TCAD Simulation Template Setup of Novel Vertical Gallium Nitride Power Device

Group：B603 **Member： Po-Hsien Liu** **Advisor：Associate Prof. Wong, Roy King-Yuen**

Abstract

Gallium nitride (GaN) , with its wide bandgap and high critical electric field, is a key material for next-generation high-voltage, high-efficiency power devices. Vertical GaN SBDs, however, suffer from electric-field crowding at the Schottky edge when the electrode width is finite, leading to breakdown voltages far below the drift-layer limit.

This work adopts the p-GaN junction termination extension (JTE) concept in paper [1] and uses Sentaurus TCAD to compare the electric field and breakdown behavior of an ideal SBD (i-SBD), a conventional SBD (c-SBD), and a JTE-based SBD (j-SBD)

Research Methodology

1.Device modeling

Built 2D vertical GaN SBDs (i-SBD, c-SBD, j-SBD) in TCAD with a common drift/substrate stack; c-SBD and j-SBD differ only in Schottky width and the presence of p-GaN JTE.

2.Bias and boundary conditions

Simulated forward and reverse I–V under a unified bias scheme; used an external-resistor method with J = 0.1 mA/cm² as the breakdown criterion.

3.Simulation flow

The simulation flow first sweeps drift-layer doping in i-SBD and c-SBD to establish baseline drift concentration, then introduces a p-GaN JTE and sweeps its n_j, t_j, l_j (Table 1), and finally extracts V_{BR}, field/impact-ionization profiles, $R_{on,sp}$, and BFOM.

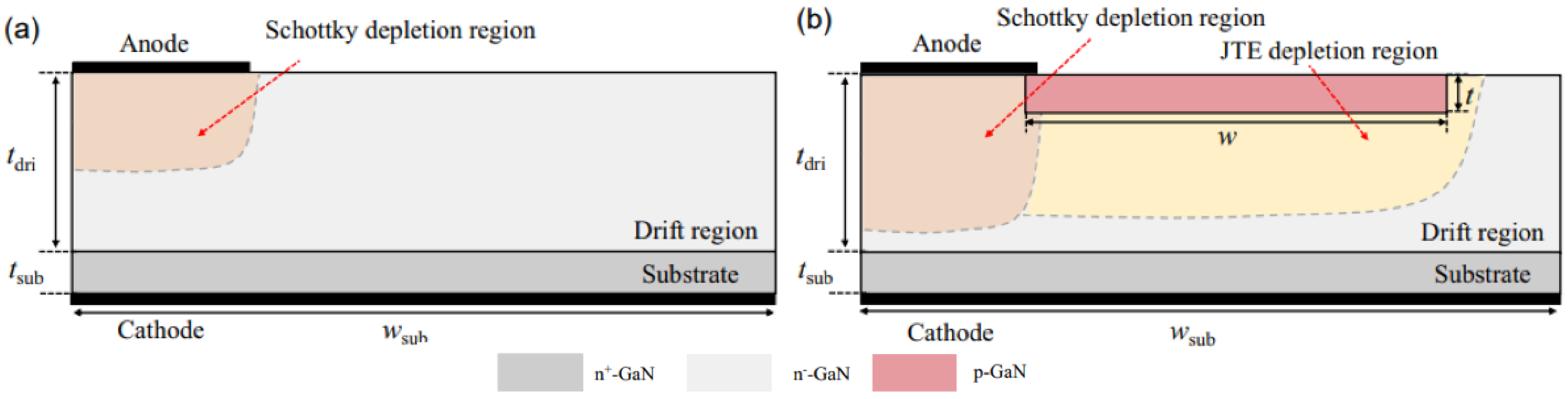

Fig 1. Schematic cross section of
(a) conventional GaN SBD (C-SBD) and (b) GaN SBD with p-GaN JTE (J-SBD) , reproduced from [1].

Parameter	Values
Sub N_d (cm^{-3})	10^{18}
Drift N_d (cm^{-3})	10^{15}, 5×10^{15}, 10^{16}, 5×10^{16}
JTE doping n_j (cm^{-3})	10^{16}, 5×10^{16}, 10^{17}
JTE thickness t_j (μm)	0.3, 0.5, 0.8
JTE length l_j (μm)	20, 30, 40
T_{dri} (μm)	11
T_{sub} (μm)	2
W_{sub} (μm)	60
W_{cont} (μm)	10

Table 1. Key drift, JTE, and geometrical parameters used in the TCAD simulations.

Simulation Results

(1) Edge-induced breakdown in c-SBD: With Drift $N_d = 10^{15}$, i-SBD reaches ~2.7 kV, whereas c-SBD breaks down at only ~100 V (~3–4% of the ideal value). Electric-field distribution shows a sharp peak at the Schottky edge.

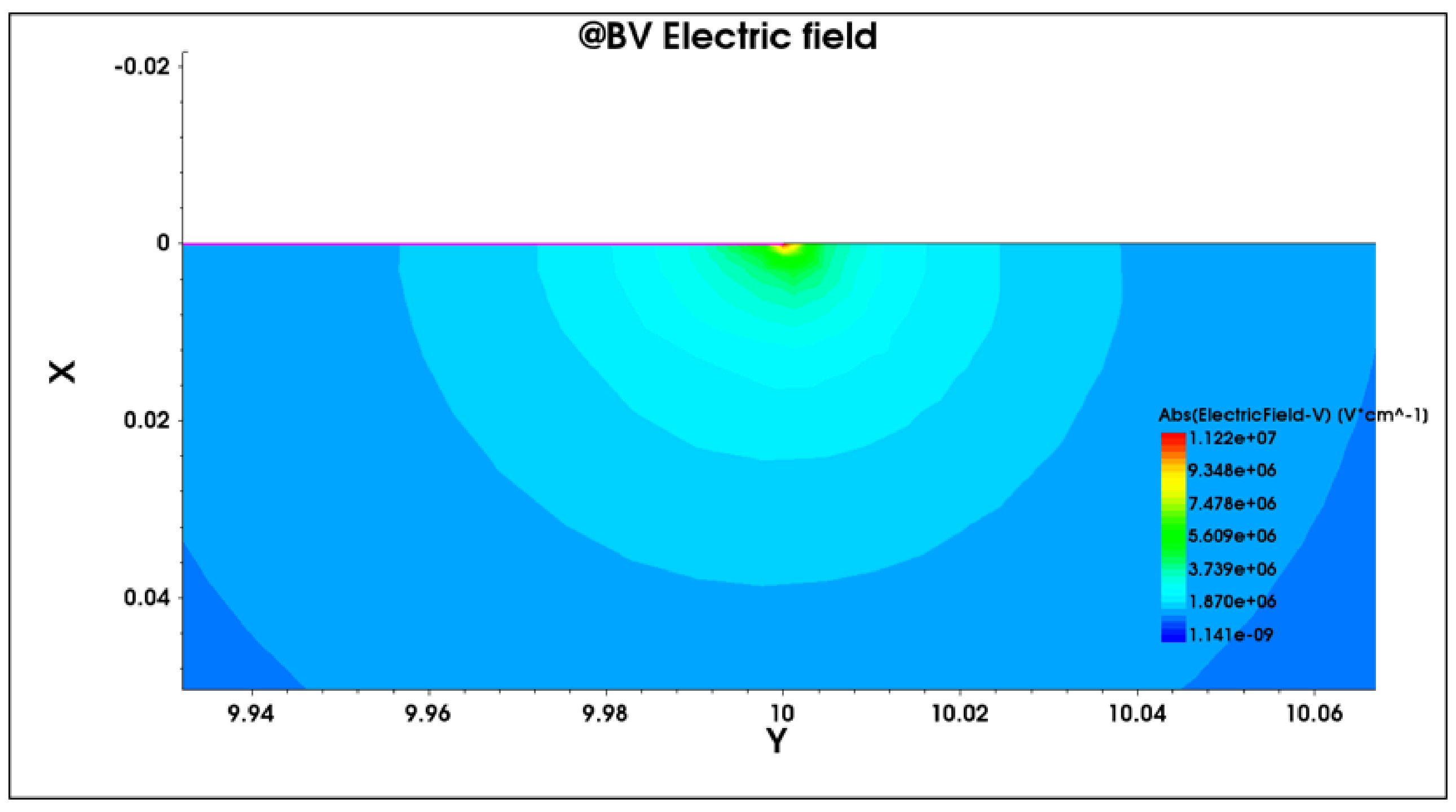

Figure 2. c-SBD electric field @BV = 103.7 V

(2) Field redistribution by j-SBD: An optimized p-GaN JTE ($n_j \approx 1\times10^{17}$ cm^{-3}, $t_j \approx 0.8$ μm, $l_j \approx 40$ μm) raises BV to ~1.7 kV under the same drift concentration. The peak field shifts from the metal edge into the JTE/drift region with flatter equipotential lines.

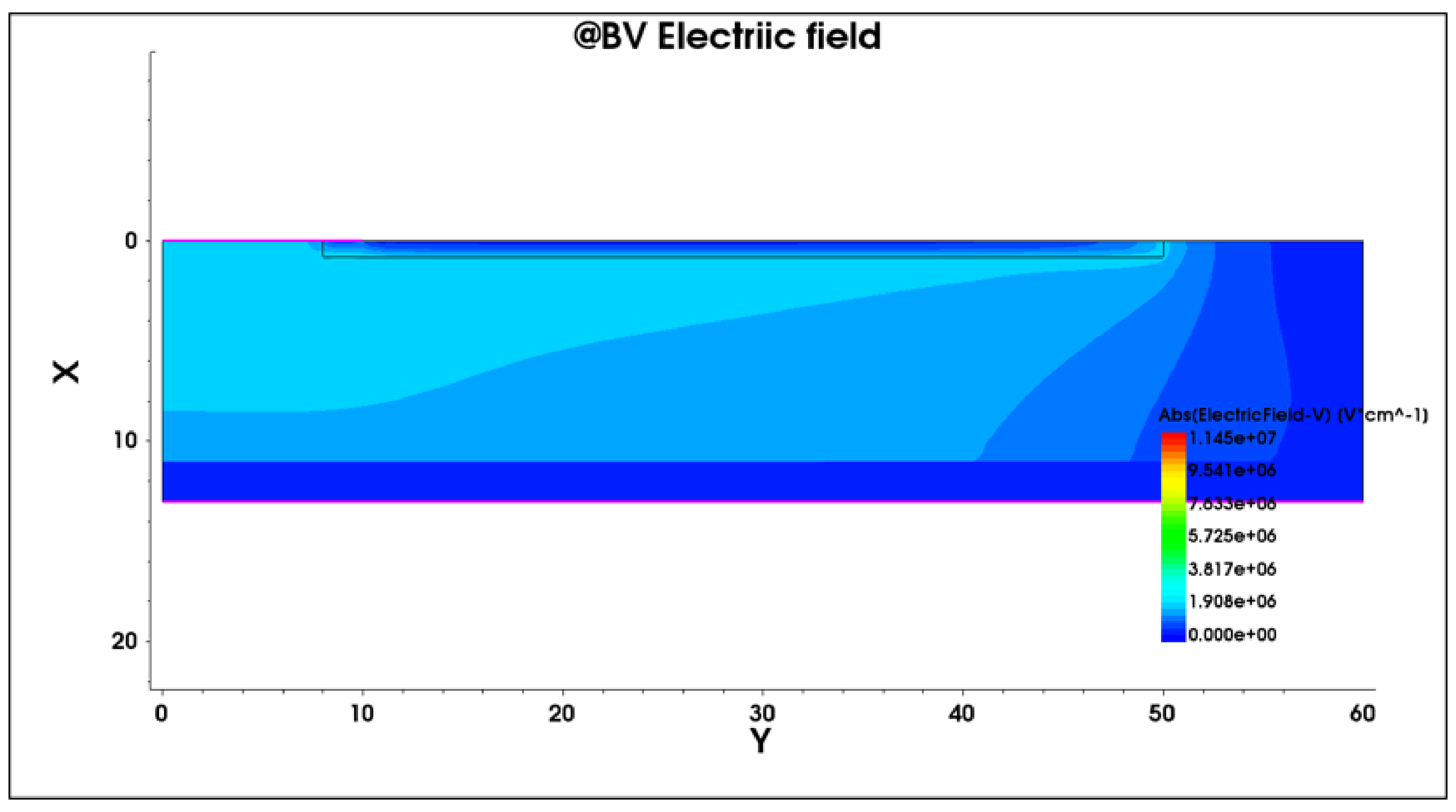

Figure 3. j-SBD electric field @BV = 1748 V

(3) I–V characteristics comparison

Reverse bias: at J = 0.1 mA/cm², $V_{BR} \approx 10^2$ V (c-SBD), $\approx 1.7\times10^3$ V (j-SBD), and $\approx 2.7\times10^3$ V (i-SBD).

Forward bias: all devices turn on at ~0.9 V; j-SBD has only slightly higher on-resistance, so JTE mainly enhances blocking with minor impact on conduction.

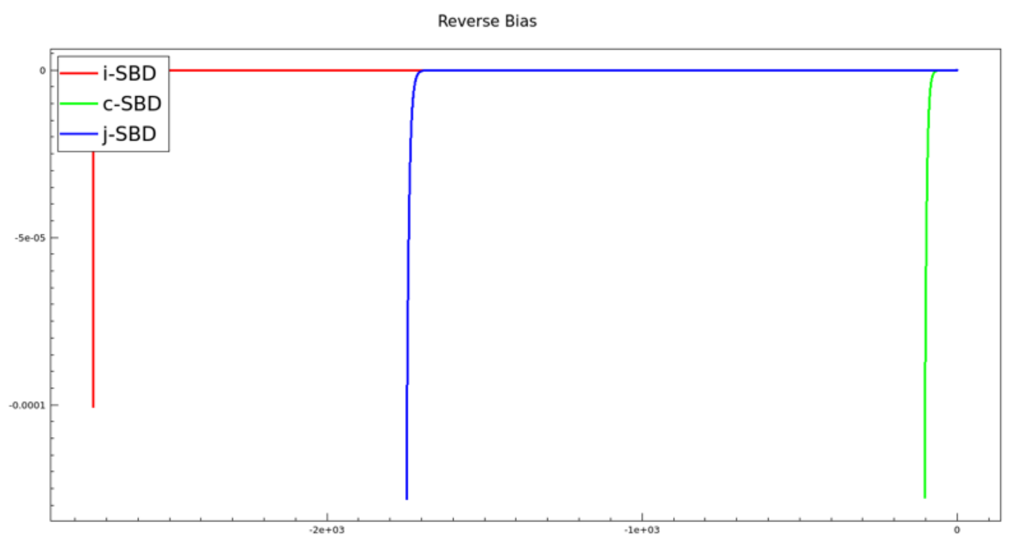

Figure 4.(a) Reverse I-V

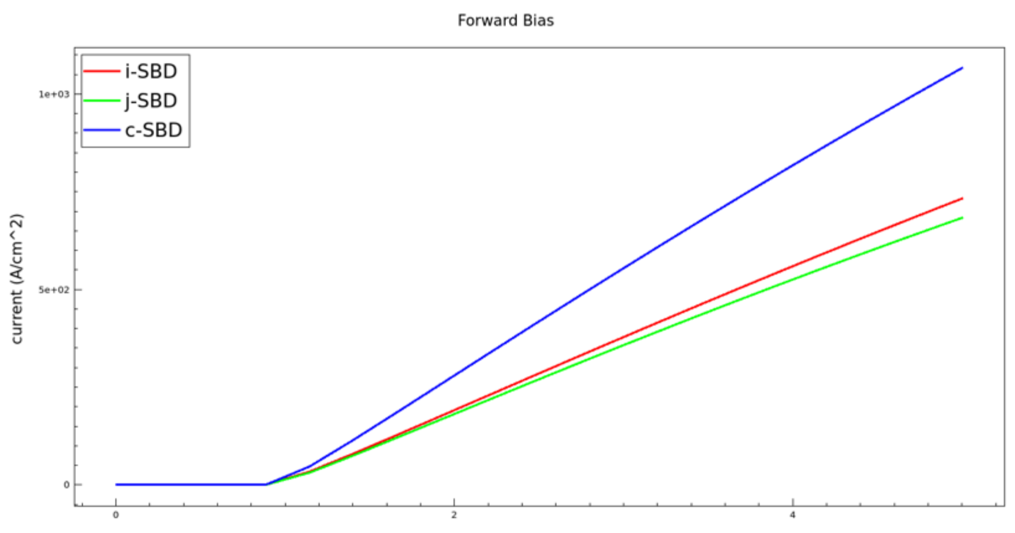

Figure 4.(b) Forward I-V

(4) BFOM comparsion

BFOM combines V_{BR} and $R_{on,\,sp}$ into a single metric to evaluate the overall power performance of a device, where a higher BFOM indicates better high-voltage, low-loss capability.

$$BFOM = \frac{V_{BR}^2}{R_{on,sp}} \propto \varepsilon\mu E_c^3$$

	i-SBD	c-SBD	j-SBD
V_{BR} (V)	2741	103.7	1748
R_{on} (mΩ*cm²)	5.677	3.656	5.347
BFOM (W/cm²)	1.325G	2.941M	0.571G

Table2. comparsion of V_{BR} , R_{on}, and BFOM

Reference：[1] H. Chen, S. Chen, H. Wang, and C. Liu, “Design Strategy of Vertical GaN Power Schottky Barrier Diodes with p-GaN Junction Termination Extension and Experimental Demonstration of Selective p-Doping by Implantation,” physica status solidi (a), 2024