GaN Power: the solution that is not SiC

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Abstract— **In this talk, we will present why the jury is still out as to which power electronics conversion technology will be dominant in 2035; GaN or SiC. GaN cascode technologies show: high-voltage rating up to 1200 V, high-current rating up to 170 A for a single die, short-circuit capability up to 5 µs for fail-safe operations in motor drives, and monolithic bi-directional switches for novel, more compact circuit topologies for single-stage AC/DC battery chargers, solar harvesting, and motor drives.**

I. INTRODUCTION

GaN power devices are penetrating and improving the efficiency of several consumer applications, including fast chargers and power supplies. The next step for GaN is to enter high-power applications, such as solar harvesting and electric vehicles. As GaN devices enter high-power applications, several myths have to be “busted”; one of them is that GaN is good for low power and SiC will serve the high power market. Though a convenient talking point it is far from the truth. In this talk, we will address what are presented as shortcomings of GaN devices: GaN cascode technologies that provide 1200-V rating, 650V rated large periphery GaN devices for high-current rating up to 170 A for a single chip, short-circuit capability up to 5µs for fail-safe operations. Unique devices such as monolithic bi-directional switches for novel, more compact circuit topologies such as matrix converters, cycloconverters and current-source inverters will also be discussed.

II. 1200-V GAN

Transphorm’s 1200 V GaN switches are made with HEMTs on sapphire substrates (Figure 1) [1]. These are fast-switching, low loss devices extending the high performance of GaN switches to higher voltage levels. The insulating nature of sapphire substrates extends the rated voltage of GaN HEMTs to 1200 V, while simultaneously using a thinner buffer layer compared to GaN-on-Si for similar voltages. Using a 70 mΩ GaNon-sapphire 2-chip normally-off GaN FET in TO-247 package, we obtained >99% efficiency for a 900:450V buck converter operating at 50 kHz. The device shows excellent switching FOMs with Ron·Qg = 0.9 Ω·nC, and Ron·Qrr = 11 Ω·nC. The sapphire substrate is thinned to below 200 µm to give a thermal resistance comparable to that of packaged GaN-on-Si switches. An engineered GaN-on-sapphire technology can be a very competitive platform for the 1200V power device market.

III. SHORT-CIRCUIT CAPABILITY

As GaN devices enter the motor drives, short-circuit survivability is a key requirement. In 2021, Transphorm presented a patented GaN technology to achieve a short-circuit withstanding time (SCWT) as high as 3 microseconds on a 50-mΩ device [2]. This year, we present a significant improvement, demonstrating a longer SCWT of 5 µs on a 15-mΩ device capable of high-power operations (12 kW). The device is packaged in TO-247, has a rated voltage of 650 V, and rated DC current of 145 A. It reaches a peak efficiency of 99.2% and a max output power of 12 kW. It shows a short-circuit withstand time of 5 µs at a drain-bias of 400V and it passes 1000-hour 175°C high-temperature reverse-bias stress (Figure 2).

IV. MONOLITHIC BIDIRECTIONAL SWITCHES

A bidirectional switch provides bidirectional current carrying and bidirectional voltage blocking capability. Monolithic bidirectional switches enable significant size, complexity, and cost savings compared to traditional implementations that use multiple components. In this work, we demonstrate a GaN monolithic bidirectional technology, where the lateral GaN HEMT technology combined with a common drain configuration allows us to share the high-voltage drift region resulting in a 40% reduction in the die size compared to two discrete GaN switches. The monolithic bidirectional switch demonstrated here has an on-state resistance of 60 mΩ and is assembled in a TO-247 package with a floating tab (Figure 3). The device has excellent bidirectional current conduction and voltage blocking with symmetric current-voltage and capacitance-voltage behavior. The Ron·Qg and Ron·Qrr are 80% and 30% lower than state-of-art SiC MOSFETs resulting in 60% lower switching losses.

V. SUMMARY

The supply chain stability of GaN epi on sapphire and Si substrates will enable GaN to provide performance at a lower price; the key to gaining significant market share even vs. Si.

REFERENCES

[1] G. Gupta *et al.*, ISPSD 2022.
[2] D. Bisi *et al.*, IRPS 2022
[3] G. Gupta *et al.*, WIPDA 2023

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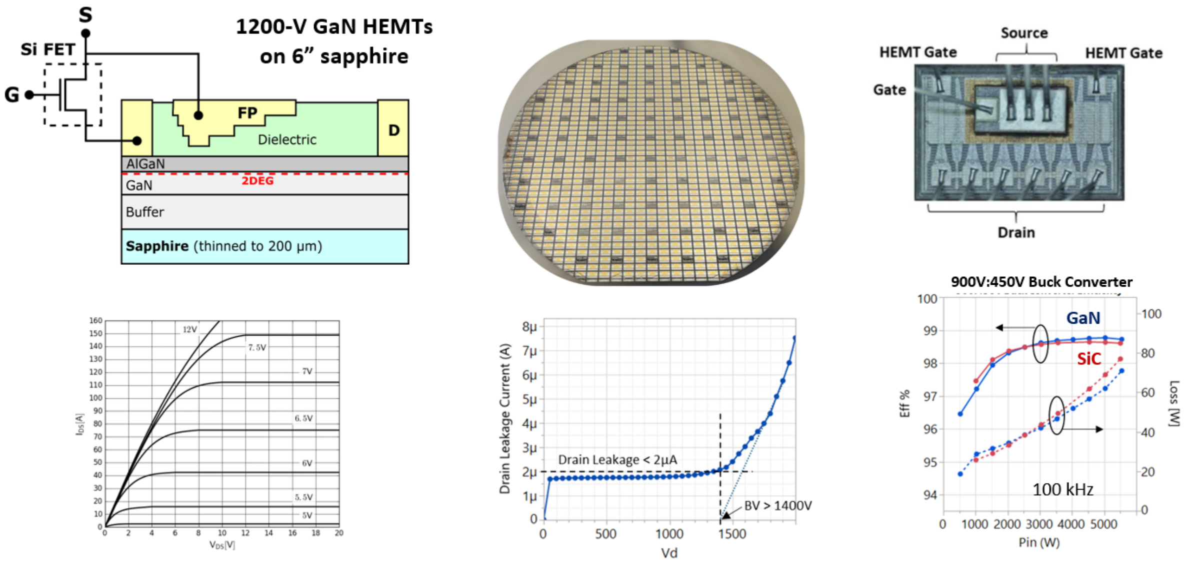

Fig. 1. 1200-V GaN HEMTs in cascode configuration on low-cost, large-diameter, insulating sapphire substrates.

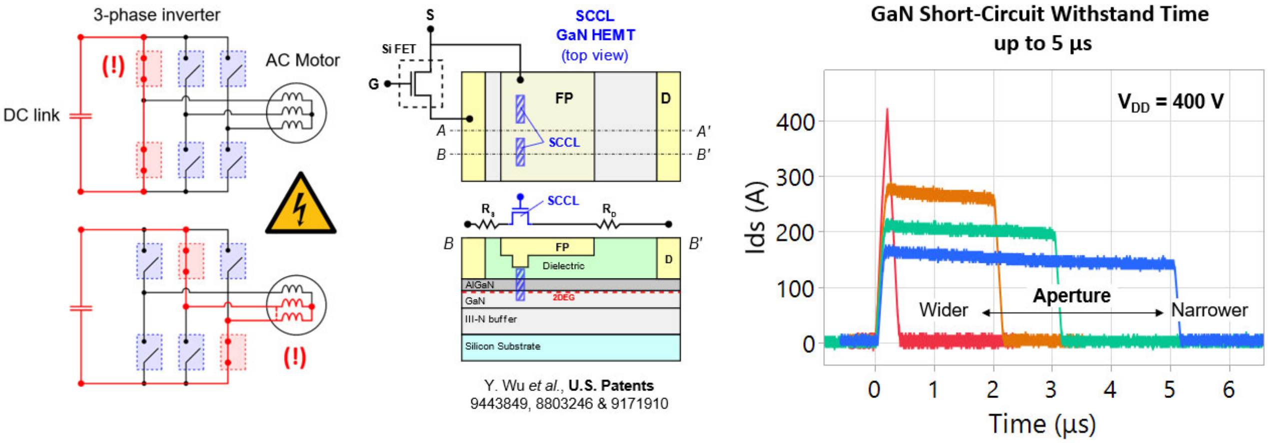

Fig. 2. Patented GaN technology to achieve a Short-Circuit Withstand Time up 5 µs for fail-safe operations in motor drive inverters.

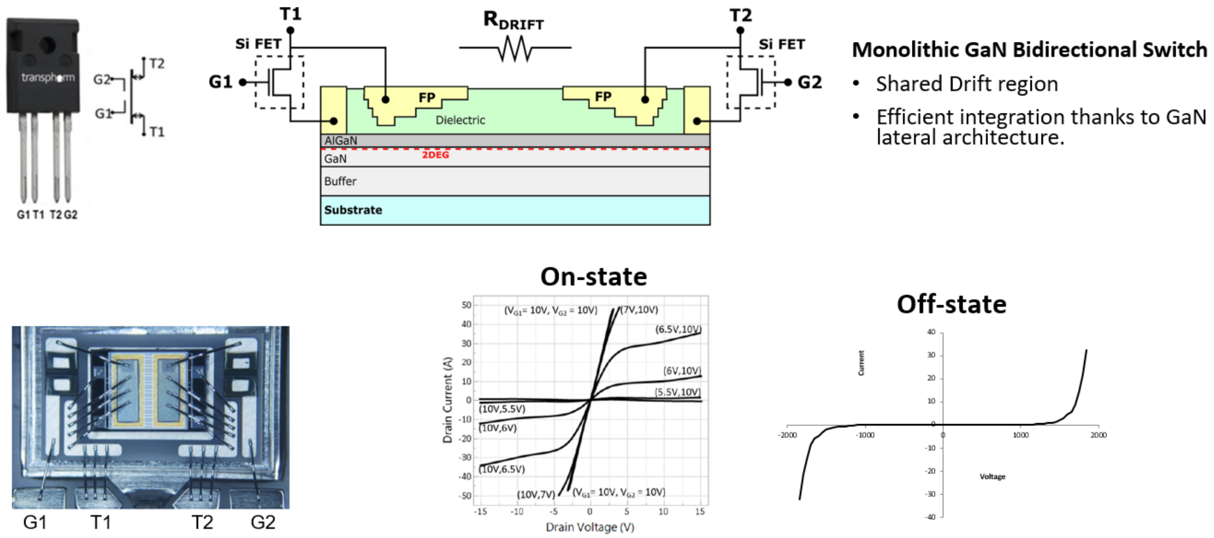

Fig. 3. Monolithic GaN bidirectional switches, with common drain, shared drift region for high figure-of-merit.