GaN Technology for Power Electronics Applications

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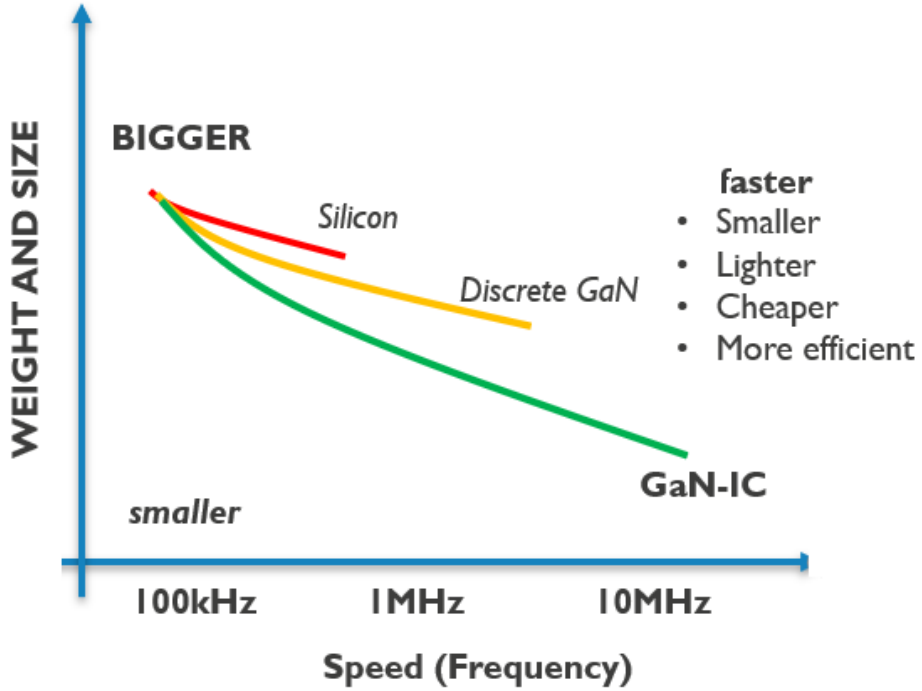
Introduction

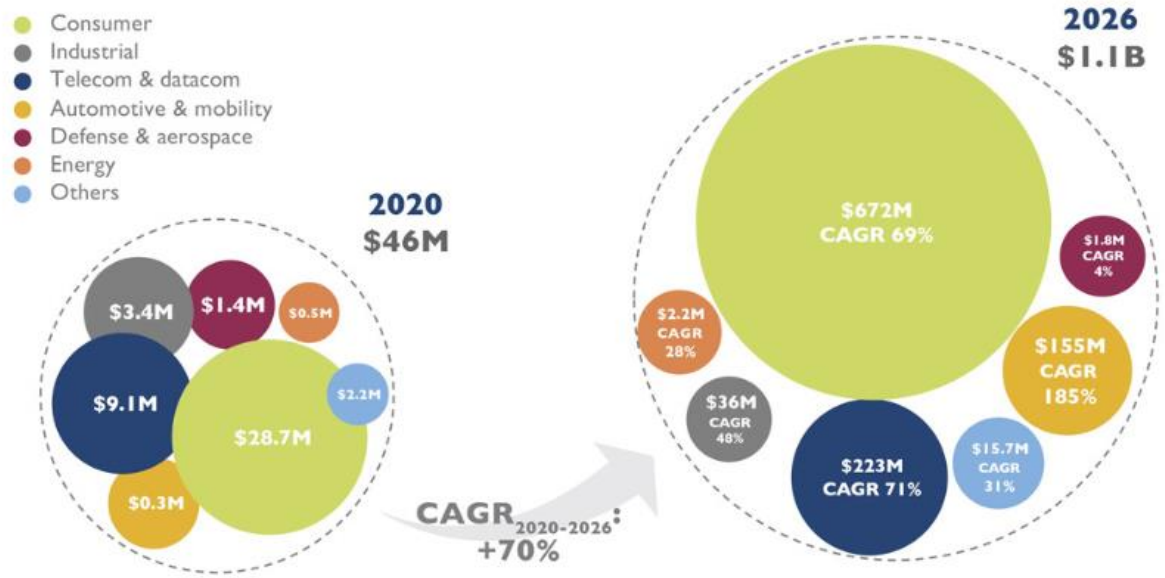
GaN Technology: A breakthrough for PE Application

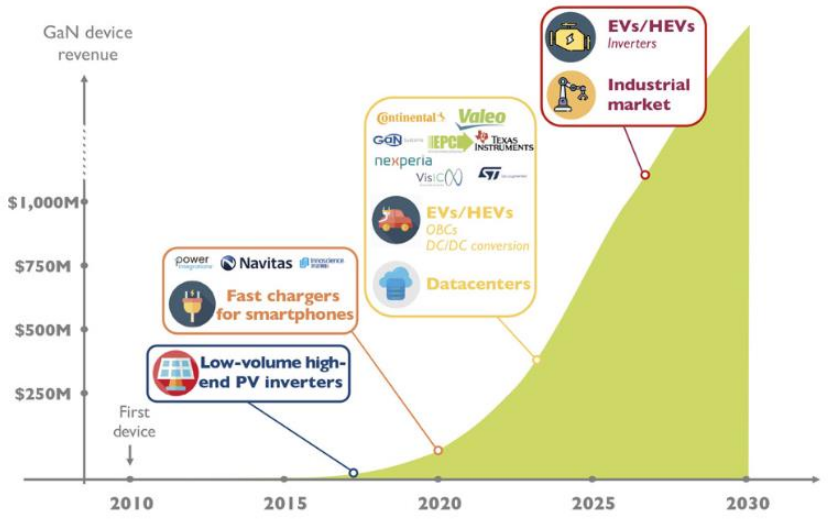


Higher integration	•Enables higher frequency operation •Integrate higher power
More efficient	•Less parasitic reduces gate ringing & switching loss
Compact & cost-effective	•Higher frequency, higher power density •Further reduction in filter size & cost
Easy to control	•Reduce gate overshoot undershoot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

Introduction

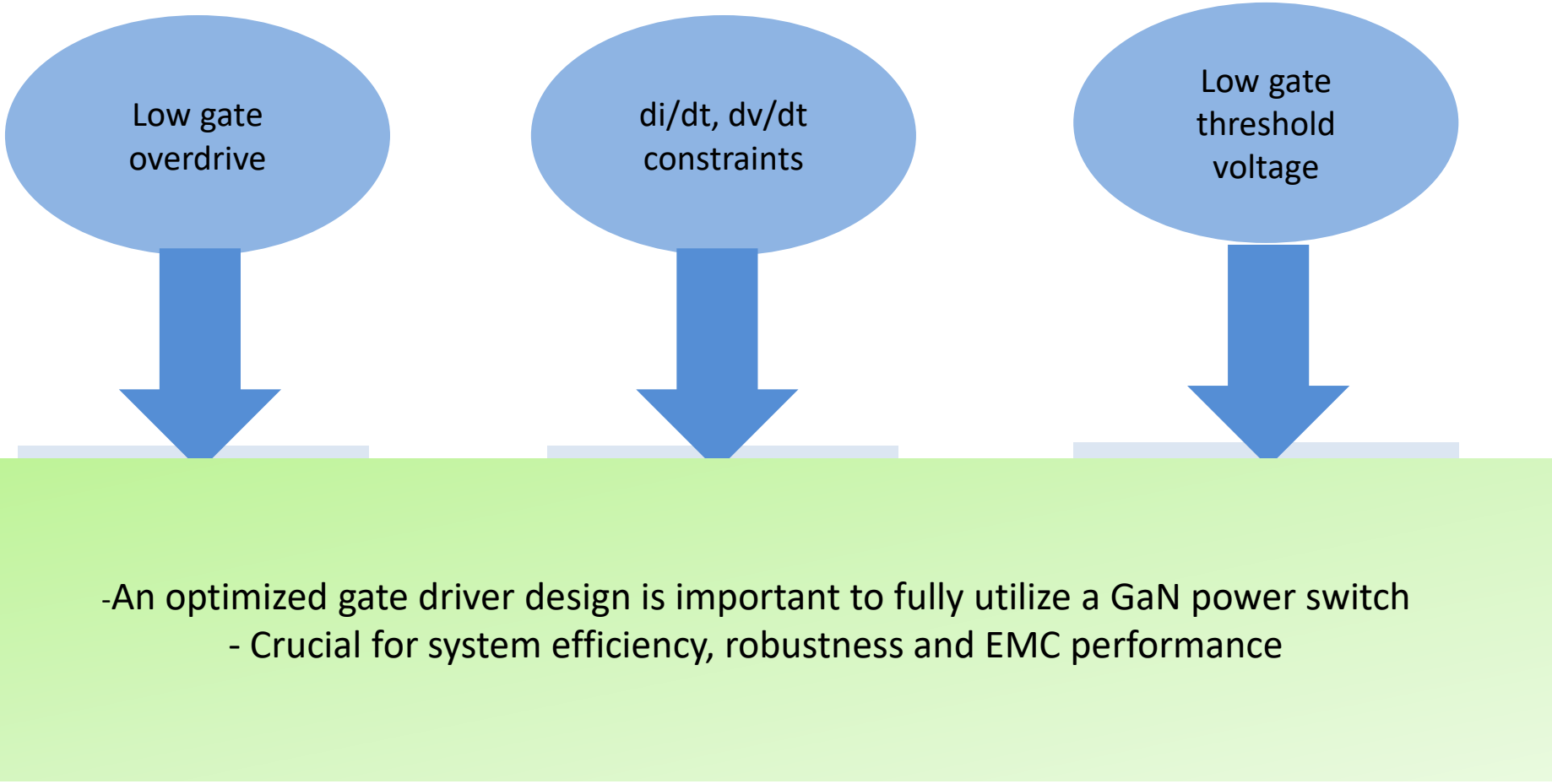
GaN Market Share





Source:: GaN power 2021, Yole Development, 2021

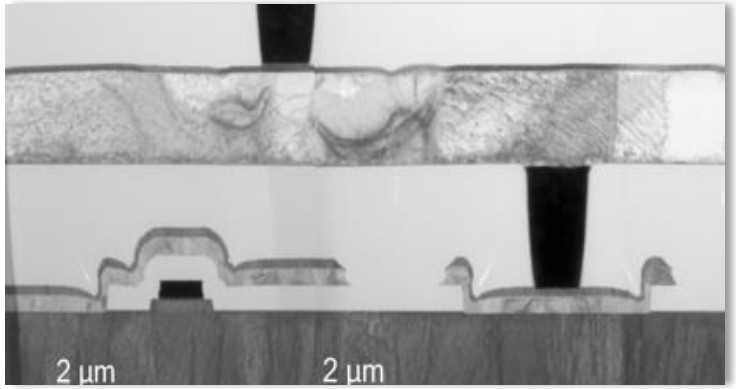
Operating a GaN Power Device



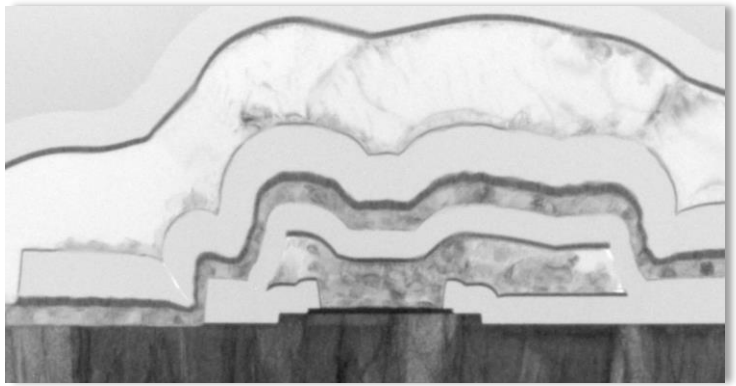
-An optimized gate driver design is important to fully utilize a GaN power switch
- Crucial for system efficiency, robustness and EMC performance

IMEC GaN Power Technology Overview

40V/100V p-GaN HEMT

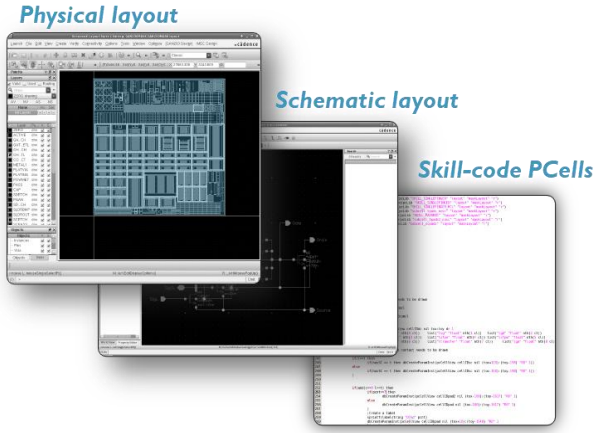


200V/650V p-GaN HEMT



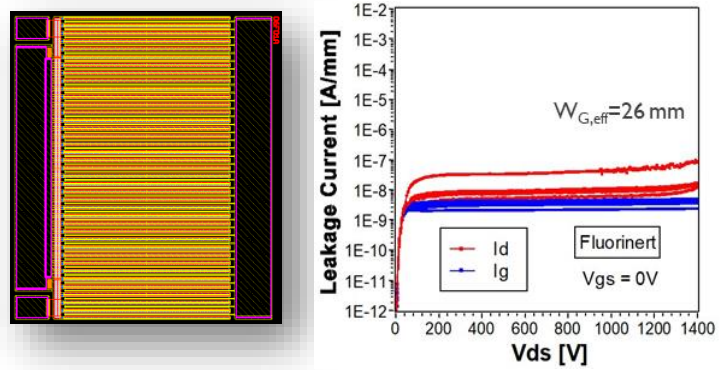
Monolithic integration (GaN-IC)

J. Thone, PWR SOC 2021

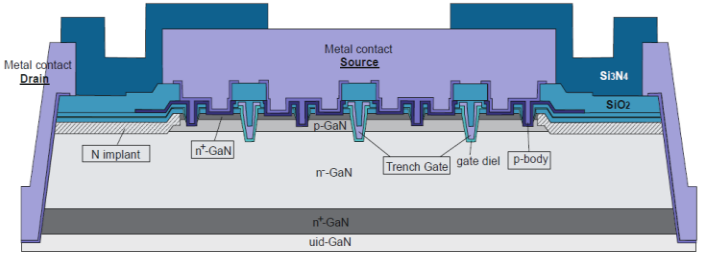


1200V GaN under development

Lateral p-GaN HEMT



Vertical GaN FET



Outline

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

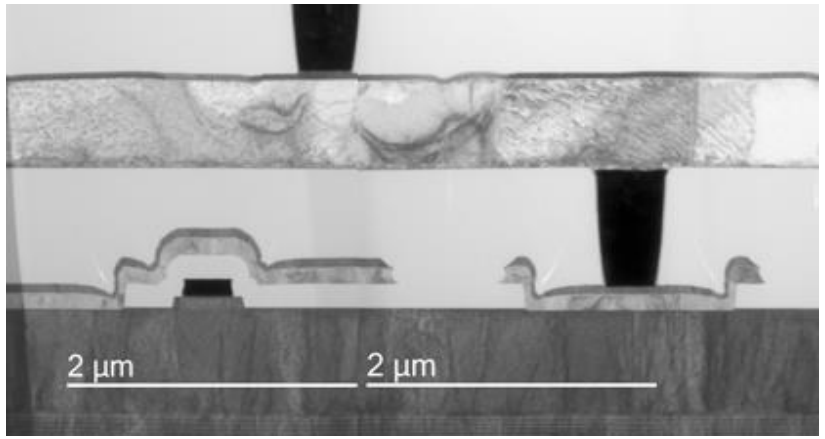
Discrete Power Devices & More

Discrete Device Development

Low Voltage Platform 40V/100V

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

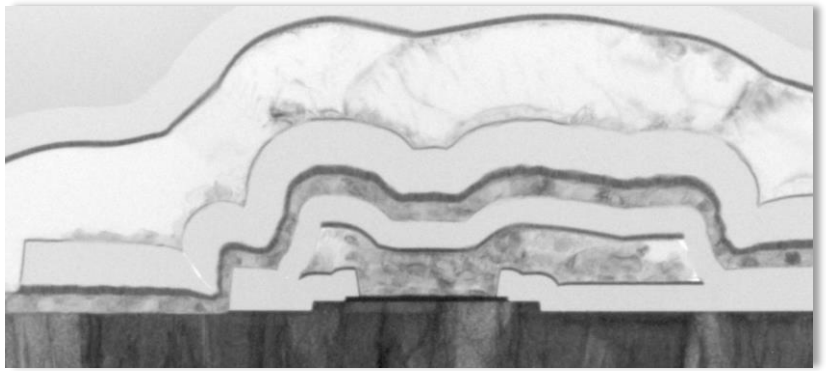
- Oxide CMP
- W-plugs



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

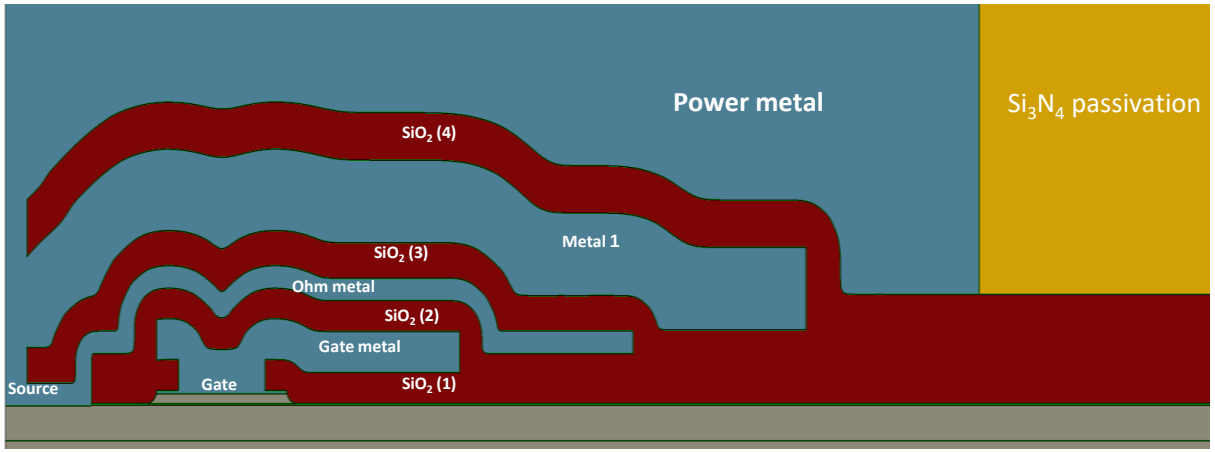


*N. Posthuma, *et al*, An ind-ready..pow tech, *ISPSD 2018, doi: 10.1109/ISPSD.2018.8393658*

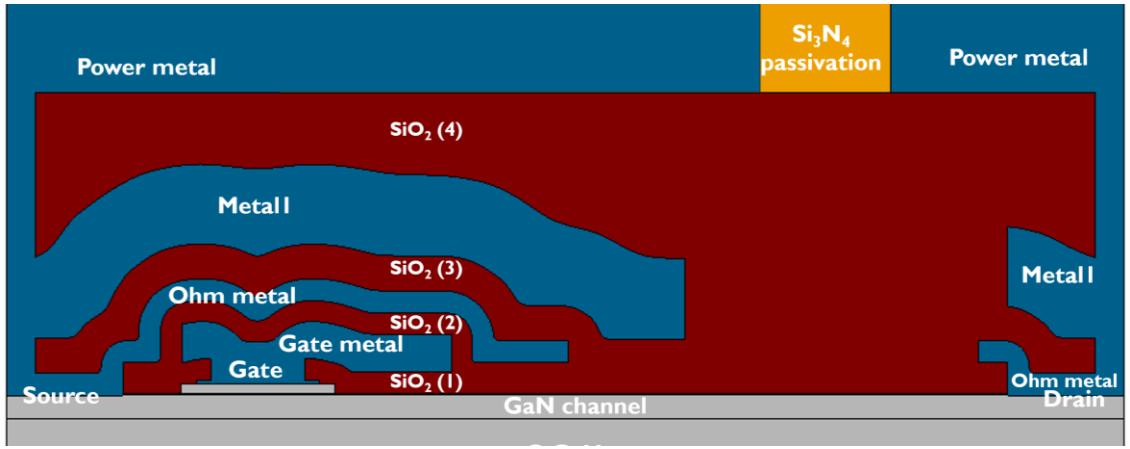
Device Architecture

Discrete & IC Technology Platform

Discrete devices on Si

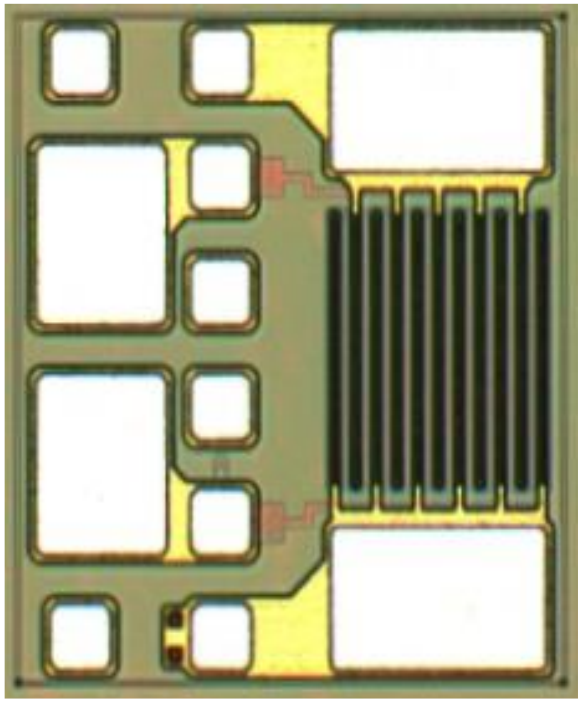


GaN-IC devices



- 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

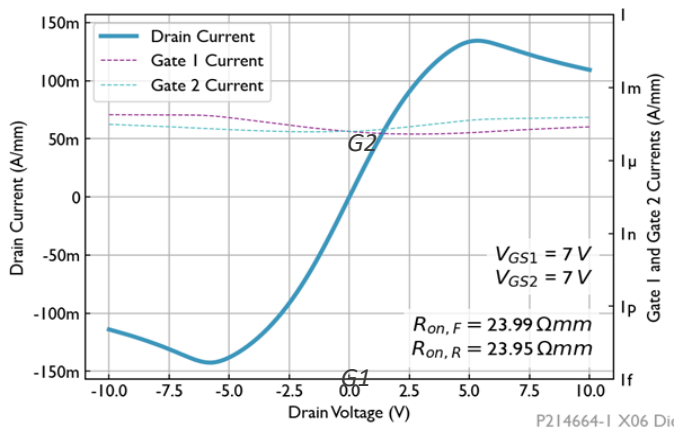
GaN Bidirectional Switch



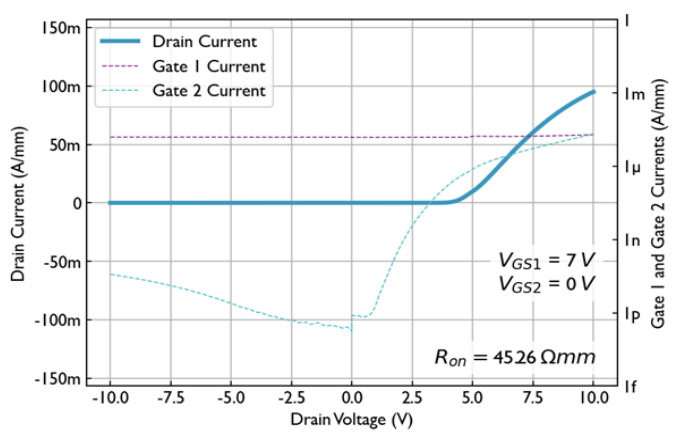
Microscopic image of a dual gate bidirectional switch

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

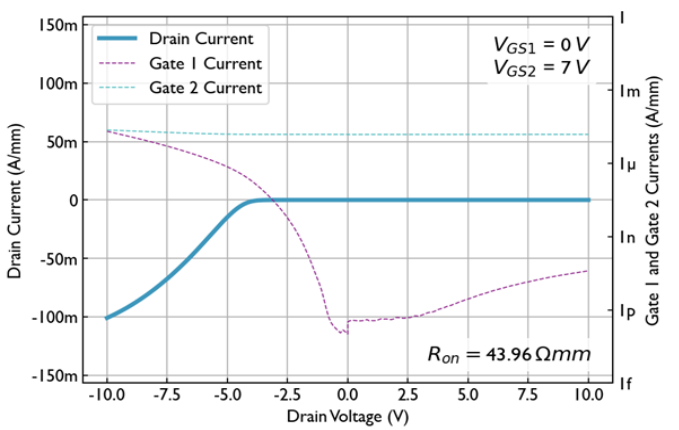
ON state (bidirectional mode)



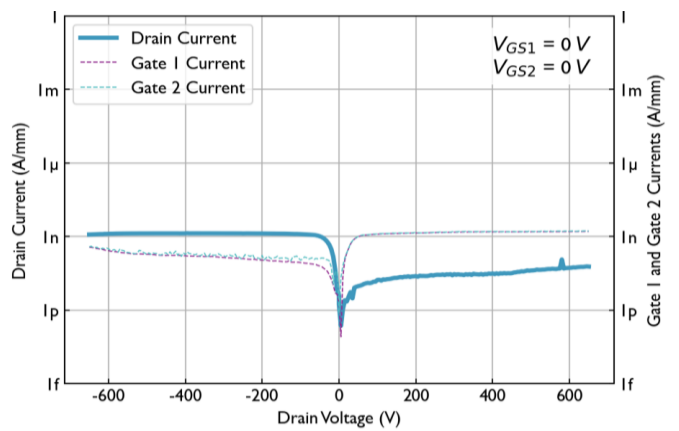
Forward diode mode



Reverse diode mode

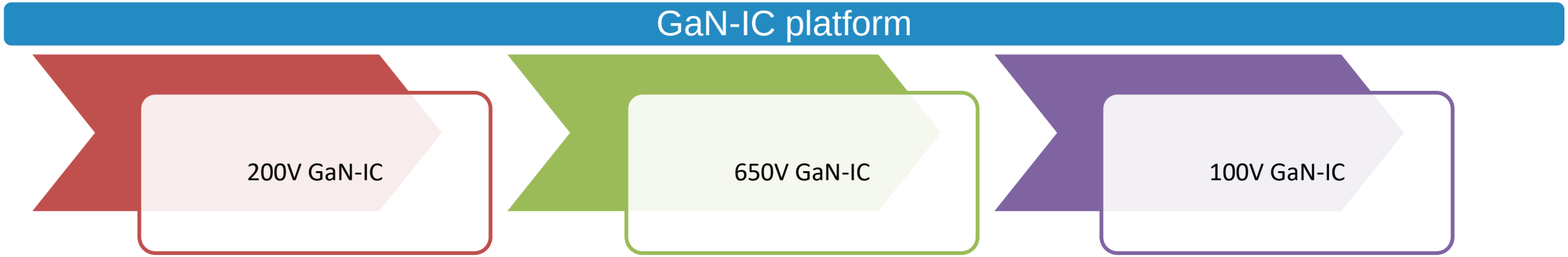


OFF state (blocking mode)

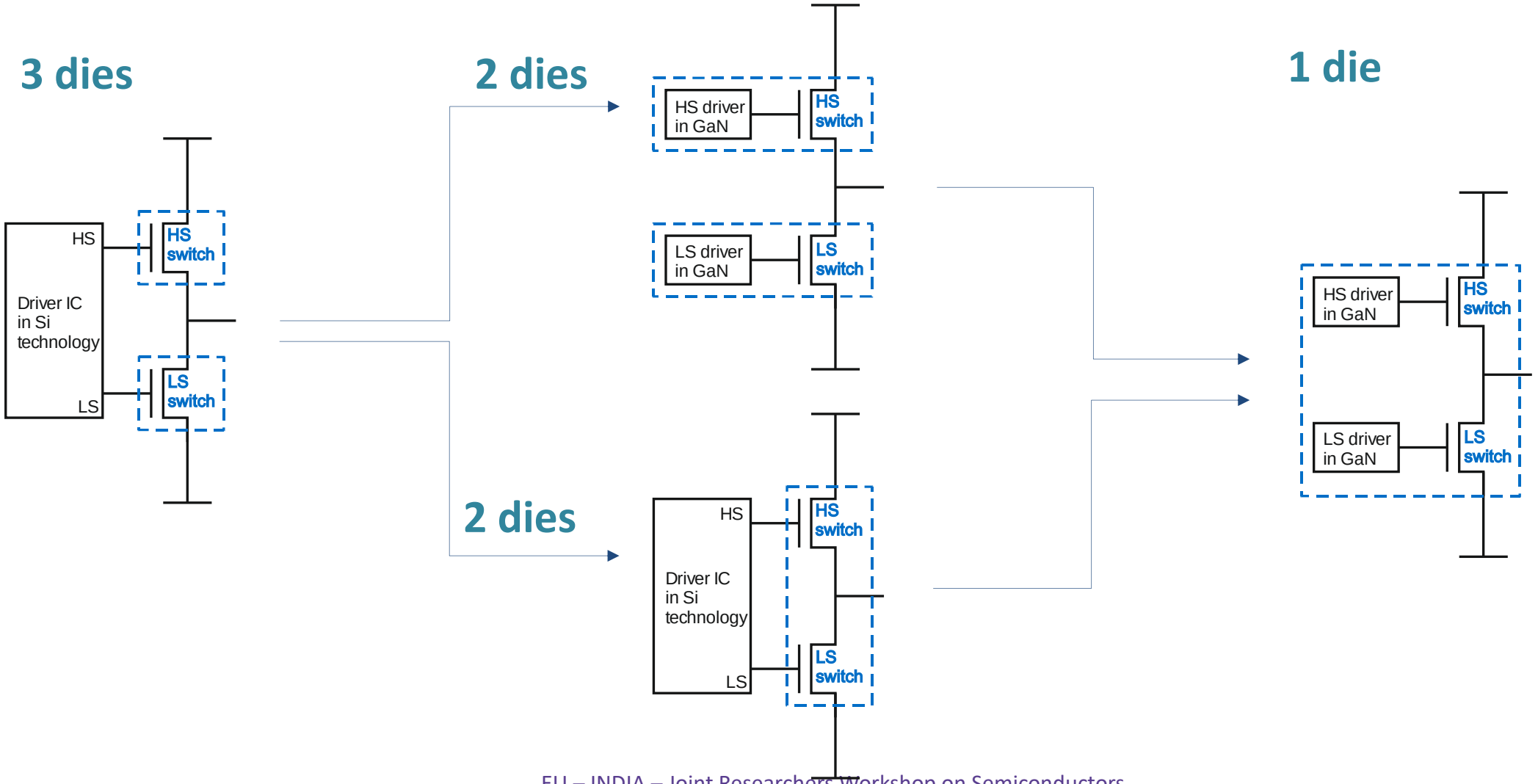


Towards Integration: GaN Power ICs

MPW April 2025

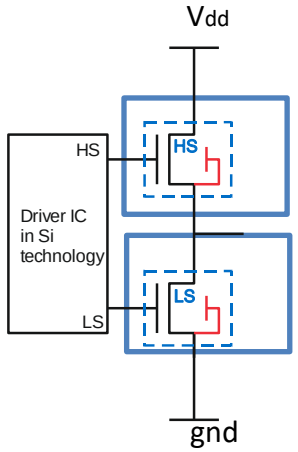


Discrete components to GaN-ICs

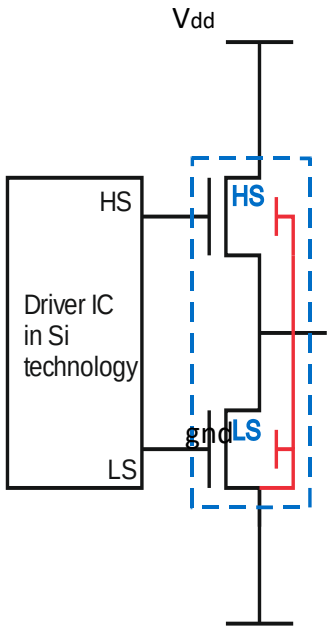


Monolithic Integration

Technological Challenges



Discrete devices : V_{SB} = 0 Volt



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

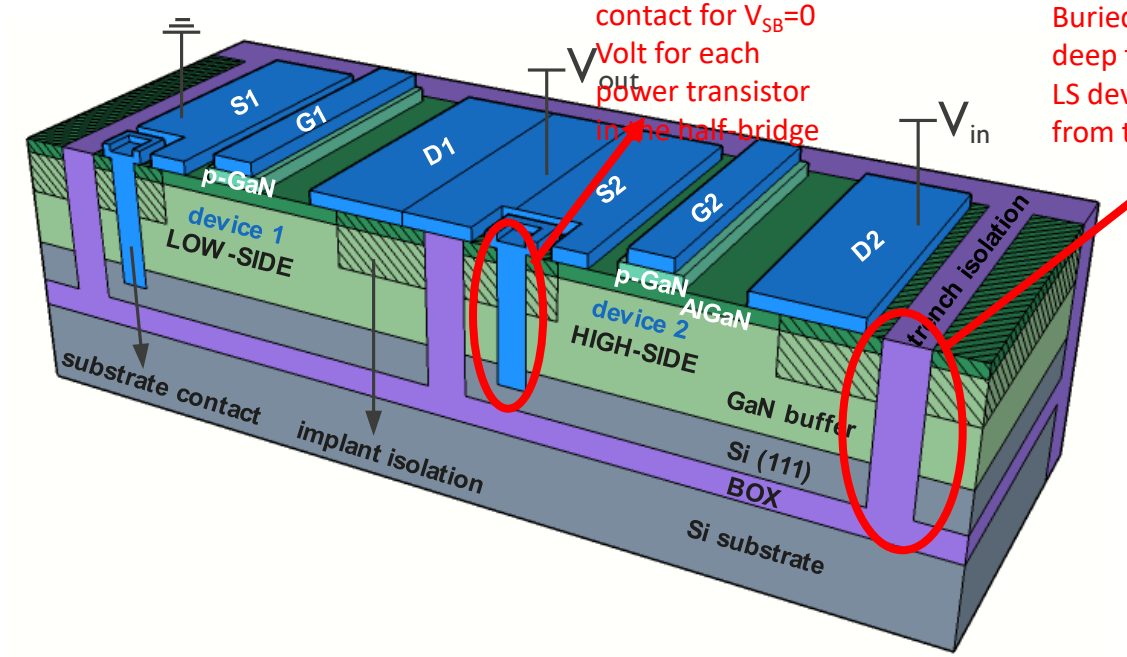
VS_LS = 0 Volt
VSB_LS = 0 Volt
VS_HS ~ 399 Volt

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

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

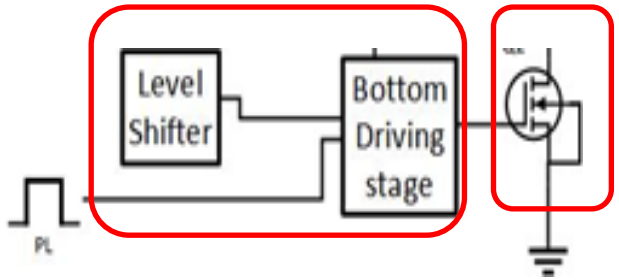
GANIC Solution

SOI substrate for isolation



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

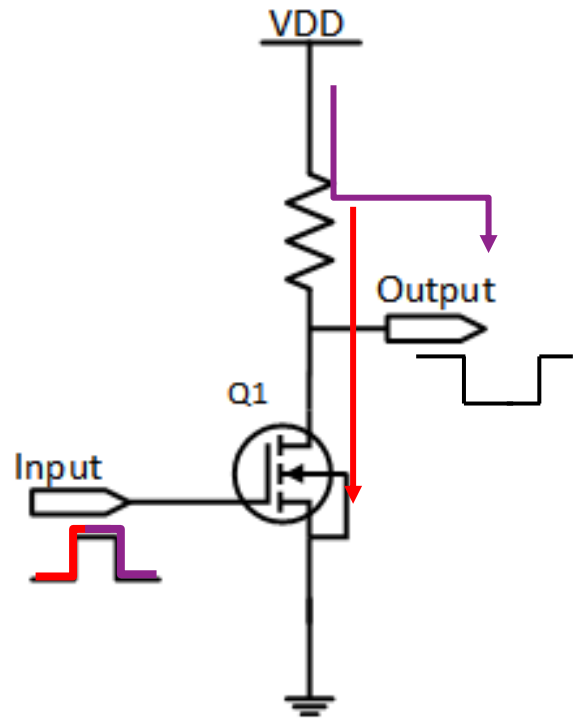
Buried oxide and oxide filled deep trench isolate the HS and LS devices from each other and from the silicon substrate.



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

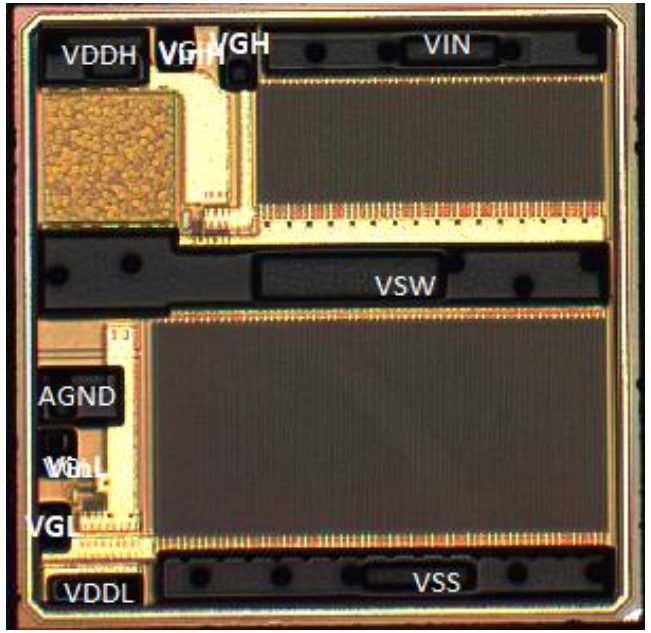
Monolithic Integration:
Circuit level challenges

- 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



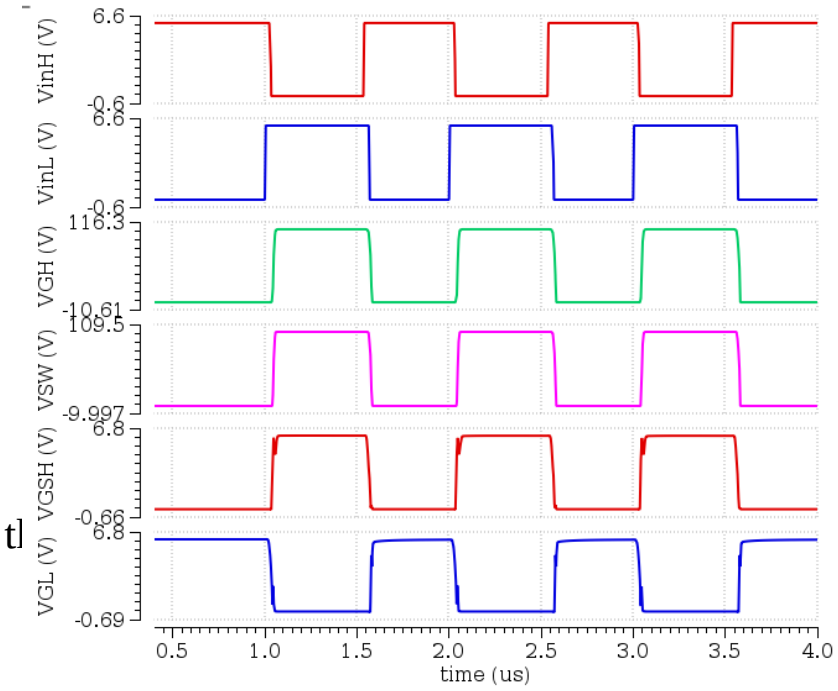
- RL increases => gain & transition delay increases
- RL increases => V_{OL} & power dissipation decreases

GANIC Demonstrator:200V GANIC



GaNIC sample

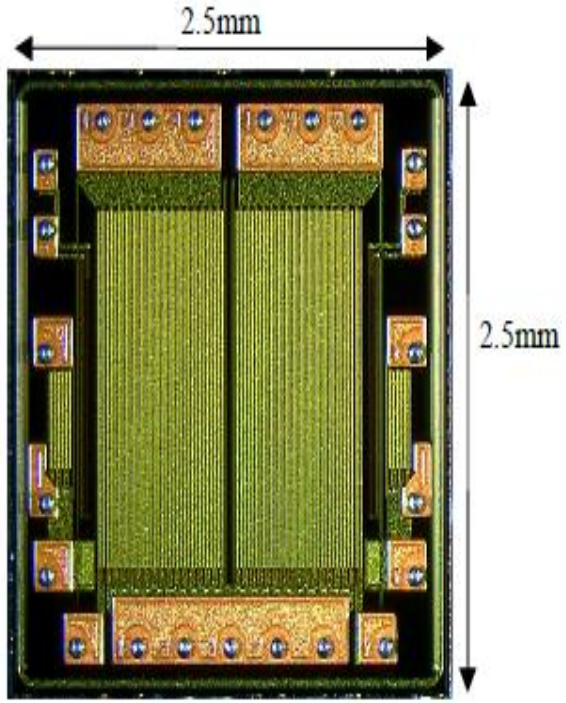
Thermal vias and metal on tl back



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

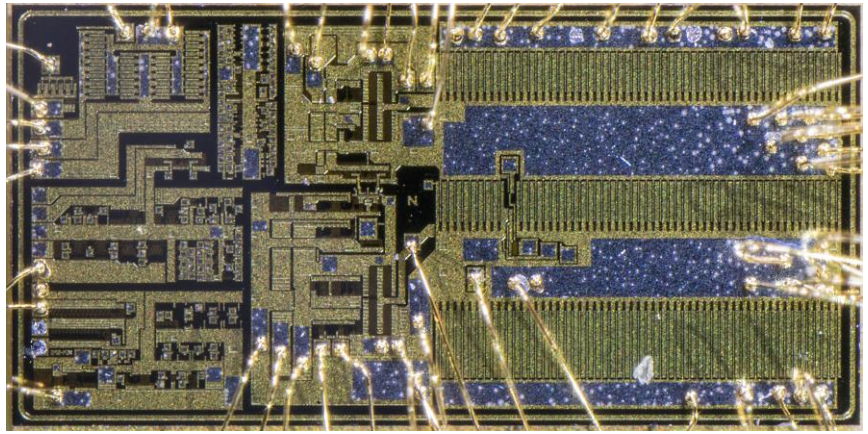
*U. Chatterjee, *et al*, Elsevier SSE, https://doi.org/10.1016/j.sse.2023.108707

GANIC Demonstrator:650V GANIC



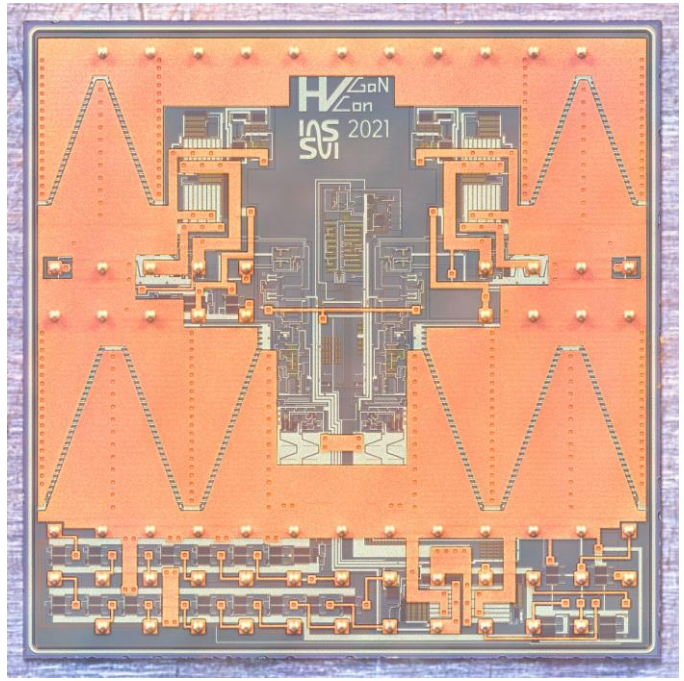
Monolithic Royer-circuit switching cell

*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



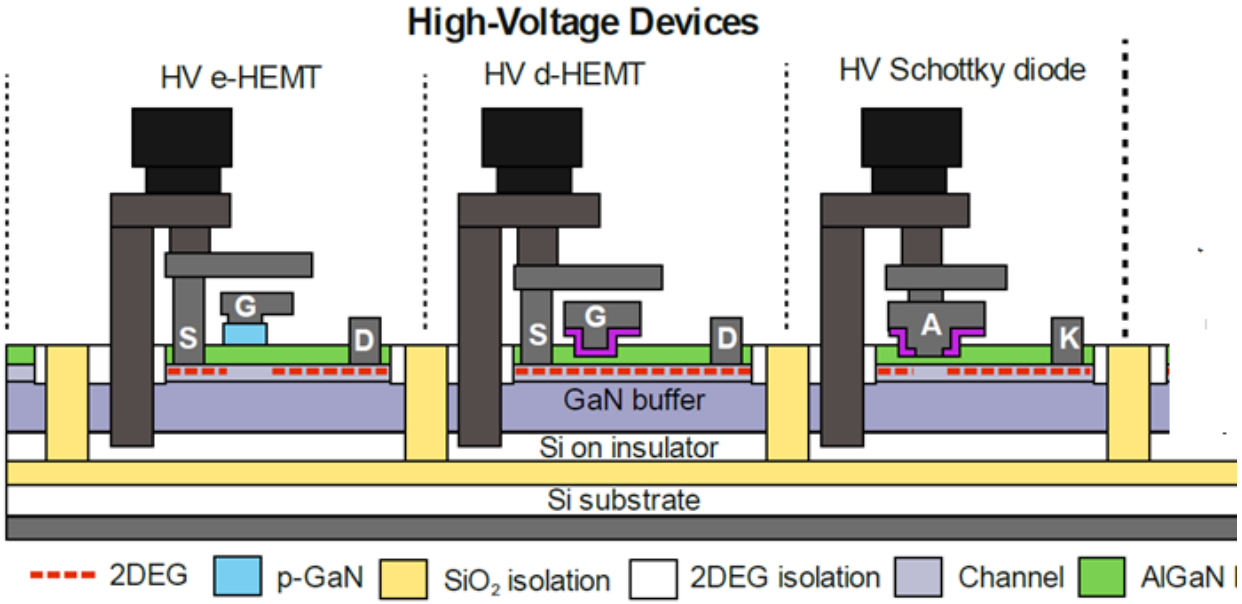
Monolithically Integrated Dual Half-Bridge Converter

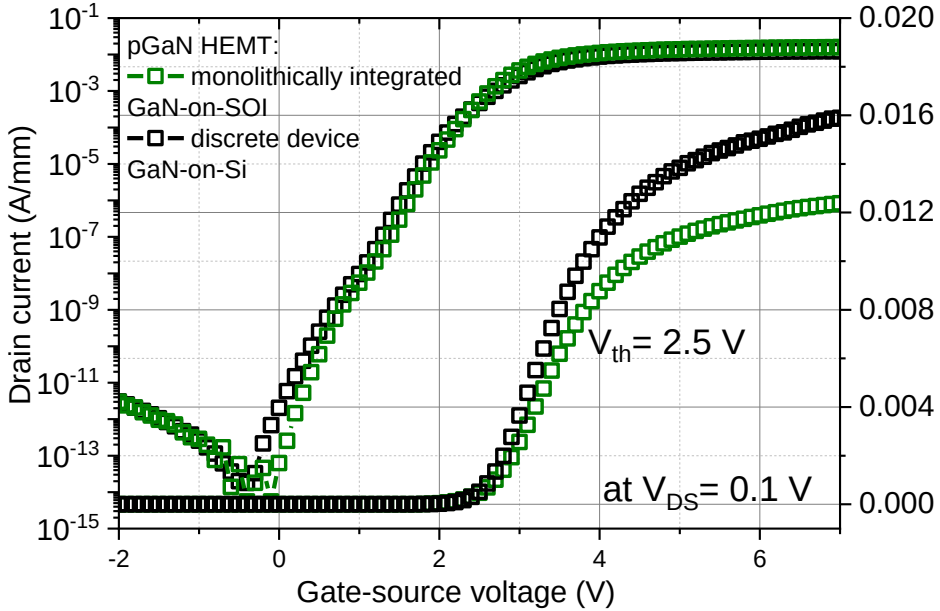
*J.Grobe, University of Aachen, 2023

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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THANK YOU

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European Commission

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