Tri-anode/slant-gate GaN Schottky barrier diode on silicon

Structure reduces leakage current and increases breakdown voltage for high-performance, competitive-cost power converters.

Jun Ma and Elison Matioli of École polytechnique fédérale de Lausanne (EPFL) in Switzerland have used a hybrid tri-anode/slanted tri-gate structure to reduce leakage current and increase breakdown voltages in gallium nitride (GaN) lateral Schottky barrier diodes (SBDs) produced on silicon substrates [Appl. Phys. Lett., vol112, p052101, 2018].

Ma and Matioli comment: "The hybrid tri-anode pins the voltage drop at the Schottky junction (V_{SCH}), despite a large applied reverse bias, fixing the reverse leakage current (I_R) of the SBD." They see the devices as having potential for power converters with high performance and competitive cost.

The researchers used templates with an aluminium gallium nitride ($Al_{0.25}Ga_{0.75}N$) barrier and 5μm GaN buffer on silicon substrate. The slanted tri-gate SBD structures were etched to a depth of 180nm with inductively coupled plasma (Figure 1). The width in the

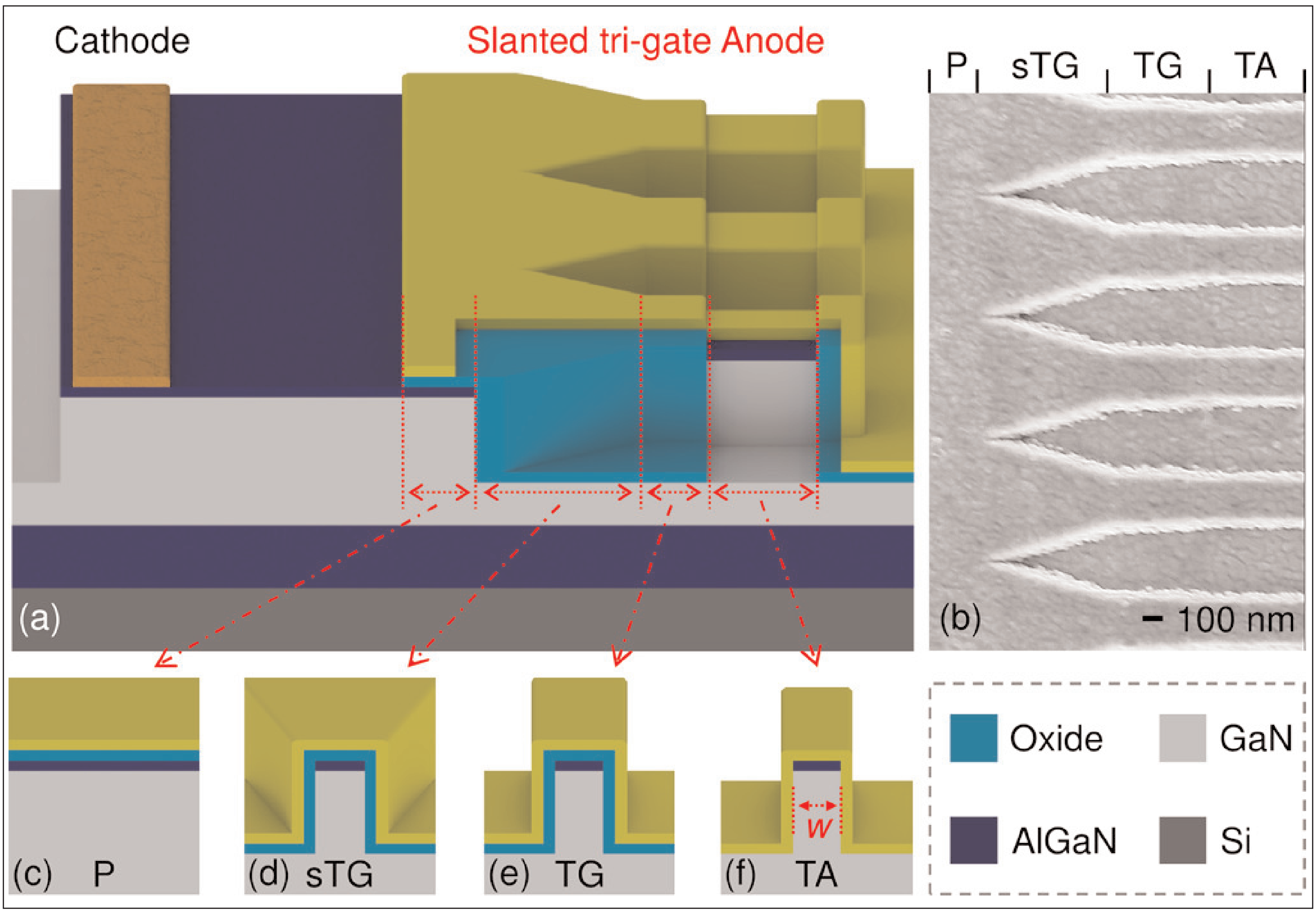

Figure 1. (a) Schematic of slanted tri-gate SBD and (b) top-view scanning electron microscopy (SEM) image of anode region. Cross-sectional schematics of (c) planar (P), (d) slanted tri-gate (sTG), (e) tri-gate (TG), and (f) tri-anode (TA) regions comprising anode.

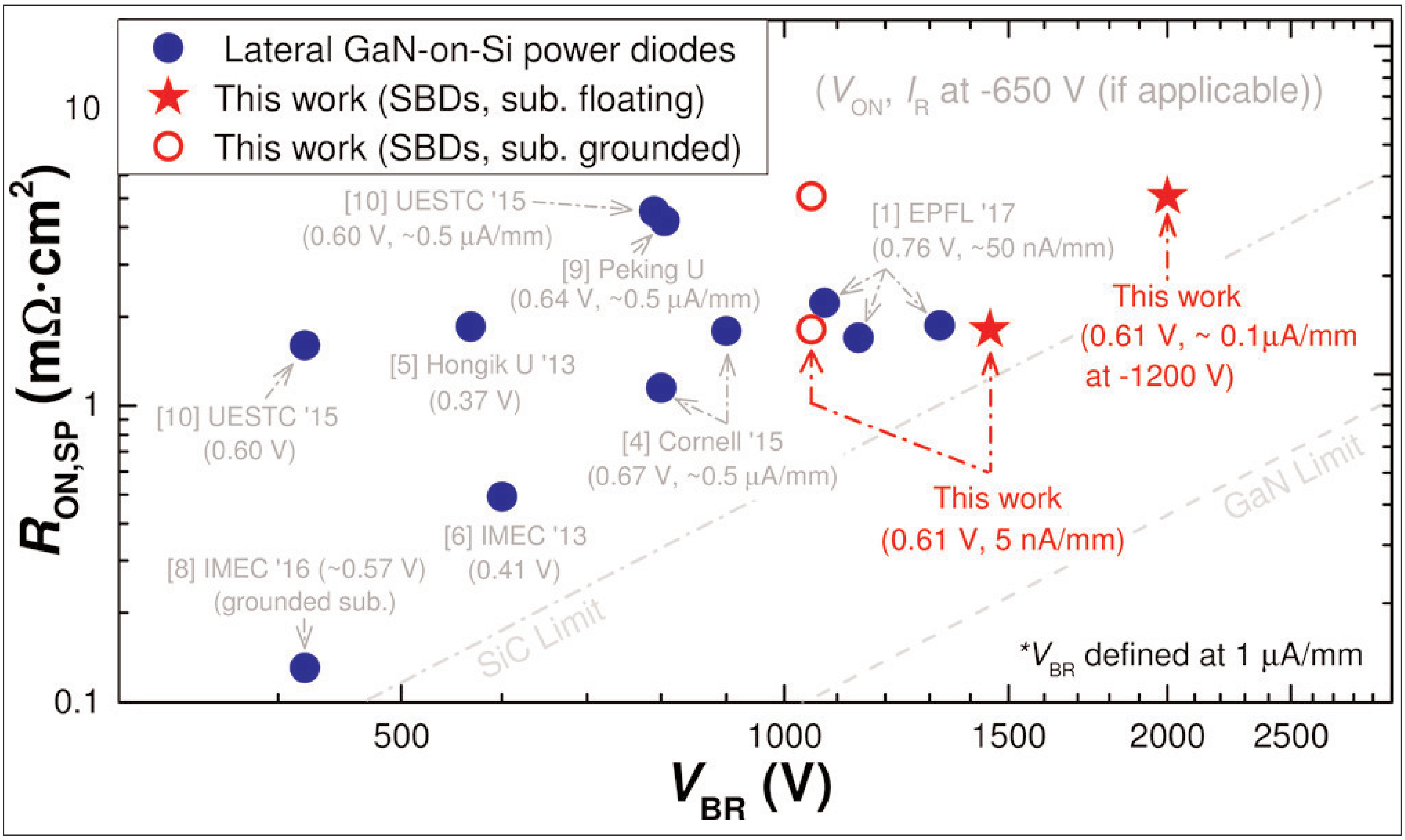

Figure 2. $R_{ON,SP}$ versus V_{BR} benchmark of slanted tri-gate SBDs against state-of-the-art lateral GaN-on-Si SBDs.

anode region was 200nm. The slanted tri-gate region increased from 200nm up to 600nm towards the cathode.

The 60μm-wide devices were isolated with mesa etching. The ohmic cathode consisted of alloyed titanium/aluminium/titanium/nickel/gold. After cathode formation, 10nm of silicon dioxide and 10nm of aluminium oxide were deposited. The oxides were removed and replaced with nickel/gold to form the 4μm-long Schottky tri-anode. The nickel/gold also formed a 1.3μm-long planar single gate, 0.7μm slanted tri-gate, and 0.5μm tri-gate leading into the anode.

The researchers modeled the devices as a tri-anode SBD connected in series with a tri-gate, a slanted tri-gate, and a planar-gate transistor. The slanted and planar gate sections also operate as field plates, designed to increase breakdown voltage.

Devices with anode-cathode distances of 15μm and 25μm demonstrated, respectively, 14Ω-mm and 22Ω-mm on-resistance at room temperature. These respective values increased to 28Ω-mm and 37Ω-mm at 150°C. The 1mA/mm on-voltage was as low as 0.61V. The ideality was 1.40 at room temperature and 1.27 at 150°C.

The performance puts the shorter device in the frame for 600V/650V applications, while the longer devices could handle 1200V ratings with ~100% safety margin

Under reverse bias, the devices pinched-off around −1.7V. Increasing the magnitude of the reverse bias to -650V did not change the ~5.5nA/mm leakage (I_R) significantly. At −830V, the leakage was still only 10nA/mm. Ma and Matioli add: "Extremely low I_R of 51±5.9nA/mm was observed at −1000V, which is significantly smaller than in any other reports of GaN-on-Si SBDs."

The leakage was increased by around 50nA/mm at 150°C. For −200V, the reverse current of 57±13nA/mm is claimed to be the smallest value among reported lateral GaN SBDs at such a high temperature.

The 1μA/mm breakdown points came at −1450V and −2000V, respectively, for the 15μm and 25μm anode–cathode devices with floating substrate bias. The corresponding hard breakdown voltages (V_{BR}) were −1500V and −2500V. The researchers estimate the critical field at 1MV/cm. Grounding the substrate gave a unified 1μA/mm breakdown of −1060V with hard failure at −1200V.

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The researchers compared their breakdown voltage and specific on-resistance ($R_{ON,SP}$) results with other reports (Figure 2). The team also gives a high power figure of merit of 1.16GW/cm^2 ($V_{BR2}/R_{ON,SP}$). ■

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