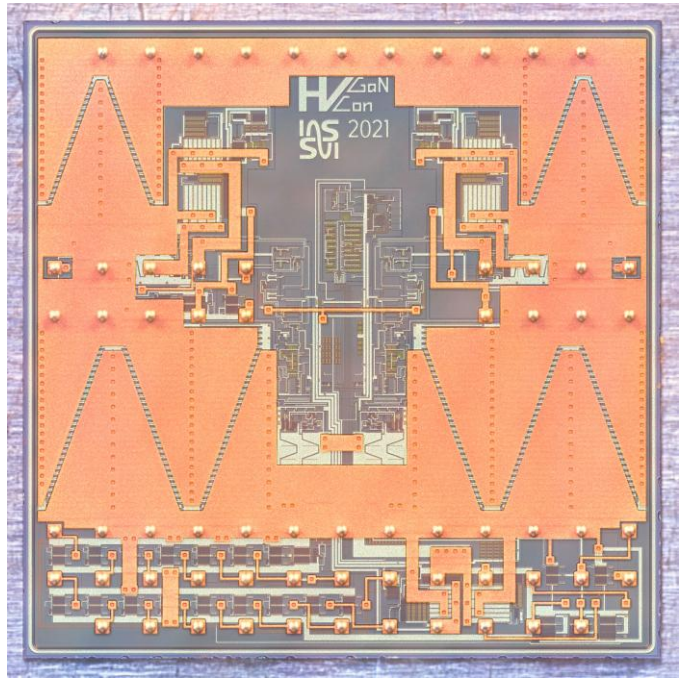
Monolithic Royer-circuit switching cell

*M. Rueß, University of Stuttgart, *WIPDA 2023*



400V, 1MHz, 200W high-efficiency totem-pole PFC converter

*M. Basler, N. Deneke, University of Hannover, IEEE Open J. Pow. Electron. 2023



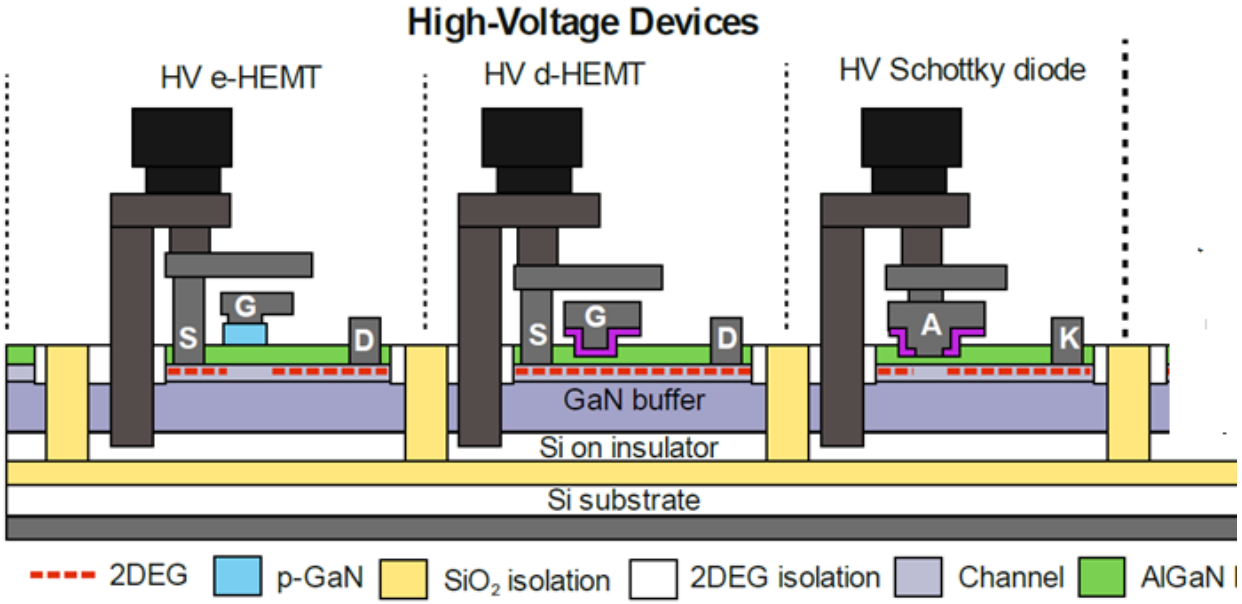
Monolithically Integrated Dual Half-Bridge Converter

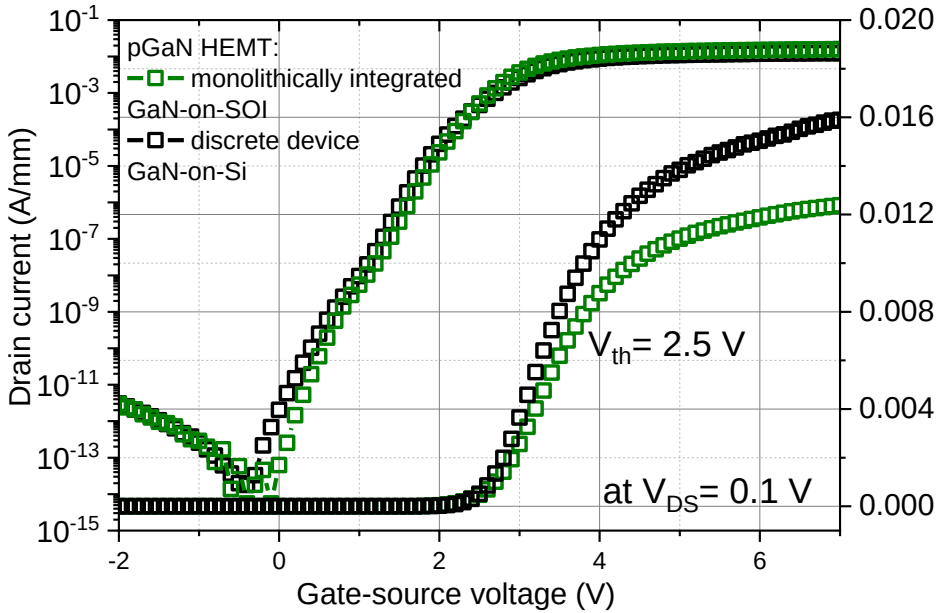
*J.Grobe, University of Aachen, 2023

Access through MPW service

http://europractice-ic.com/mpw-prototyping/power-electronics/

Extended GANIC Platform





Transfer Characteristics

*T. Cosnier, *et al*, IEDM 2021, doi:10.1109/IEDM19574.2021.9720591

*O. Syshchyk, *et al*, ESSDERC 2022, doi:10.1109/ESSDERC 55479.2022.9947150, 2022

*P. Vudumula, *et al*, SSE 2023, doi:org/10.1016/j.sse.2022.108496

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        - Or here

Or here some other text

THANK YOU

ICOS International Cooperation On Semiconductors

European Commission

This project has received funding from the European Union's Horizon Europe research and innovation programme under GA Nº 101092562

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