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# GaN Technology for Power Electronics Applications

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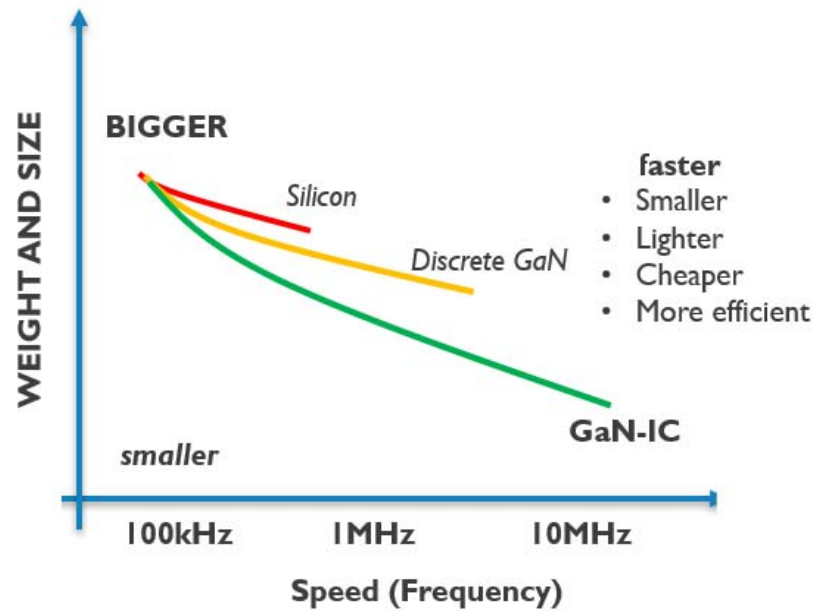
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## GaN Technology: A breakthrough for PE Application



Higher integration

- Enables higher frequency operation
- Integrate higher power

More efficient

- Less parasitic reduces gate ringing & switching loss

Compact & cost-effective

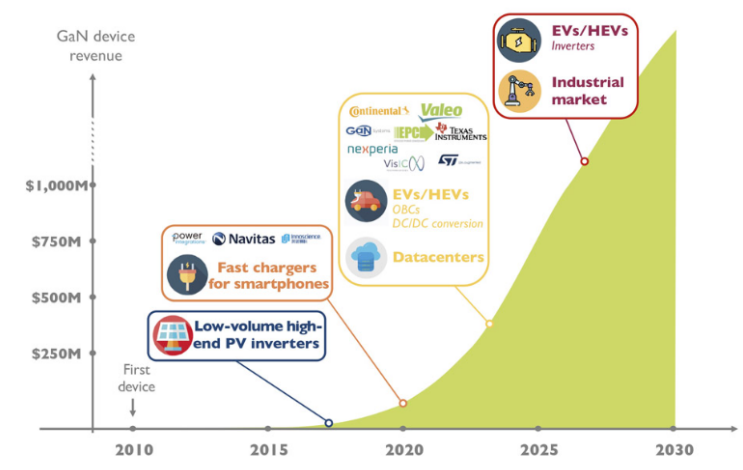
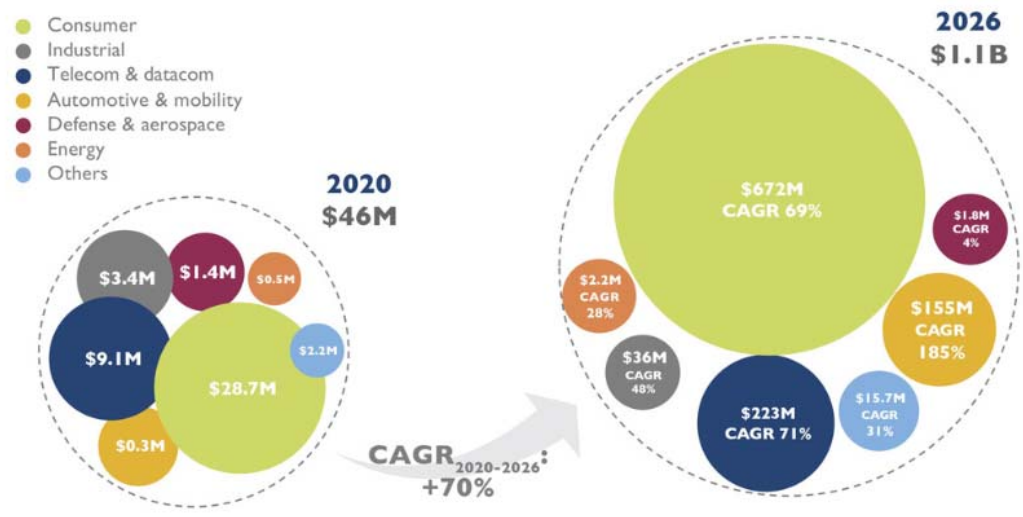
- Higher frequency, higher power density
- Further reduction in filter size & cost

Easy to control

- Reduce gate overshoot undershoot
- Easier control due to reduced ringing

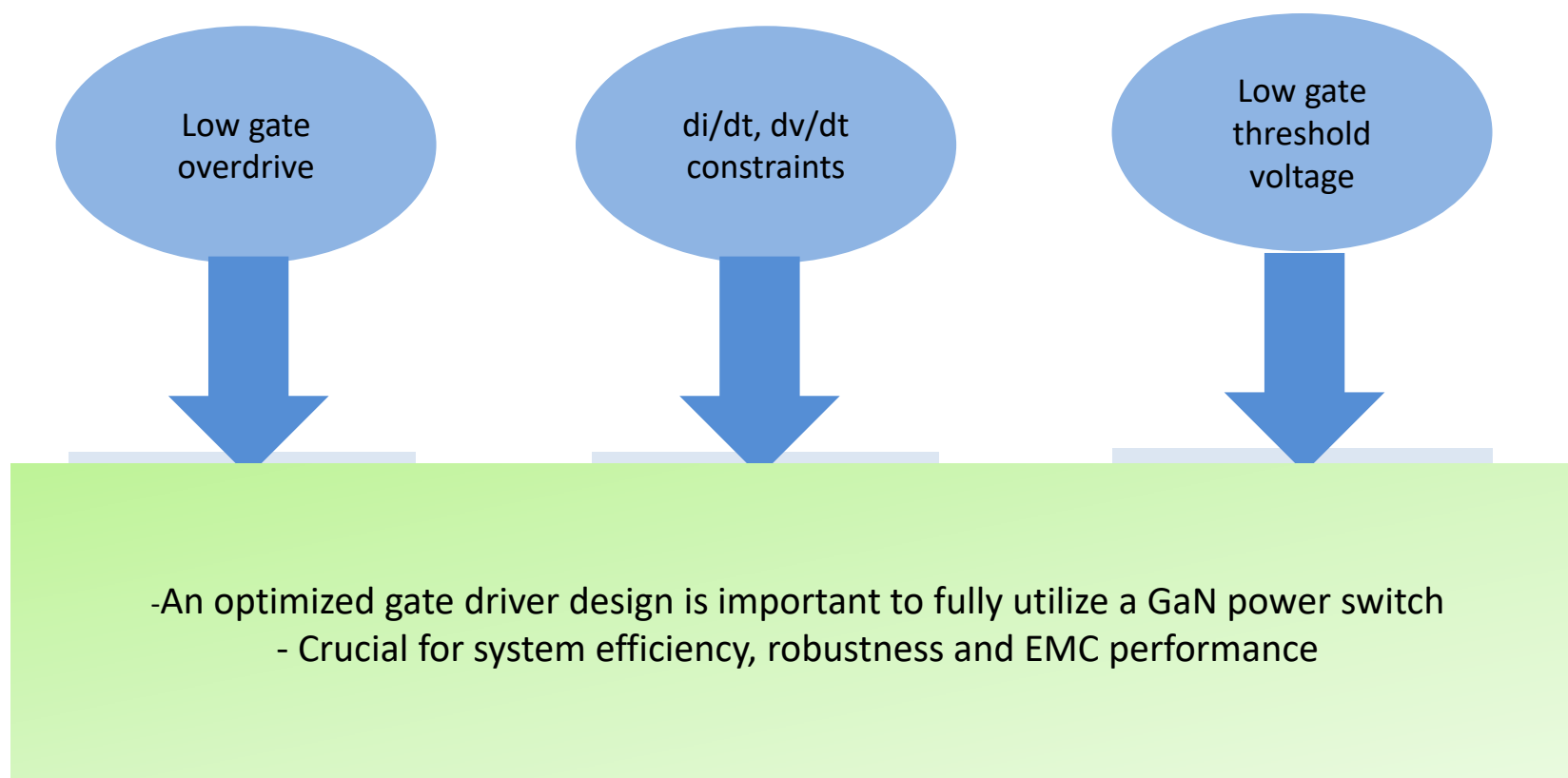
# Introduction

## GaN Market Share

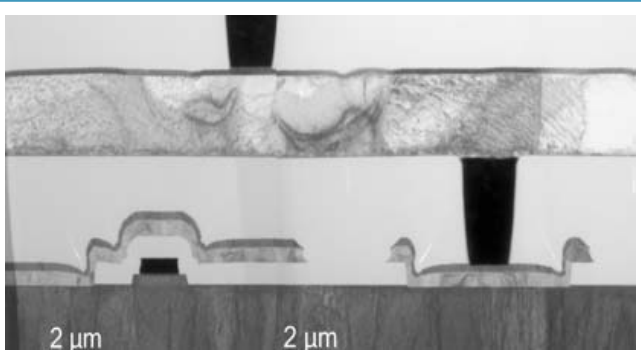


Source:: GaN power 2021, Yole Development, 2021

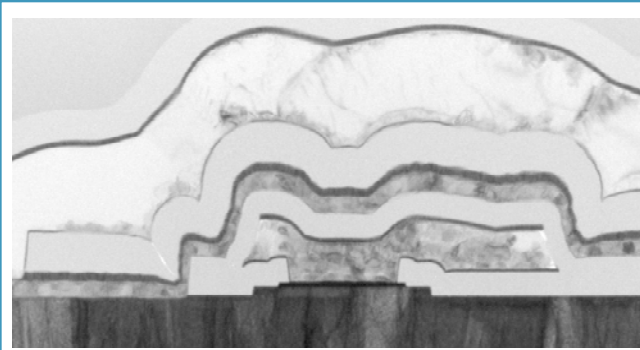
# Operating a GaN Power Device



## 40V/100V p-GaN HEMT

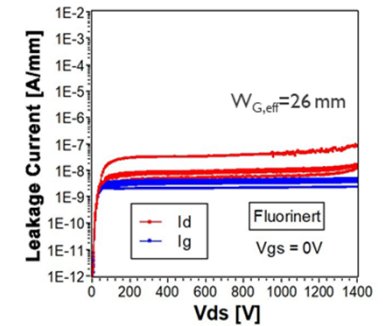
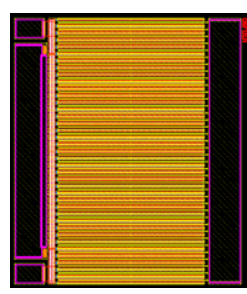


## 200V/650V p-GaN HEMT

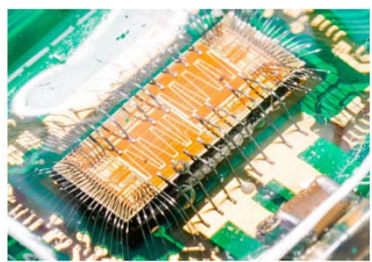


## 1200V GaN under development

### Lateral p-GaN HEMT



## Monolithic integration (GaN-IC)

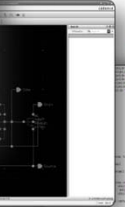


\*J. Thone, PWR SOC 2021

### Physical layout



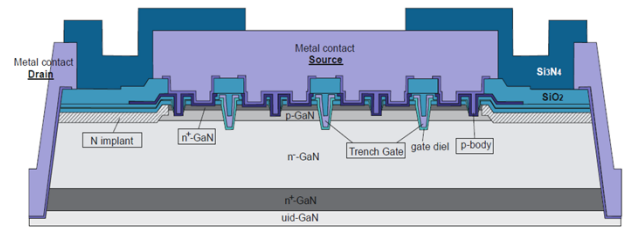
### Schematic layout



### Skill-code PCells



### Vertical GaN FET



# Outline

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



# Discrete Power Devices & More

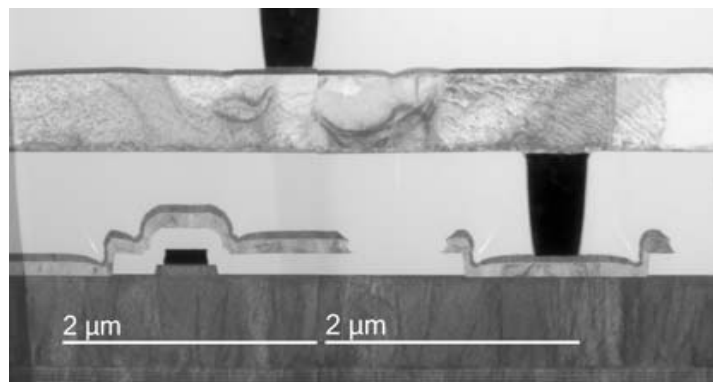
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# Discrete Device Development

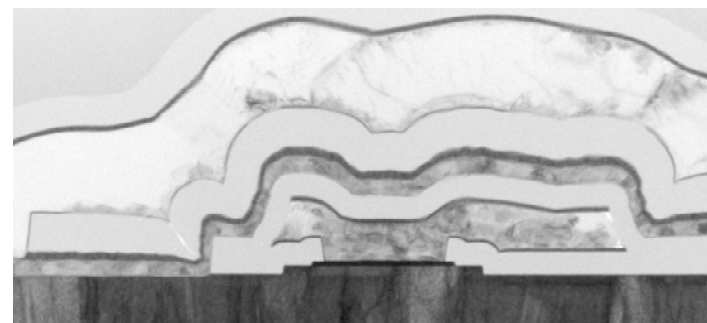
## Low Voltage Platform 40V/100V

- 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



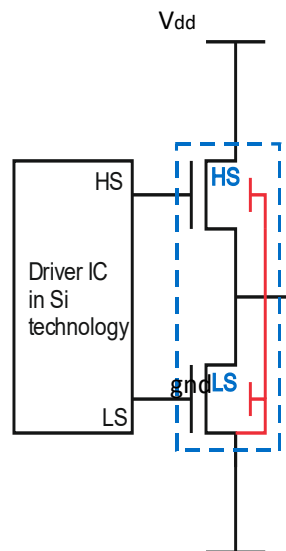
\*N. Posthuma, *et al*,  
An ind-ready..pow  
tech, *ISPSD 2018*,  
doi:  
[10.1109/ISPSD.2018.  
.8393658](https://doi.org/10.1109/ISPSD.2018.8393658)



# Towards Integration: GaN Power ICs

## Technological Challenges

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



Example for  $V_{in} = 400$  Volt.  
When HS switch is ON, and  
LS switch is OFF :

$$V_{S\_LS} = 0 \text{ Volt}$$

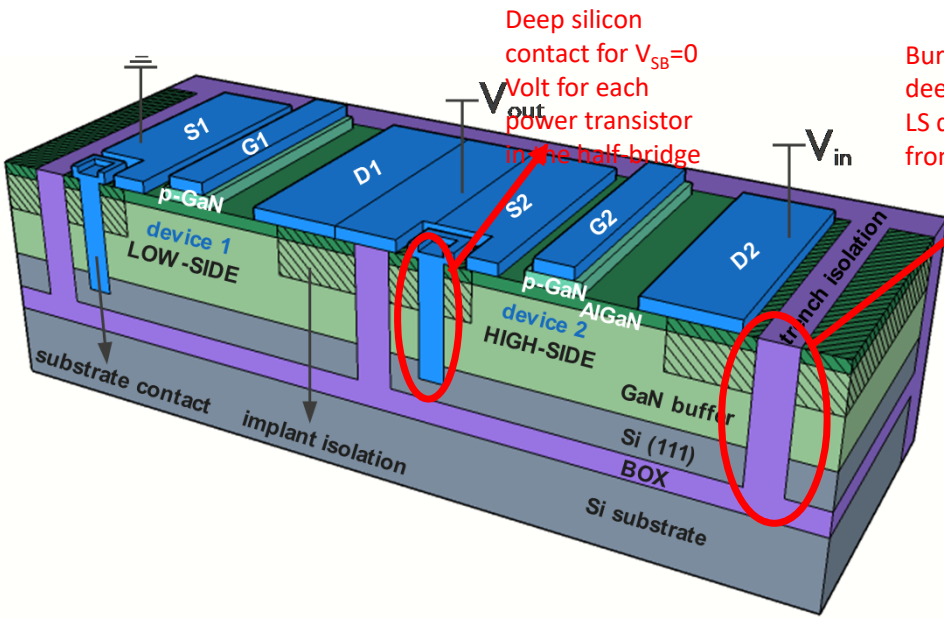
$$V_{SB\_LS} = 0 \text{ Volt}$$

$$V_{S\_HS} \sim 399 \text{ Volt}$$

- Current in substrate
- Disconnect substrate from Source<sub>HS</sub>, then  $V_{SB} = 399$  Volt

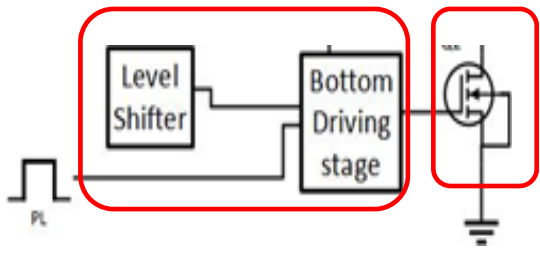
# GANIC Solution

## SOI substrate for isolation



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

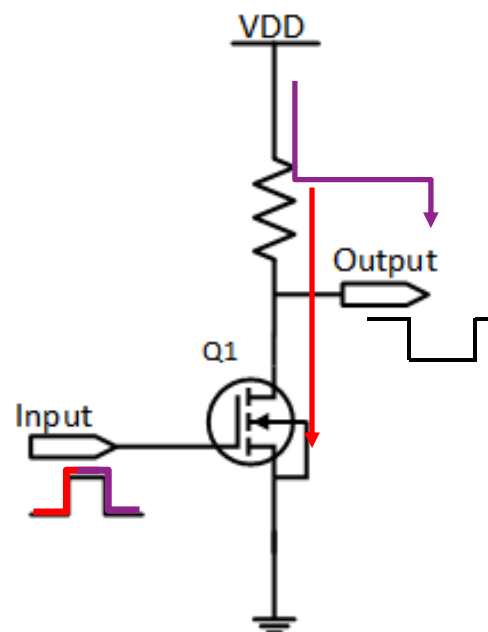
Buried oxide and oxide filled deep trench isolate the HS and LS devices from each other and from the silicon substrate.



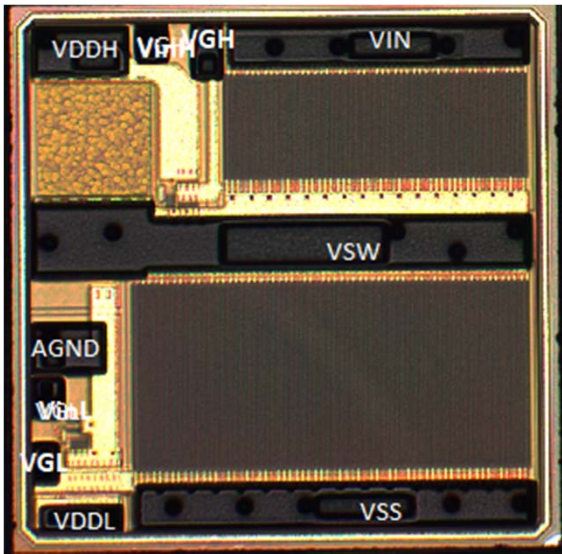
\*X. Li, *et al*, "200V enh..integration" IEDM,38.7 (2017): 918-921.

# 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

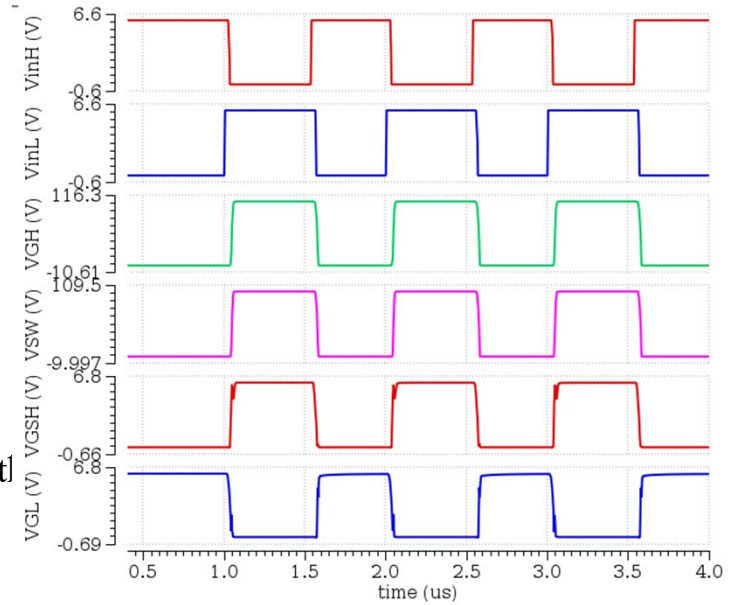


- $RL$  increases  $\Rightarrow$  gain & transition delay increases
- $RL$  increases  $\Rightarrow V_{OL}$  & power dissipation decreases



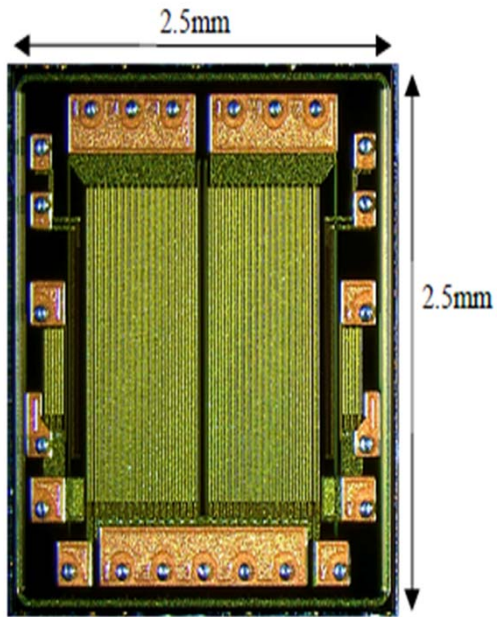
GaNIC sample

Thermal vias and metal on the back



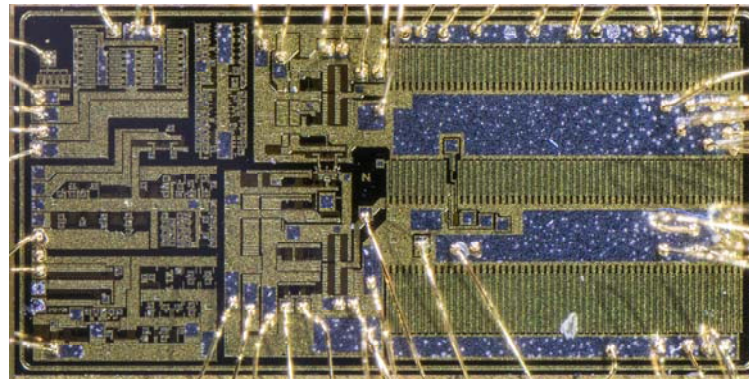
## 200V Asymmetric Half-Bridge switch with integrated driver for synchronous power converters

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



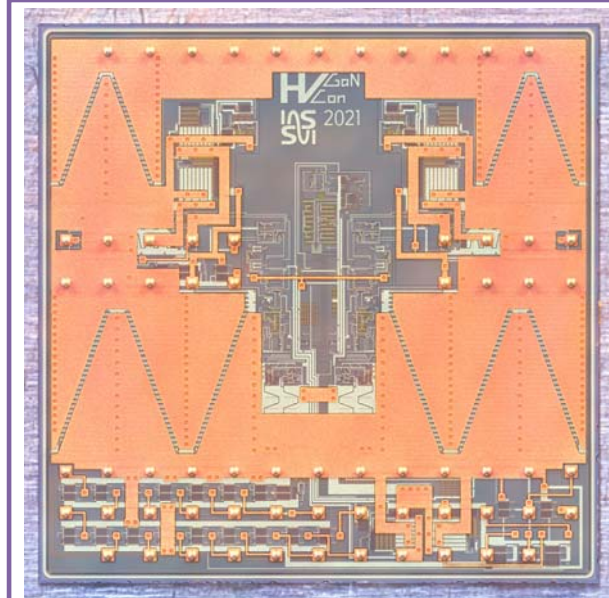
Monolithic Royer-circuit switching cell

\*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

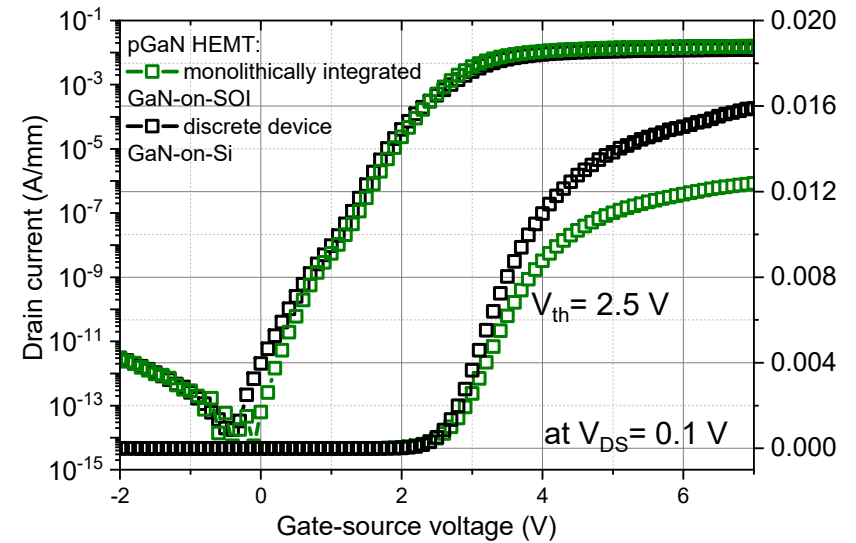
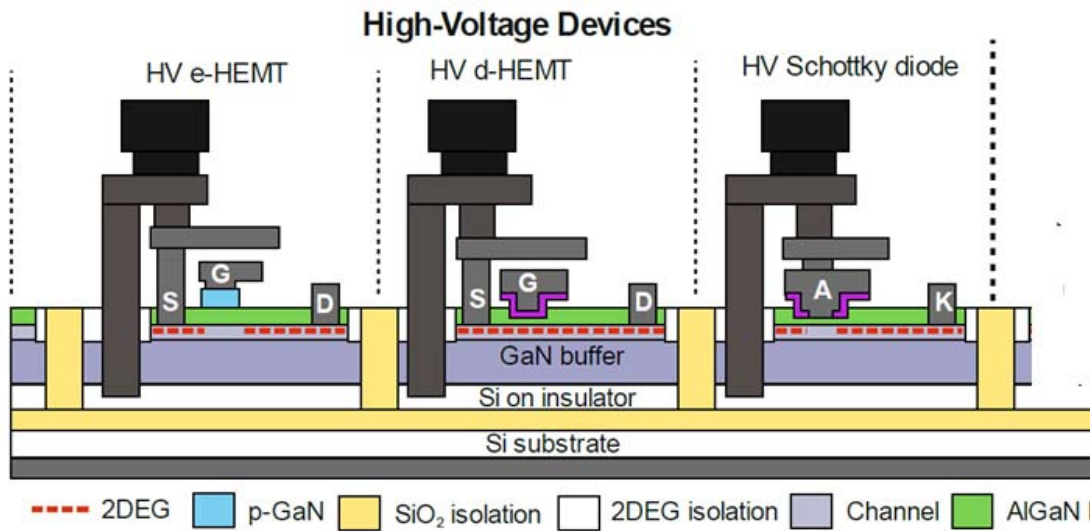
\*J. Grobe, University of Aachen,  
2023

Access through MPW service



<http://euopractice-ic.com/mpw-prototyping/power-electronics/>

# Extended GANIC Platform



## Transfer Characteristics

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

\*O. Syshchuk, *et al*, ESSDERC 2022, doi:10.1109/ESSDERC55479.2022.9947150, 2022

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





## IMEC (founded in 1984)



- World-leading R&D center in **nano-electronics**
- **International top talent** in a unique **2B€ leading-edge fab infrastructure**
- Delivering **industry relevant technology** solutions serving ICT, Healthcare and Energy markets serving 600+ companies
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- **5000+** people
- **HQ** in Leuven, Belgium
- **8** sites worldwide



THANK YOU



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