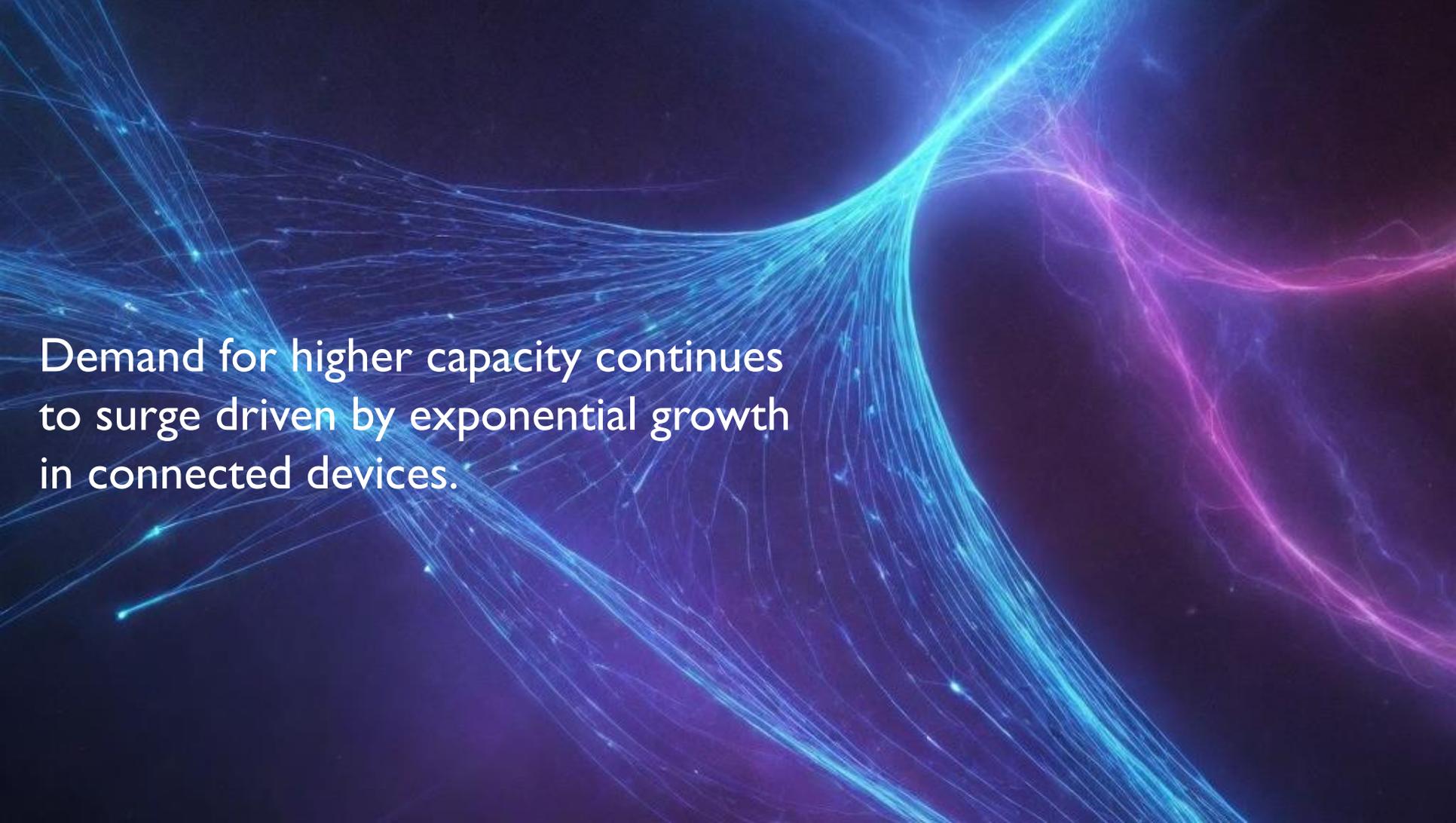




Exploring the impact of the substrate in RF GaN-on-Si Technologies

Nadine Collaert

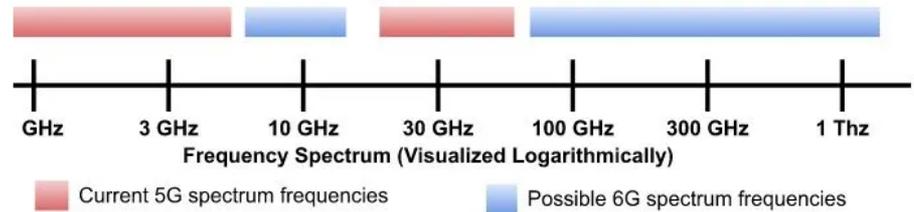
The background features a complex network of glowing lines in shades of blue and purple, set against a dark, almost black background. The lines are thin and numerous, creating a sense of depth and movement. Some lines are thicker and more prominent, while others are faint and wispy. The overall effect is that of a digital or data network, with lines converging and diverging in various directions. The colors transition from a bright cyan/blue on the left to a deep purple and magenta on the right.

Demand for higher capacity continues to surge driven by exponential growth in connected devices.

# Growing challenges...

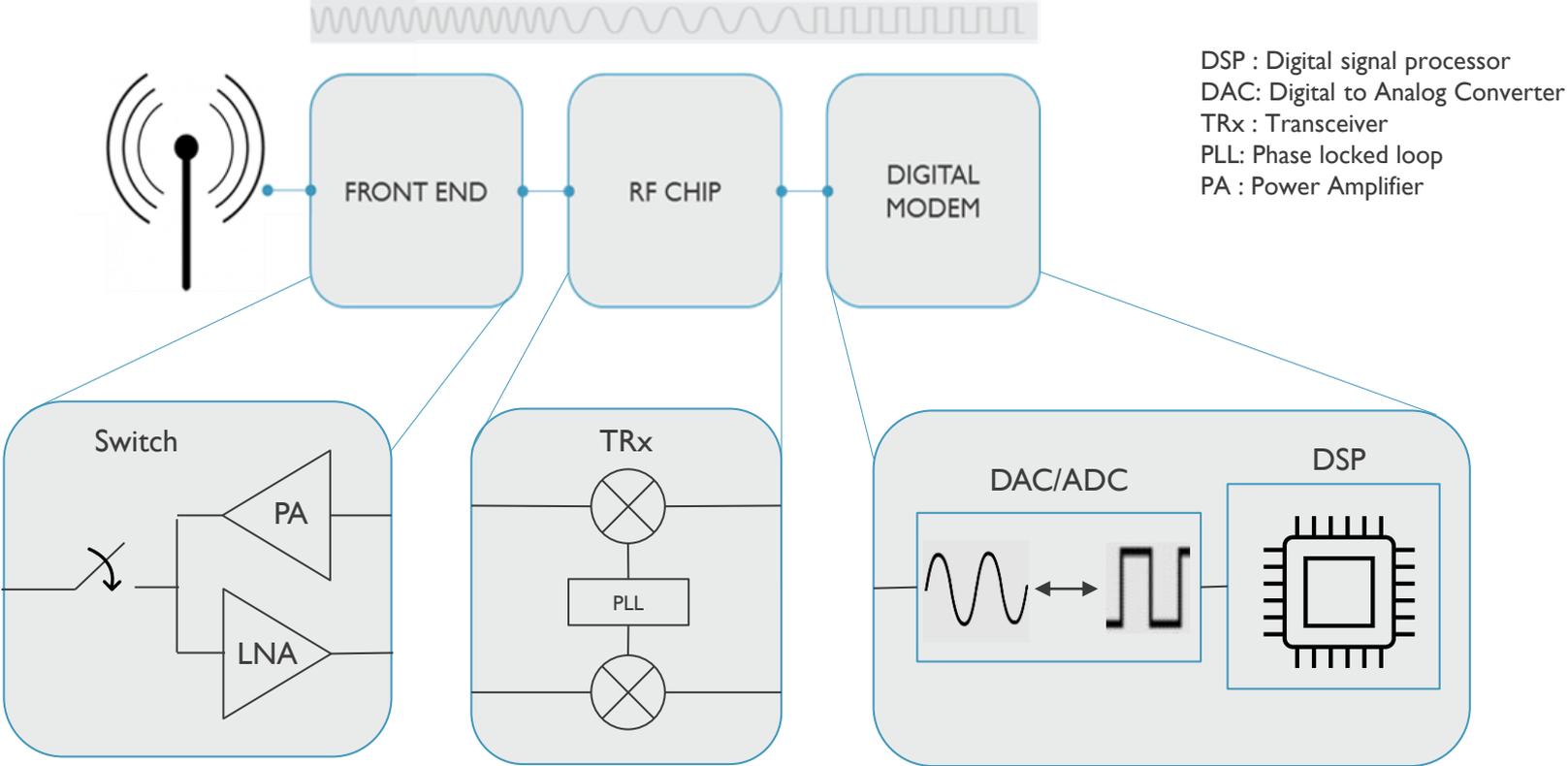
- Spectrum congestion
- Bandwidth limitations
- Coverage at higher frequencies
- Energy efficiency
- Security and privacy
- Interoperability
- Scalability

## Frequency Spectrum Range for 5G and Future 6G Applications

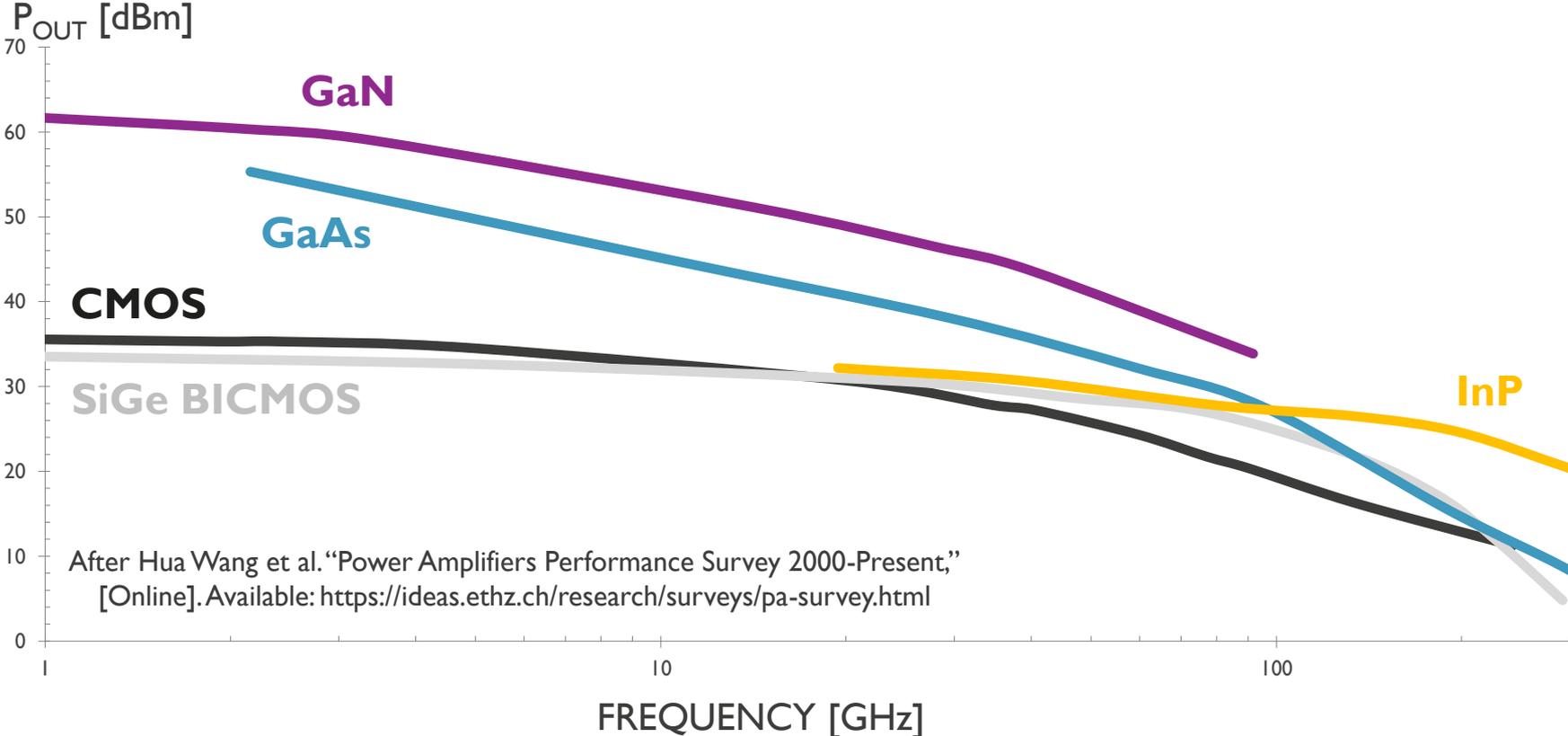


<https://resources.pcb.cadence.com/blog/2023-terahertz-communication-for-a-6g-future>

# Challenges from baseband to antenna to tackle higher frequencies

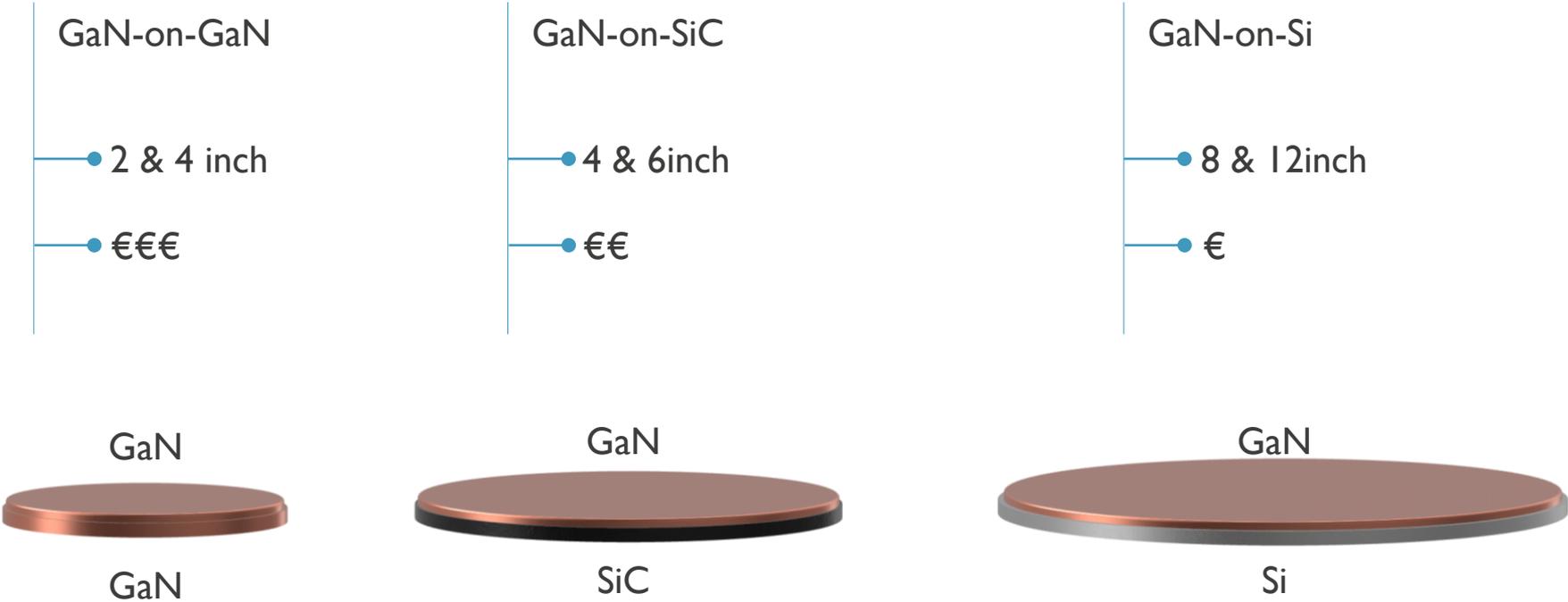


# GaN is the champion in delivering power

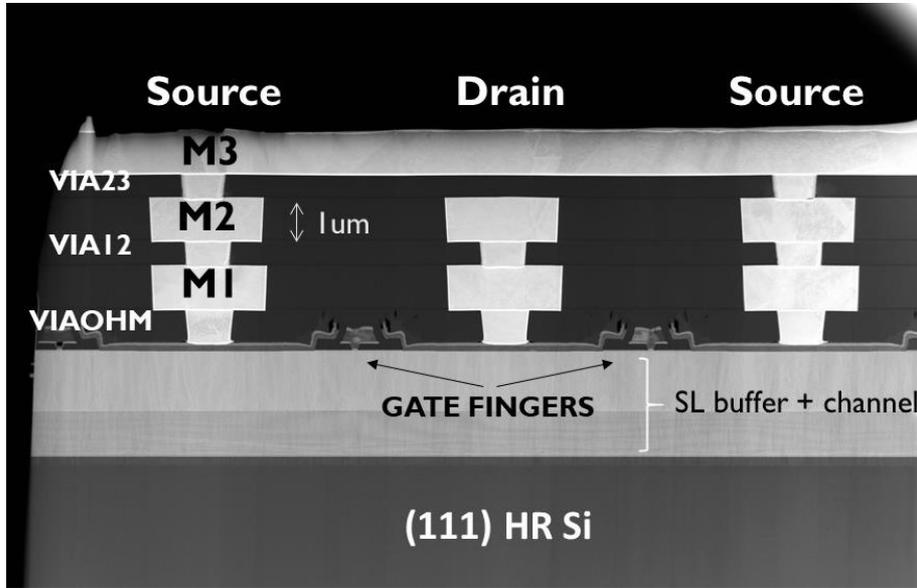


After Hua Wang et al. "Power Amplifiers Performance Survey 2000-Present,"  
[Online]. Available: <https://ideas.ethz.ch/research/surveys/pa-survey.html>

# GaN-on-Si is the most cost-efficient and scalable flavor of GaN



# Imec's RF GaN-on-Si platform for infra & UE

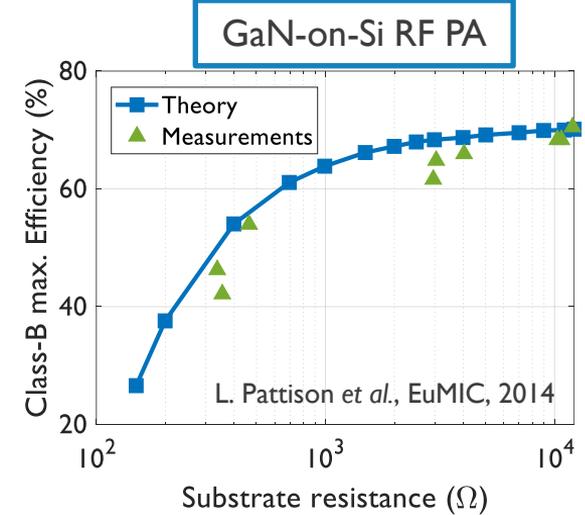
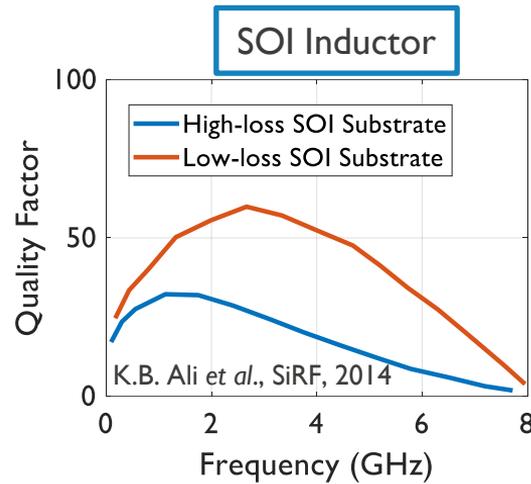
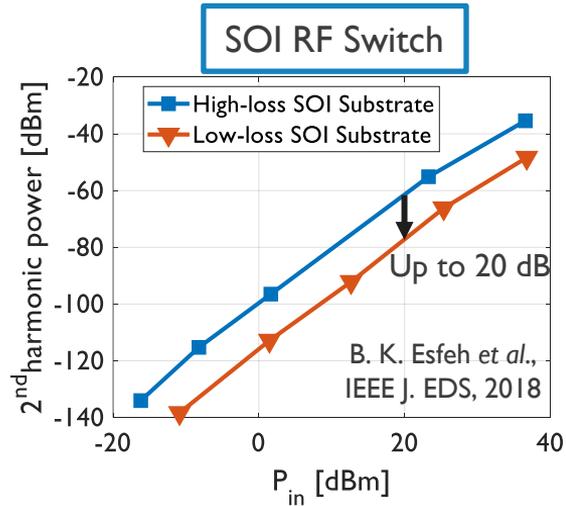


B. Parvais et al., IEDM 2020.  
R. ElKashlan et al., EUMW 2022.  
R. ElKashlan et al., IMS 2023 & 2024.

- CMOS-compatible and scalable GaN-on-Si platform
- Topics of active research:
  - Material improvement
  - Device design and scaling
  - E-mode vs. D-mode
  - Reliability
  - Thermal management
  - Impact of Si substrate

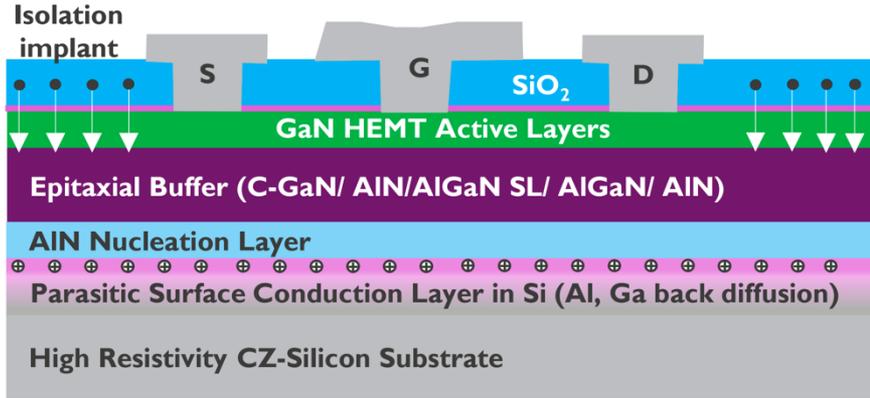
# Why are substrate losses a problem ?

The importance of substrate for RF applications



- Substrate can have a detrimental impact on:
  - Switch linearity
  - Q Factor of passives
  - PA efficiency

# Substrate RF losses in GaN-on-Si



S. Yadav et al., IEDM 2020.

S. Yadav et al., ICICDT 2021.

Diffusion of Al and Ga atoms  
at the AlN/Si interface

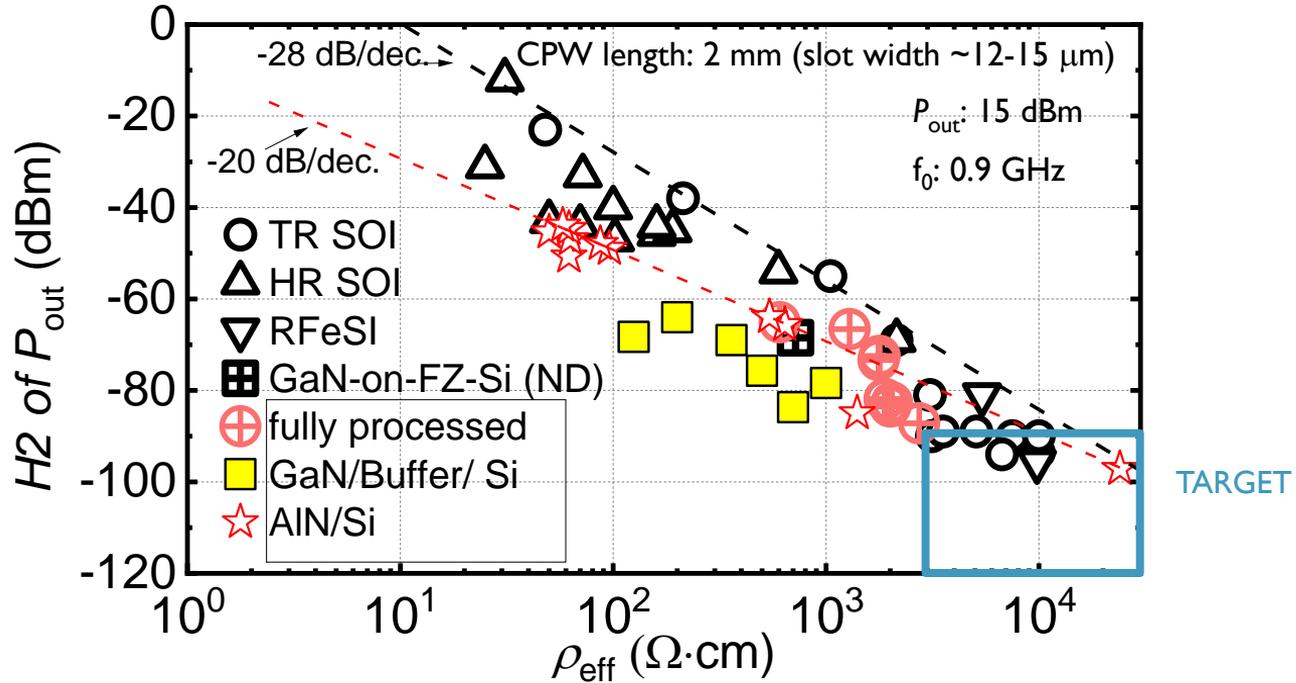


High conduction layer

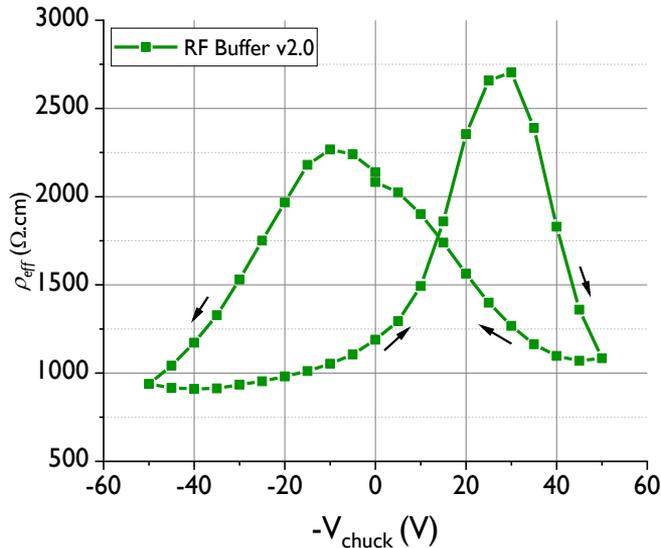


RF circuits suffer from  
a conductive substrate  
even with HR-Si

# GaN-on-Si getting closer to TR SOI target substrate performance



# Complex behavior for GaN-on-Si substrates



- Strong hysteresis observed in  $\rho_{\text{eff}}$ (V) for GaN-on-Si substrate
- Correlation between  $\rho_{\text{eff}}$ (V) and HD(V) is not straightforward for time-dependent stacks

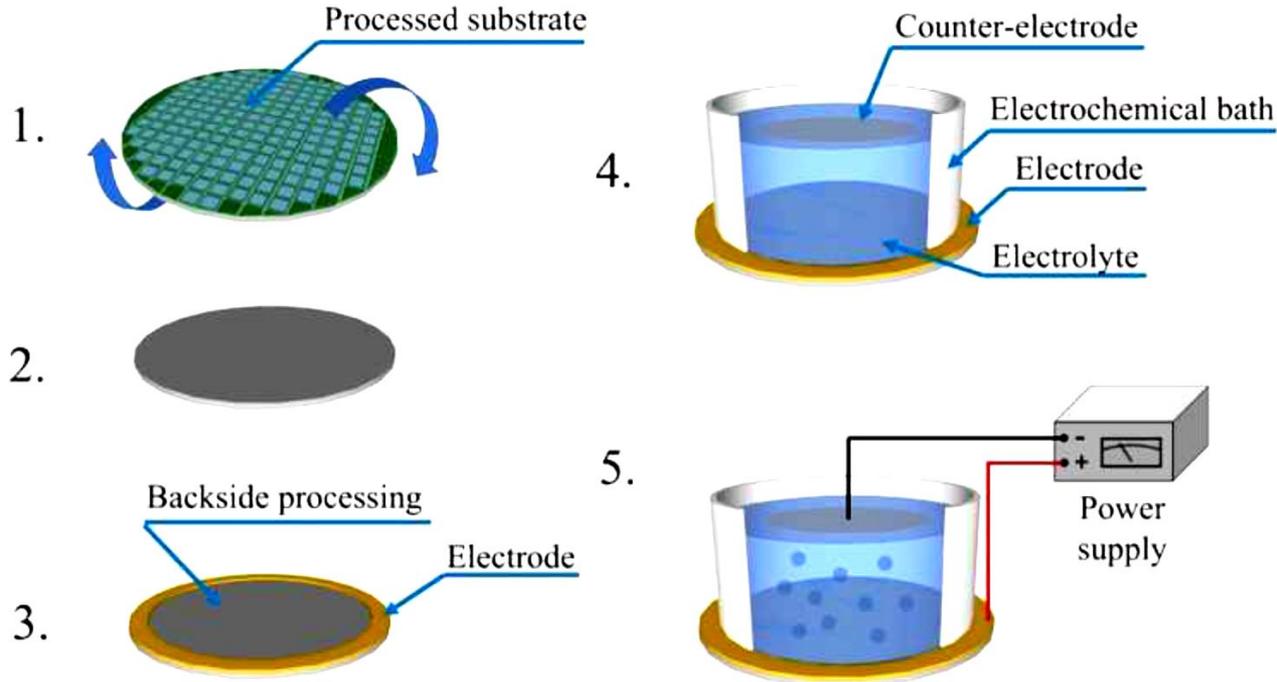
P. Cardinal et al., ESSDERC 2021.

P. Cardinal et al., IEEE Microwave and Wireless Technology Letters 2022 & 2023.

P. Cardinal et al., J-EDS 2024.

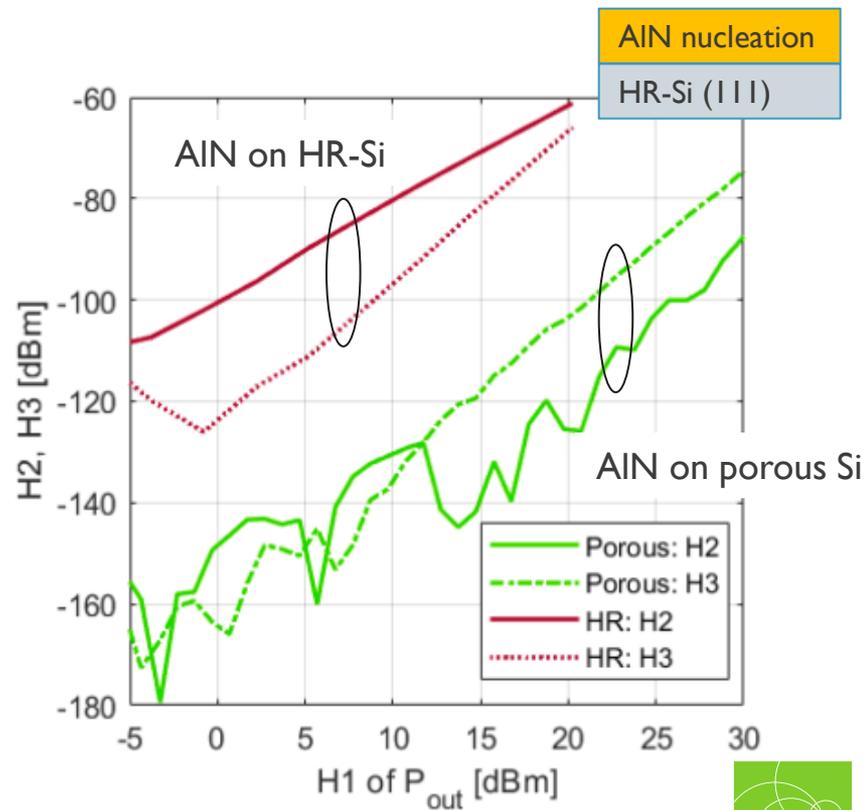
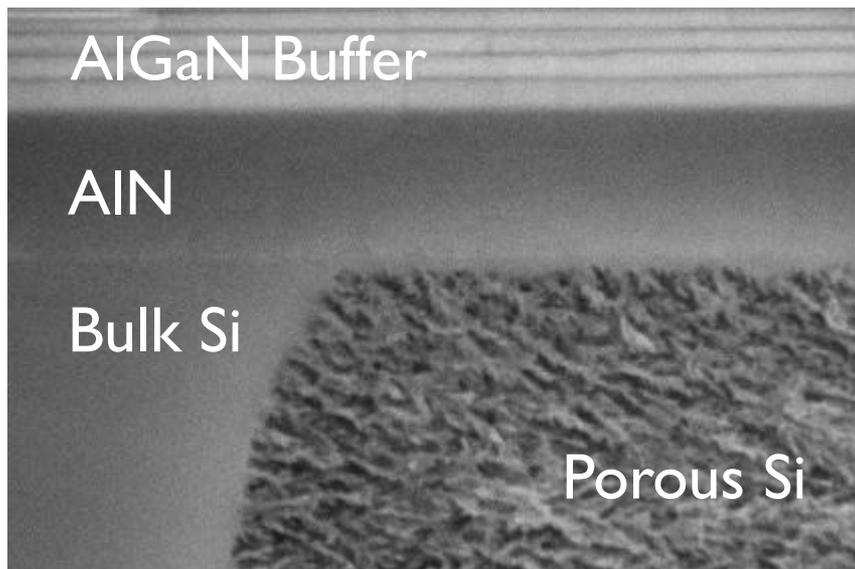
# Porosification of the silicon substrate

G. Scheen et al., EuMC 2023.



# Porous silicon method to reduce losses and improve linearity

G. Scheen et al., EuMC 2023.



## Key take-aways

- Growing interest from industry in RF GaN-on-Si technology for both infrastructure and handset applications.
- Understanding the impact of non-idealities related to defects, thermal, substrate on RF FOM is key
- Significant progress has been made in understanding and mitigating substrate-related challenges in RF GaN-on-Si technology, paving the way for enhanced device performance and integration.





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