Optimized Device Geometry of Normally-On Field-Plate AlGaN/GaN High Electron Mobility Transistors for High Breakdown Performance Using TCAD Simulation

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Abstract: This study presents the optimization of the lateral device geometry and thickness of the channel and barrier layers of AlGaN/GaN high electron mobility transistors (HEMTs) for the enhancement of breakdown voltage \( V_{BR} \) characteristics using a TCAD simulation. The effect of device geometry on the device performance was explored by varying the device design parameters, such as the field plate length \( L_{FP} \), gate-to-drain length \( L_{GD} \), gate-to-source length \( L_{GS} \), gate length \( L_{G} \), thickness of the SiN4 passivation layer \( T_{ox} \), thickness of the GaN channel \( T_{CH} \), and AlGaN barrier \( T_{BARRIER} \). The \( V_{BR} \) was estimated from the off-state drain current versus the drain voltage \( I_{DS} - V_{DS} \) curve, and it exhibited a strong dependence on the length and thickness of the parameters. The optimum values of \( V_{BR} \) for all the device’s geometrical parameters were evaluated, based on which, an optimized device geometry of the field-plated AlGaN/GaN HEMT structure was proposed. The optimized AlGaN/GaN HEMT structure exhibited \( V_{BR} = 970 \text{ V} \) at \( I_{GS} = 0.14 \text{ A/mm} \), which was considerably higher than the results obtained in previous studies. The results obtained in this study could provide vital information for the selection of the device geometry for the implementation of HEMT structures.

Keywords: AlGaN/GaN; HEMT; device parameters; breakdown voltage; high power; TCAD simulation

1. Introduction

AlGaN/GaN high-electron mobility transistors (HEMTs) have attracted extensive attention for high-frequency and high-voltage applications owing to their excellent properties, such as the high electron mobility of their two-dimensional electron gas (2-DEG) channels, their wide energy band-gap, and their high breakdown field [1,2]. It is well known that the breakdown voltage \( V_{BR} \) of power devices is one of the most important parameters for providing reliable performance for high-power applications; however, the reported values are considerably below the theoretical limit [3–5]. Hence, it is necessary to improve the \( V_{BR} \), especially without increasing the device’s size. Trew et al. reported a model that described the dependence of the \( V_{BR} \) on the avalanche process associated with the maximum electric field generated at the gate edge toward the drain side, resulting in a drain-to-gate breakdown [6,7].

The high breakdown field of GaN allows high voltages to be sustained between the drain and the gate. However, because of the much higher critical electric field of AlGaN, an early breakdown occurs near the heterointerface [8]. Various edge termination techniques, such as floating gates, field modulating plates, source-extended field plates, and multiple field plates, have been proposed to achieve a high \( V_{BR} \) and improve the device performance in AlGaN/GaN HEMTs [9–11]. To enhance the device’s performance...
for high-voltage power devices and microwave applications, GaN-based HEMTs were
developed using field-plate technology, through which tremendous improvements in the
$V_{BR}$ and power densities were demonstrated [1,12–16]. The field plate is an extension
of the gate deposited onto the passivation layer toward the drain side to minimize the electric
field at the AlGaN surface. This leads to a reduction in the DC-to-RF dispersion, resulting
in an increase in the $V_{BR}$ [17]. Berzoy et al. [18] demonstrated an improvement in the $V_{BR}$
in an AlGaN/GaN HEMT structure through the inclusion of various field plates on their
structures. They reported an optimum $V_{BR}$ of 880 V at a gate current of 40 A/mm for the
best field plate case.

In addition to the field plate dimension, the device’s geometrical parameters, such as
the gate length ($L_G$), gate width ($W$), source-drain distance ($L_{SD}$), source-gate separation
($L_{GS}$), gate-drain separation ($L_{GD}$), thicknesses of the Si$_3$N$_4$ passivation layer ($T_{ox}$), GaN
channel ($T_{ch}$), and AlGaN barrier ($T_{barrier}$) can significantly affect the device’s characteristics.
These parameters are correlated with and affected by each other. In other words, all
the geometrical parameters should be tuned to achieve high performance GaN-based HEMTs
with field plates. Nevertheless, reports on the effect of the device’s geometry on device
performance are limited. For instance, as summarized in Table 1, previous reports mainly
investigated the effects of a few device geometrical parameters, such as $L_{GD}$, $L_G$, and field
plate length ($L_{FP}$), on the operational characteristics of HEMTs, mainly in terms of $V_{BR}$.
Unlike previous simulation studies, which focused primarily on the structural optimization
of HEMTs by changing the limited number of geometrical parameters, the present work
performed an extensive and systematic investigation of the impact of all the possible device
design parameters, such as $L_G$, $W$, $L_{SD}$, $L_{GS}$, $L_{GD}$, $T_{ox}$, $T_{ch}$, and $T_{barrier}$ on the DC output and
$V_{BR}$ characteristics of the field-plated AlGaN/GaN HEMTs, using technology computer
aided design (TCAD) simulations. In the present study, the simulation was performed by
varying one of the geometrical parameters of the field-plated AlGaN/GaN HEMT struc-
ture, while keeping the other geometrical parameters constant. Based on the simulation
results, we propose an AlGaN/GaN HEMT structure with optimized device geometry to
achieve the best possible device performance in terms of $V_{BR}$. In addition, a simulation
of the output characteristics, transfer curve, and transconductance was performed. The
optimized AlGaN/GaN HEMT structure exhibited a $V_{BR}$ of 970 V at $I_{GS} = 0.14$ A/mm.
The recorded values of the on-resistance and the power device figure of merit (FOM),
defined by $V_{BR}^2/R_{ON}$ [19], were $3.12$ $\Omega\cdot$cm and $0.3$ MV$^2$/Ω·cm, respectively. It should be
noted that the operational behavior of the devices simulated by varying the key device
geometrical parameters, i.e., $L_{GD}$, $L_G$, and $L_{FP}$, showed a similar tendency to previous
works. In other words, a thorough comparison of the simulated results demonstrated in
this work exhibited a close match with the previously reported experimental and simu-
lated results. This implies that the accuracy, along with the validation, of our simulation
approach is sufficient to provide verification of the results, although the present study
does not include any experimental verification [20]. Furthermore, the AlGaN/GaN HEMT
structure proposed can be achieved from a technological standpoint, of which optimization
with realistic means is intricate, expensive, and time consuming. The optimized device
design parameters obtained from the simulation in this study provide a potential guideline
for the development of high-performance AlGaN/GaN HEMTs.
Table 1. $V_{BR}$ comparison of the various HEMT dimensions of the device structure (S: Simulation, E: Experiment).

| Ref. Author, Year | S/E | $L_{GD}$ (µm) | $L_{G}$ (µm) | $L_{FP}$ (µm) | $V_{BR}$ (V) |
|------------------|-----|---------------|--------------|---------------|--------------|
| [16] Karmalkar. S. (2001) | S   | 4.7           | 0.4          | 2             | 630          |
| [21] Saito. W. (2003) | E   | 5             | 1.5          | 1.6           | 350          |
|                   |     | 10            | 1.5          | 5             | 600          |
| [22] Lin Zhu (2016) | S/E | 3             | 3            | -             | 120          |
|                   |     | 5             | 3            | -             | 220          |
|                   |     | 7             | 3            | -             | 320          |
| [18] A. Berzoy (2017) | S   | 6.9           | 0.7          | 1.4           | 880          |
| [23] D. Nirmal (2018) | S   | 2.7           | 0.25         | 1             | 291          |
|                   |     | 4             | 0.25         | 1             | 370          |
|                   |     | 6             | 0.25         | 1             | 420          |
| [24] L. Wang (2018) | S   | 3             | -            | -             | 620          |
|                   |     | 5             | -            | -             | 700          |
|                   |     | 10            | -            | -             | 800          |
| [25] P. Bhavana (2019) | E   | 4             | 0.7          | -             | 72           |
|                   |     | 6             | 0.7          | -             | 118          |
| [26] A.S.A. Fletcher (2019) | E   | 2.7           | 0.25         | 0.9           | 300          |
| [5] B. Liao (2019) | S   | 22            | 3            | 4             | 450          |
| Present Study     | S   | 5             | 1.5          | 1.5           | 970          |

2. Materials and Methods

The schematic cross-section of the field-plated AlGaN/GaN HEMT structure used for the simulation and the corresponding energy band profile is shown in Figure 1. It was obtained using two-dimensional (2D) TCAD device simulator software. The transistor structure consisted of a 2 µm undoped GaN buffer layer on a sapphire substrate, a 200 nm thick GaN channel, and a 15 nm thick Al$_{0.28}$Ga$_{0.72}$N barrier layer [27]. The doping concentration of the GaN channel layer and AlGaN barrier layer were assumed to be $10^{15}$ cm$^{-3}$ and $5 \times 10^{16}$ cm$^{-3}$, respectively, which is similar to those reported in Refs. [16,21,23,27].

The Al$_{0.25}$Ga$_{0.75}$N barrier layer provides an appropriate confinement of electrons towards the channel from the top. Without intentional doping, a huge number of electrons appears at the GaN channel due to piezoelectric and spontaneous polarization effects, resulting in two-dimensional electron gas (2DEG), as shown in Figure 1b. Si$_3$N$_4$ was used as the dielectric because it exhibits a high dielectric constant and good breakdown strength, and helps to avoid the cross-talk and noise interference from the atmosphere [23]. The gate field plate was deposited on the Si$_3$N$_4$ passivation layer, and the surface state at the interface between the passivation film and AlGaN was neglected. The source and drain ohmic contacts were formed on the 50 nm thick n-type GaN layer with a doping concentration of $5 \times 10^{19}$ cm$^{-3}$ grown on the GaN channel. The simulations were performed using a 2D device simulator and Atlas TCAD device software. The material parameters used in the simulation are listed in Table 2 [16,21,23,27].

The gate electrode formed for the proposed structure was assumed to be metal, with a work function of 5.23 eV. The Newton method was used to solve the built-in equations in the Atlas TCAD, such as the transport equation, and Poisson’s equation. The simulations were performed by varying the various device geometrical parameters, such as the $L_{FP}$, $L_{GD}$, $L_{GS}$, $L_{G}$, $T_{ox}$, $T_{ch}$ and $T_{barrier}$. The $V_{BR}$ was calculated from the off-state drain current versus drain voltage ($I_{DS}$–$V_{DS}$) curve with a gate bias of $V_G = -6$ V. The $V_{BR}$ was determined as the drain voltage for a drain current of 1 mA/mm. Following the simulation results, the values of the geometrical parameters were optimized. These optimized parameter values are included in the caption of Figure 1.
Figure 1. (a) Schematic cross-sectional 2D structure of the AlGaN/GaN HEMT on an insulation substrate with a single-gate field plate (device dimensions of the optimized device structure: $L_{GS} = 2 \, \mu m$, $L_{GD} = 5 \, \mu m$, $L_G = 1.5 \, \mu m$, $L_{FP} = 1.5 \, \mu m$, $Si_3N_4$ passivation layer thickness ($T_{ox} = 200 \, nm$), GaN channel layer thickness ($T_{ch} = 200 \, nm$), GaN buffer layer ($T_{buffer} = 2 \, \mu m$), AlGaN barrier layer ($T_{barrier} = 15 \, nm$), and gate width ($W_G = 200 \, \mu m$)), and (b) the corresponding energy band profile.

Table 2. Physical parameter of AlGaN/GaN used in Atlas TCAD simulation [16,21,23,27].

| TCAD Parameters                  | GaN        | AlGaN     | Unit          |
|----------------------------------|------------|-----------|---------------|
| Electron mobility ($\mu_n$)      | 900        | 600       | cm$^2$/V-s    |
| Hole mobility ($\mu_p$)          | 10         | 10        | cm$^2$/V-s    |
| Energy band gap (E_g)            | 3.40       | 3.96      | eV            |
| Conduction band density of state ($N_c$) | 1.07  | 2.07      | $10^{18}$/cm$^3$ |
| Valance band density of state ($N_v$) | 1.16  | 1.16      | $10^{19}$/cm$^3$ |
| Saturation velocity ($V_{sat}$)  | 2.00       | 1.10      | $10^7$ cm/s   |
| Relative permittivity ($\varepsilon$) | 9.50  | 9.50      | -             |
| Trap lifetime ($e$, $p$)          | 1          | 1         | $10^7$ s      |

3. Results and Discussion

In this study, a TCAD simulation was performed for an AlGaN/GaN HEMT structure, shown in Figure 1, by varying the dimensions of the lateral device geometry. It is well known that the length of the various geometries of the HEMT structure affects the device’s performance and $V_{BR}$. The field plate connected to the gate was introduced to modify the electric field at the gate edge on the drain side, which significantly suppressed the effect of the surface traps and increased the $V_{BR}$ of the HEMT devices [1]. The $V_{BR}$ is directly related to the $L_{FP}$ because the extension of the gate edge point redistributes the peak electric field in the channel layer and reduces the electron punch-through effect. A simulation of the effect of the $L_{FP}$ on the $V_{BR}$ was carried out for the proposed HEMT structure, as shown in Figure 1. The results are depicted in Figure 2 as a function of $L_{FP}$ varying in the range of 0.5–2.5 $\mu m$, with the other geometrical parameters constant. It was observed that the $V_{BR}$ increased along with the increase in $L_{FP}$ until it reached a value of 1.5 $\mu m$, at a maximum $V_{BR}$ of 956 V. This increase in $V_{BR}$ with an increase in $L_{FP}$ was associated with the formation of a depletion layer under the field plate electrode, which reduces the electric field strength at the gate on the drain side [10]. However, a further increase in the $L_{FP}$ beyond 1.5 $\mu m$ led to a reduction in the value of the $V_{BR}$, which was attributed to the increase in the electric field-driven impact ionization process at the drain side of the field plate edge [21,28]. Furthermore, a longer field plate extension increased the main electric field peak under the field plate edge, resulting in an increase in the gate capacitance and a decrease in the $V_{BR}$ [16].
It is well known that the $L_{GD}$ affects the $V_{BR}$ characteristics of HEMTs, and an increase in the $L_{GD}$ leads to an increase in the $V_{BR}$ of the device, which is associated with the higher spacing [29]. Figure 3a shows the breakdown characteristics of the AlGaN/GaN HEMTs at various values of $L_{GD}$ varying in the range of 3–15 $\mu$m. Figure 3b shows the variation in the $V_{BR}$ with respect to the $L_{GD}$. It is evident that the $V_{BR}$ increased along with the increase in the $L_{GD}$. This may have been associated with the reduction in the peak electric field at the gate edge of the drain side. However, $V_{BR}$ strongly depends on the electric field at the gate field-plate edge on the drain side. Further, it can be observed from Figure 3a that the breakdown occurred at $I_{DS} = 0.5$ A, regardless of the $L_{GD}$. Figure 3 shows the $V_{BR}$ characteristics for the field-plated AlGaN/GaN HEMT, with the device’s structure shown in Figure 1a, as a function of varying gate-drain lengths in the range of 3–15 $\mu$m at $V_{GS} = -6$ V. It is noteworthy that the drain current remained constant until a voltage of 400 V, regardless of the $L_{G}$. However, for $L_{GD} = 3$ $\mu$m, the current increased drastically for voltages greater than 400 V. For the AlGaN/GaN HEMT, the current levels were sustained until higher voltages, which increased with an increase in the $L_{GD}$. From Figure 3b, it can be observed that the $V_{BR}$ increased to 600 V, 900 V, 1150 V, and 1175 V, with an increase in the $L_{GD}$ of 3 $\mu$m, 5 $\mu$m, 10 $\mu$m, and 15 $\mu$m. The $V_{BR}$ increased proportionally with the increase in the $L_{GD}$ when the breakdown was primarily due to the high electric field at the drain side of the gate edge. As the $L_{GD}$ increased, the electric field at the gate edge reduced, with an increase in the distance between the gate and the drain. The breakdown voltage increased along with the increase in the $L_{GD}$ associated with the increased parasitic channel resistance [30].

Figure 4 displays the $V_{BR}$ curves of the AlGaN/GaN HEMT at various values of $L_{GS}$ varying from 1 $\mu$m to 5 $\mu$m. Figure 4b depicts the values of $V_{BR}$ with the variation in $L_{GS}$ at $V_{G} = -6$ V. It is notable that the impact of the $L_{GS}$ on the $I_{DS}$ was negligible. The $V_{BR}$ increased along with the increase in the $L_{GS}$ at $V_{G} = -6$ V, resulting in the extraction of higher output power. Unlike an increase in $L_{GD}$, an increase in $L_{GS}$ does not increase the width of the leakage path. This is because at high leakage, the current flows primarily through the source terminal, and not the source-side channel. Therefore, an increase in the $L_{GS}$ will lead to an increase in the resistance of the bugger layer, resulting in an increase in the $V_{BR}$. This could be associated with the increase in the space between the source and gate, enabling the distribution of the electric field over a wider area. As shown in Figure 4, the $L_{GS}$ increased as a function of $V_{BR}$. As shown in the plot of the simulation results, the $V_{BR}$ increased along with the increases in the $L_{GS}$ of 1 $\mu$m, 2 $\mu$m, 3 $\mu$m, and 5 $\mu$m at $V_{G} = -6$ V, which then increased to 885 V, 920 V, 930 V, and 980 V, respectively. The enhancement in the electric field with the spacer between the source and the gate resulted in the improvement of the $V_{BR}$ performance. The optimization of $L_{GS}$ has a significant
impact on the $V_{BR}$ of the device. This is because of the source-injection buffer leakage, in contrast to the decrease in $V_{BR}$ caused by the increase in $L_{GD}$, with the decrease in the width of the current flow.

![Figure 3](image-url-a)  
**Figure 3.** (a) $I_{DS}$–$V_{DS}$ characteristic curve at bias $V_{GS} = -6$ V, and (b) $V_{BR}$ at various values of $L_{GD}$.

![Figure 4](image-url-b)  
**Figure 4.** (a) $I_{DS}$–$V_{DS}$ characteristic curve at bias $V_{GS} = -6$ V, and (b) $V_{BR}$ at various values of $L_{GS}$.

Figure 5a shows the $V_{BR}$ characteristics of the AlGaN/GaN HEMTs as a function of $L_{G}$ varying from 0.2 µm to 2.5 µm. As the $L_{G}$ increased, the area of the gate electrode increased, while the areas of the source and drain electrodes remained the same. The leakage current decreased along with an increase in $L_{G}$. As can observed in Figure 5b, the $V_{BR}$ increased along with the increase in $L_{G}$, varying in the range of 110–960 V, with the $L_{G}$ varying in the range of 0.2–2.5 µm. Furthermore, the current levels were lowered significantly with the increase in $L_{G}$. This could be due to the fact that an increase in $L_{G}$ suppresses the punch-through and improves $V_{BR}$ [31]. In addition, a higher value of $L_{G}$ lowers the impact ionization at the gate edge on the drain side, which significantly lowers the leakage current. Additionally, a higher value of $L_{G}$ effectively suppresses the drain-induced barrier lowering [32].
Figure 5. (a) $I_{DS}$–$V_{DS}$ characteristic curve at bias $V_{GS} = -6$ V, and (b) $V_{BR}$ at various values of $L_G$.

The $V_{BR}$ behavior of the AlGaN/GaN heterostructure field-plated HEMT as a function of the thickness of the Si$_3$N$_4$ insulator passivation layer was investigated through simulation. Figure 6a shows the variation in the $V_{BR}$ of the AlGaN/GaN HEMTs as a function of the Si$_3$N$_4$ thickness in the range of 0.1–0.7 µm. It is noteworthy that the leakage current increased along with the increase in Si$_3$N$_4$ thickness. By contrast, it can be observed from Figure 6b that the $V_{BR}$ of the HEMT increased initially, exhibiting a higher value of 970 V for the Si$_3$N$_4$ layer with a thickness of 0.2 µm, followed by a drastic decrease in the $V_{BR}$ along with increasing thickness of the Si$_3$N$_4$ insulator passivation layer. Generally, in the case of an insulator layer with thickness at the lower end of a certain thickness range, the electric field is concentrated at the field plate edge. Conversely, for a layer with maximum thickness, the field concentration is at the gate edge [17]. For a layer with an optimum thickness, the field is distributed between the gate edge and the field plate edge. The observed decrease in the $V_{BR}$ with an increase in the thickness above 0.2 µm (the optimum thickness) implies that the nitride layer used was extremely thick and the field plate was far away from the semiconductor, so that the field plate did not have any effect on the electric field distribution. This demands the optimization of the thickness of the insulator passivation layer to produce a high-performance AlGaN/GaN HEMT.

Figure 6. (a) $I_{DS}$–$V_{DS}$ characteristic curve at bias $V_{GS} = -6$ V, and (b) $V_{BR}$ at various values of thickness of the Si$_3$N$_4$ under the field plate ($T_{ox}$).
Figure 7a shows the $V_{BR}$ characteristics of the AlGaN/GaN HEMT as a function of the GaN channel layer thickness ($T_{ch}$) varying between 100 nm, 200 nm, 500 nm, 1000 nm, and 2000 nm. From Figure 7a, it can be seen that the leakage current increased along with the increase in the channel layer thickness. This resulted in a decrease in the $V_{BR}$, as shown in Figure 7b. This increase in leakage current with an increase in the channel layer thickness was associated with the wider current path and higher 2DEG concentration resulting from the thicker channel region. This lowered the channel resistance, which tends to lower the $V_{BR}$. Furthermore, the decrease in $V_{BR}$ might have been associated with the increase in the drain-induced barrier lowering with an increase in the channel thickness. In addition, the deterioration of the gate control causes higher punch-through leakage [33].

![Figure 7a](image1.png)

**Figure 7.** (a) $I_{DS}$–$V_{DS}$ characteristic curve at bias $V_{GS} = -6$ V, and (b) $V_{BR}$ at various values of thickness of the GaN channel ($T_{ch}$).

Figure 8a shows the $V_{BR}$ characteristic curves of the AlGaN/GaN HEMTs as a function of the AlGaN barrier layer thickness varying in the range of 10–35 nm. It was observed that the drain current increased slightly along with the increase in the thickness of the AlGaN barrier layer. A total of $V_{BR} = 860$ V was obtained for the AlGaN/GaN HEMT (Figure 8b) with an AlGaN barrier layer thickness of 10 nm. The $V_{BR}$ increased to 935 V along with the increase in the thickness of the AlGaN barrier layer to 15 nm, and subsequently decreased along with the increase in the thickness of the AlGaN barrier layer. This implies that the critical value of the thickness of the AlGaN barrier layer is 15 nm for effective device operation. The decrease in the $V_{BR}$ below a certain critical value of the thickness of the AlGaN barrier layer could be explained as follows. For the AlGaN/GaN HEMT with low AlGaN barrier thickness, the surface donor-like trap level was below the Fermi level. At the critical barrier thickness, the surface traps reached the Fermi level and the electrons from these traps were driven into the channel by the strong polarization-induced electric field in AlGaN, creating the 2DEG and leaving behind the positive charge [34]. Until all the surface traps were empty, the Fermi level remained essentially at the donor energy and an increase in the number of electrons transferred with an increase in the barrier thickness. As the negative voltage was increased, the electrons from the gate might have leaked into the trap states in the ungated surfaces and created a “virtual gate” modulating the depletion region. This abrupt change in the gate voltage led to the RF drain current collapse phenomenon.
Figure 8. (a) $I_{DS}$–$V_{DS}$ characteristic curve at bias $V_{GS} = -6$ V, and (b) $V_{BR}$ at various values of thickness of the AlGaN barrier ($T_{\text{barrier}}$).

The simulated output and transfer characteristics of the proposed field-plated AlGaN/GaN HEMT structure shown in Figure 1, with an optimized geometry of $L_{GS} = 2 \mu$m, $L_{G} = 1.5 \mu$m, $L_{CD} = 5 \mu$m, $T_{ox} = 0.2 \mu$m, and $L_{FP} = 1.5 \mu$m, are presented in Figure 9a,b, respectively. The $I_{DS}$–$V_{DS}$ characteristics in Figure 9a are shown as a function of $V_{GS}$ varying from $-4$ V to $+1$ V in steps of 1 V. It can be noted that the current increased distinctly along with the increase in $V_{GS}$. The drain current $I_{DS}$ was 186 mA/mm at 14 V for $V_{GS} = 0$ V. Figure 9b displays the corresponding transfer characteristic and transconductance curve at $V_{DS} = 10$ V. The device exhibited a $V_{th}$ of approximately $-4$ V, $I_{\text{max}}$ of 310 mA/mm at $V_{GS} = 2$ V, and a peak transconductance ($G_m$) of 70 mS/mm at $V_{GS} = 1$ V. The $V_{BR}$ of the optimized device structure with the gate bias was maintained at $-6$ V, and the device displayed a value of 970 V at $I_{GS} = 0.14$ A/mm, as shown in Figure 9c. The various values obtained from the optimized AlGaN/GaN HEMT structure are mentioned in Figure 1 and the results are presented in Table 2. An on-resistance ($R_{ON}$) of 3.12 $\Omega$ cm, determined by the slope of the $I_{DS}$–$V_{DS}$ curve at $V_{GS} = 0$ V, and the power device figure of merit (FOM) of 0.3 MV$^2$/$\Omega$ cm, are comparable with the results obtained from the simulated and experimentally fabricated devices possessing various HEMT structures reported earlier.

Figure 9. Cont.
4. Conclusions

The impact of device geometry and the thickness of the channel and barrier layer on the \( V_{BR} \) characteristics of field-plated AlGaN/GaN high-electron mobility transistors (HEMTs) was explored using Atlas TCAD numerical simulation. The effect of device geometry was investigated by varying the parameters, such as the \( L_{FP}, L_{GD}, L_{GS}, L_{G}, T_{ox}, T_{d}, \) and \( T_{barrier} \). The \( V_{BR} \) strongly depends on the length and thickness of the aforementioned parameters. Based on the optimum \( V_{BR} \) values obtained for all the geometrical parameters, an optimized device geometry of the field-plated AlGaN/GaN HEMT structure was proposed following a simulation of the output, transfer characteristics, and transconductance. A \( V_{BR} \) of 970 V was obtained at \( I_{GS} = 0.14 \) A/mm for the optimized AlGaN/GaN HEMT structure. This optimized device geometry of the proposed AlGaN/GaN HEMT structure could be useful for the implementation of HEMT-structured AlGaN/GaN heterostructures.

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