GaN Micropillar Schottky Diodes with High Breakdown Voltage Fabricated by Selective-Area Growth

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Herein, selective-area growth (SAG) of lightly n-doped GaN micropillars on masked GaN-on-sapphire templates is investigated. Using the micropillar SAG approach, the maximum GaN drift layer thickness in Schottky diodes on foreign substrates is increased. Thus, cost-efficient vertical power devices with large breakdown voltages \(V_{BD}\) based on heteroepitaxy are enabled. The influence of different hard-mask materials and SAG temperatures \(T_{SAG}\) on growth selectivity, morphology, and net doping concentration \(N_D - N_A\) is investigated. By using an AlO\(_x\) hard mask and \(T_{SAG} = 1045\, ^\circ\)C, 3.7 \(\mu\)m high GaN micropillars are grown in circular mask openings. Quasi-vertical Schottky diodes on these pillars exhibit low \(N_D - N_A = 5.2 \times 10^{16}\, \text{cm}^{-3}\), \(V_{BD} = 393\, \text{V}\), and a critical electric field \(E_C = 2.63\, \text{MV cm}^{-1}\).

1. Introduction

Vertical and quasi-vertical GaN devices have been extensively studied over the last decade and are promising candidates to enter the power electronics market. Free-standing GaN substrates would enable both a strain-free GaN epitaxy and a fully vertical device geometry, but suffer from high costs, varying quality, and limited availability. Therefore, efforts to fabricate vertical power devices on foreign substrates have been intensified during the last years. On the one hand, there are numerous publications of Schottky or p–n diodes on sapphire or silicon substrates revealing promising Baliga’s figure of merit (BFOM) values.\(^{[1–4]}\) On the other hand, the total thickness of the epitaxial stack and, as a consequence, the achievable breakdown voltage \(V_{BD}\) are limited due to the stress induced by different lattice parameters and thermal expansion coefficients (TEC).

For silicon substrates, which are most attractive from commercial point of view, the onset of plastic substrate deformation during GaN growth restricts the maximum drift layer thickness to \(\approx 6\, \mu\)m.\(^{[5]}\) To overcome this limitation and increase the maximum achievable \(V_{BD}\), selective-area growth (SAG) is a promising approach. It has been shown that during SAG of GaN micropillars, stress is effectively reduced by the formation of hexagonal facets, and thus the maximum epitaxial layer thickness can be increased.\(^{[5]}\) Further inherent advantages of the SAG approach are a shorter growth time due to an increase in growth rate\(^{[6]}\) and a simplified fabrication route for quasi-vertical diodes. Here, the exposure of a backside contact layer by deep dry-etching is no longer required.

In this article, we report on SAG of lightly n-doped GaN micropillars on (n\(^+\))-GaN/sapphire templates and on the fabrication of Schottky diodes. The influence of different mask materials and SAG temperatures \(T_{SAG}\) on growth selectivity, micropillar morphology, and net doping concentration is investigated. Afterward, the electrical characterization of GaN micropillar Schottky diodes is presented and potential benefits and limitations of the proposed SAG approach are discussed.

2. Experimental Section

Template fabrication and SAG were both performed in an AIXTRON multi-wafer Close-Coupled Showerhead metal organic vapor phase epitaxy (MOVPE) tool. Trimethylgallium (TMGa) and ammonia (NH\(_3\)) were used as precursors, and silane (SiH\(_4\)) was used for n-type doping. The Schottky diode fabrication process is shown in Figure 1. Template growth started with GaN nucleation on 2-in. single-side-polished sapphire substrates. After 2 \(\mu\)m GaN buffer growth, template fabrication was completed with 2 \(\mu\)m (n\(^+\))-GaN \(N_D \approx 5 \times 10^{18}\, \text{cm}^{-3}\), serving as a quasi-vertical backside contact layer for the Schottky diodes (Figure 1a).

To investigate the influence of the hard-mask material on SAG, three different hard masks were deposited on the (n\(^+\))-GaN templates. In addition to the common hard-mask materials SiO\(_2\) and Si\(_x\)N, AlO\(_x\) was used due to its high thermal stability.\(^{[7]}\) SiO\(_2\) and Si\(_x\)N, as well as AlO\(_x\), were deposited by plasma-enhanced chemical vapor deposition (PECVD) and atomic
layer deposition (ALD), respectively (Figure 1b). The hard-mask thickness was 100 nm for SiO$_2$ and Si$_3$N$_4$, and 50 nm for AlO$_x$.

In the next step, Si$_3$N$_4$ was patterned with fluorine-based inductively coupled plasma reactive ion etching (ICP-RIE), and buffered oxide etch (BOE) was used for SiO$_2$ and AlO$_x$ removal (Figure 1c). The mask layout exhibited circular openings with radii from 40 to 100 μm which is comparable with the work of Tanaka et al.[8] The fill-factor, which is defined as the unmasked area fraction, was ≈50%.

Subsequently, SAG of lightly n-doped (n$^+$)-GaN drift layers with a nominal net doping concentration (N$_D$–N$_A$) of 5 × 10$^{16}$ cm$^{-3}$ was performed (Figure 1d) in the same MOVPE tool used for template growth. In addition to the masked templates, also unmasked (n$^+$)-GaN templates were overgrown for in situ temperature control and as planar layer thickness reference. In the following, the growth temperature $T_{SAG}$ is defined as the pyrometrical surface temperature measured on the unmasked (n$^+$)-GaN templates as the structured hard mask obstructs the temperature determination. $T_{SAG}$ and the growth time ($t_{SAG}$) were varied as described later; reactor pressure (400 hPa) and V/III ratio (1200) were kept constant and have been optimized in the previous work for low carbon background concentration, as described by Debald et al.[9]

Table 1 shows a sample overview providing hard-mask material type, $T_{SAG}$, $t_{SAG}$, layer thicknesses on unmasked references ($h_{planar}$), and heights of SAG micropillars ($h_{pillar}$). In the following, the simultaneously grown unmasked reference samples are labeled according to their run numbers as R1–R5.

Using the SiO$_2$ hard mask, the effect of surface temperature was investigated in runs 1–3, with $T_{SAG}$ varied from 1000°C over 1025°C to 1045°C with constant $t_{SAG} = 2400$ s. Simultaneous growth using all three different mask materials was performed in run 3 at $T_{SAG} = 1045$ °C for $t_{SAG} = 2400$ s. Finally, the effect of extended growth times using an AlO$_x$ hard mask and constant $T_{SAG} = 1045$ °C was investigated in runs 4 and 5.

Subsequently, SiO$_2$ and Si$_3$N$_4$ hard masks were removed (Figure 1e). The wet-chemical removal of the AlO$_x$ hard mask was impeded due to its crystallization, which is expected to occur at ≈800°C.[10,11] Nevertheless, ohmic contacts were successfully deposited on the exposed backside contact layers and on top of the AlO$_x$ hard mask, respectively, and were alloyed for 30 s at 650°C in nitrogen ambient. Schottky contact deposition on top of the micropillars completed the device fabrication process (Figure 1f). For A2 and A3, Schottky contact deposition was not possible (to be explained later).

**Figure 2** shows a 25°-tilted false-colored scanning electron microscopy (SEM) image of a fully processed micropillar Schottky diode on sample A1 with a Schottky contact on the pillar top (yellow, $r = 33$ μm), surrounded by an ohmic contact (blue) on top of the residual AlO$_x$ hard mask (green). In the upper left and bottom right corners, some parasitic GaN deposition is visible.

The discussion of results is divided into three parts: first, the impact of $T_{SAG}$ on SAG and the suitability of PECVD-SiO$_2$ as hard-mask material for SAG of GaN micropillars are discussed using samples S1–S3. Second, the influence of different hard-mask materials on growth selectivity, micropillar morphology, and N$_D$–N$_A$ is analyzed by comparing samples S3, SN, and A1. Third, the electrical characterization of GaN micropillars...
of A1 is presented, and the issues with Schottky diode fabrication for A2 and A3 are briefly addressed.

Analysis is based on height profiles of micropillars (Bruker DektakXT), SEM images, and electrical characterization of fabricated Schottky diodes, including $I-V$, $C-V$, and electrical breakdown measurements.

3. Theoretical Background

To serve as a basis for the discussion of results, SAG characteristics are briefly explained and relevant terms and definitions are introduced. Figure 3 shows an SAG schematic illustrating the assumed surface processes and incorporation sites of the growth-limiting Ga species (red circles). After being adsorbed on the hard mask, Ga adatoms diffuse with a diffusion constant $D$ for a specific time $\tau$, which is the mean time between Ga adsorption and the following event, e.g., nucleation, incorporation, or desorption. $\tau$ and thus the surface diffusion length $\lambda = \sqrt{D\tau}$ are dominated by the fastest process.[12]

Long-range surface diffusion on a mask with suppressed nucleation and incorporation can locally increase the Ga concentration at the edges of mask openings, resulting in the formation of superelevations adjacent to masked areas.[6,8,13] Adatoms are either incorporated at the transition from hard mask to micropillar or diffuse toward the pillar center. Incorporation at the transition from mask to pillar results in a lateral overgrowth onto the hard mask and thus a broadening of the micropillar basal plane; adatom diffusion to the pillar top leads to higher superelevations. The characteristics of these adatom surface processes are influenced by growth conditions, mask material, and mask layout and will be investigated in the following.

The Ga diffusion length in the gas phase is in the range of several hundred $\mu$m to 1000 $\mu$m and exceeds the dimensions of mask openings and spacings.[6,14] Therefore, the micropillar shape is expected to be unaffected by Ga gas phase diffusion.[14]

4. Results and Discussion

4.1. SAG with SiO$_2$ Hard Mask

Figure 4 shows SEM images of micropillars grown in circular SiO$_2$ mask openings ($r = 100 \mu$m) with various $T_{\text{SAG}}$. The dotted red circles in top-view SEM images in Figure 4a–c indicate the mask openings; the crystallographic orientation (valid for all samples) is shown in Figure 4c. The inclined micropillar sidewalls appear as bright areas adjacent to the dark SiO$_2$ surface. An SEM cross-section of an S3 micropillar edge including a super-elevation is depicted in Figure 4d.

For sample S1 (Figure 4a), hexagonal facets barely start to emerge from the circular basal plane. With increasing $T_{\text{SAG}}$, these hexagonal facets become more pronounced, resulting in a hexagonal micropillar basal plane (Figure 4c). Based on their orientations parallel to GaN m-planes and their relative angle to the GaN c-plane of $60^\circ$–$65^\circ$ (Figure 4d), the sidewalls are identified to be {1-101} facets, which is in agreement with the literature.[15,16] No parasitic GaN deposition on the SiO$_2$ mask is observed.

Figure 3. SAG schematic with micropillar dimensions and spacing ($d_{\text{pillar}}$) illustrating surface processes of growth-limiting Ga species (red circles).

Figure 4. SEM images of micropillars grown in circular SiO$_2$ mask openings (dotted red circles with $r = 100 \mu$m). a–c) Top-view images of S1–S3. d) Cross-section of S3 micropillar edge.
At $T_{\text{SAG}} = 1000 \, ^\circ\text{C}$ (Figure 4a), numerous V-pits are visible. With rising $T_{\text{SAG}}$, the V-pit density decreases; at $T_{\text{SAG}} = 1045 \, ^\circ\text{C}$ (Figure 4c), only few pits are left, all located on the perimeter of the micropillars. For each sample, the V-pit density at the perimeter of the micropillar is higher than in the center. The formation of V-pits during SAG has been described in several publications\cite{16–18} and is attributed to the coalescence of GaN islands during the initial 3D growth.\cite{19,20} Hence, the V-pit density can be correlated with the nucleation density. By increasing $T_{\text{SAG}}$, the nucleation density is reduced\cite{21} resulting in fewer V-pits. At the pillar edges, as described before, surface diffusion of adatoms from the masked areas locally increases the Ga concentration. This results in a higher nucleation density and thus an increased V-pit density near the micropillar perimeters.

Figure 5 shows height profiles of the micropillars grown in circular SiO$_2$ mask openings ($r = 85 \, \mu\text{m}$) of S1–S3, measured in crystallographic (1-100) direction (see Figure 4c) after mask removal. The baseline is the level of the (n$^+$)-GaN surface. In the following, the micropillar width and height are defined as the profile width at baseline level and the height in the center of the scan, respectively. With increasing $T_{\text{SAG}}$ (S1 $\Rightarrow$ S3), pillar center heights and pillar widths decrease. For all samples, the formation of superelevations adjacent to masked areas can be observed. The height of these superelevations decreases, whereas their width increases with rising $T_{\text{SAG}}$. Here, the superelevation width is defined as the full width at half maximum using the particular pillar center height as peak baseline and is indicated for S3 in Figure 5. Due to the complex evolution of the micropillar shape with temperature, the total micropillar volume was estimated from the measured height profiles and assuming, for simplicity, a circular base tangent to the micropillar perimeter instead of the original hexagonal basal plane. This results in a systematic underestimation of the volume, but allows for a consistent comparison of different samples.

The total micropillar width is determined by the supply of Ga adatoms from the gas phase and laterally from the mask surface. The latter can lead to Ga supersaturation at the transition from mask to pillar sidewall\cite{22} driving the lateral growth. The absence of any parasitic growth on the SiO$_2$ mask implies adatom desorption to be the fastest surface process. Increasing the temperature leads to enhanced desorption, consequently Ga adatom concentration and thus Ga supersaturation will be reduced, resulting in suppressed lateral pillar growth and narrower pillars as experimentally observed here (Figure 5).

The decrease of pillar center height and volume with rising $T_{\text{SAG}}$ can be attributed to the increase in GaN etch rate.\cite{23} The calculated micropillar volume of S3 is 25% lower compared with that of S1. In contrast, the planar layer thickness and, thus, the volume of R3 are only 13% lower compared with that of R1. Presumably, this significant difference originates from an increased GaN desorption during SAG compared with planar growth. The formation of micropillar sidewalls and superelevations during SAG is accompanied by an increase of the surface-to-volume ratio promoting GaN desorption. In addition, different GaN planes are exposed exhibiting possibly different desorption rates. Choi et al. have indeed shown a faster desorption on GaN m-plane compared with that on GaN c-plane\cite{24} which would lead to an overall reduced growth rate for the pillar growth.

The different height and width of superelevations with varying $T_{\text{SAG}}$ originate from the difference in Ga adatom diffusion length on the GaN surface ($\lambda_{\text{GaN}}$). For higher $T_{\text{SAG}}$, $\lambda_{\text{GaN}}$ increases\cite{14} and facilitates the distribution of Ga adatoms from pillar edges to the pillar center, resulting in shallower and broader superelevations for S3 compared with S1. The total lateral dimension of these superelevations is in the same order of magnitude as the experimentally determined $\lambda_{\text{GaN}}$ by Rozhavskaya et al. (24 $\mu\text{m}$ at $T_{\text{SGA}} = 1040 \, ^\circ\text{C}$).\cite{14}

The net doping concentration of the regrown material was determined by C–V measurements. The planar (unmasked) reference sample R1 yielded $N_D$–$N_A$ of $\approx 5 \times 10^{16} \, \text{cm}^{-3}$ as extracted by Hg C–V profiling. $N_D$–$N_A$ values of GaN micropillar Schottky diodes of samples S1–S3 are plotted in Figure 6 versus $T_{\text{SAG}}$ and reveal significantly increased doping levels. The most likely cause for this result is the unintentional incorporation of Si and/or O in the regrown layer due to the thermal decomposition of the SiO$_2$ hard mask. This assumption is supported by the increase in $N_D$–$N_A$ from S1 to S3, indicating a temperature-driven decomposition of the SiO$_2$ hard mask.

Although the degradation of SiO$_2$ does not result in any visible damage of the mask, it might suppress nucleation and contribute to the previously discussed increase of desorption processes on the mask with rising $T_{\text{SAG}}$.

In summary, SAG of GaN micropillars using a SiO$_2$ hard mask and $T_{\text{SAG}} = 1045 \, ^\circ\text{C}$ results in a highly selective growth with nearly V-pit free pillar tops. However, the strong unintentional doping presents a challenge for the use in high breakdown voltage Schottky diodes.
4.2. Comparison of Different Hard-Mask Materials

In the second part, the influence of different hard-mask materials on growth selectivity, micropillar morphology, and \( N_D - N_A \) is discussed. Samples SN (Si\(_xN\)) and A1 (AlO\(_x\)) are compared with the previously analyzed sample S3 (SiO\(_2\)). All samples were simultaneously grown for \( T_{SAG} = 2400 \) s at \( T_{SAG} = 1045 \) °C.

Figure 7 shows top-view SEM images of S3, SN, and A1 with dotted red circles, indicating the mask openings. In comparison with S3 (Figure 7a), the V-pit density for SN (Figure 7b) and A1 (Figure 7c) is lower. The micropillar width is larger for A1 and smaller for SN compared with S3. A top-view SEM image with reduced magnification of A1 visualizes parasitic GaN deposition on the AlO\(_x\) hard mask far from mask openings (Figure 7d), which is absent for SN and S3.

Height profiles of micropillars grown in circular mask openings \( (r = 85 \) μm) of samples S3, SN, and A1 (Figure 8) show significant differences not only in pillar width but also in pillar center height and dimensions of superelevations. As samples S3, SN, and A1 were simultaneously grown, these differences must be related to the different mask materials and their influence on the growth-limiting Ga species.

In the previous section, the decrease of pillar width with increasing \( T_{SAG} \) was attributed to a reduction of Ga adatom concentration on the SiO\(_2\) surface. Accordingly, the comparison of pillar width of S3, SN, and A1 implies that the Ga adatom concentration is higher on AlO\(_x\) and lower on Si\(_xN\) compared with SiO\(_2\).

On the one hand, the small adatom concentration on Si\(_xN\) results in a lower Ga supersaturation near micropillar edges reducing the Ga incorporation at the transition from mask to micropillar sidewall (Figure 7b). Only the corners of few micropillars slightly overgrow the mask; large fractions of the edges remain inside the circular mask openings resulting in the smallest micropillar width for SN (Figure 7b and 8).

On the other hand, the high adatom concentration on AlO\(_x\) promotes Ga incorporation at the transition from mask to micropillar sidewall. This results in enhanced lateral mask overgrowth and the widest micropillars for A1 (Figure 8). In addition,
Ga adatom desorption is no longer the dominant surface process. The adatom concentration is high enough to enable nucleation of Ga adatoms on AlO$_x$ away from mask openings confirmed by parasitic GaN deposition (Figure 7d). By measuring the distance between the edge of mask openings and the onset of this parasitic GaN deposition, the Ga diffusion length on the AlO$_x$ hard mask ($\lambda_{AlO_x}$) can be estimated to $\approx$50 $\mu$m (method described in previous studies \cite{25,26}).

The change of pillar width is accompanied by two additional geometrical changes: first, a reduced pillar width locally decreases the fill-factor. As a consequence, the Ga concentration in the gas phase is higher resulting in an increased GaN growth rate, which is experimentally confirmed by the largest pillar center height on SN (Figure 8). Second, a reduced pillar width decreases the pillar perimeter. Hence, the Ga adatom concentration per perimeter length is increased resulting in more pronounced superelevations, which is observed for SN (Figure 8).

In contrast to the superelevation height, the superelevation width is similar for samples S3, SN, and A1. As described in the previous section, the distribution of Ga adatoms from pillar edges toward the pillar center is determined by $\lambda_{GaN}$. Hence, the superelevation width is only influenced by $T_{SAG}$ and other process parameters and not by the hard-mask material.

The extracted $N_D-N_A$ values of GaN micropillars of S3, SN, and A1 are shown in Figure 9. A similar $N_D-N_A$ of SN compared with that of S3 suggests a similar origin, which is the thermal decomposition of the Si$_x$N hard mask and an unintentional incorporation of Si. At $T_{SAG} = 1045$ °C, only the AlO$_x$ hard mask enables the same low $N_D-N_A$ as the planar references, which is essential for high breakdown voltage Schottky diodes.

4.3. Electrical Characterization of Micropillar Schottky Diodes

In the following, the low doping micropillar Schottky diodes fabricated with AlO$_x$ mask are further discussed. Semilogarithmic $I$–$V$ curves and breakdown measurements of micropillars with same dimensions, as shown in Figure 2, are depicted in Figure 10a,b, respectively. The $I$–$V$ curves (Figure 10a) confirm excellent Schottky diode characteristics with an ideality factor of 1.13 and an on/off ratio $>10^9$. However, the specific on-resistance $R_{ON} = 53$ m$\Omega$cm$^2$ is more than one order of magnitude higher than expected for the given drift layer thickness and doping concentration.

As discussed before, the AlO$_x$ mask could not be removed after SAG due to its crystallization. Nevertheless, good ohmic contacts were still achieved by alloying the ohmic metal through the residual AlO$_x$ similar to the process found for AlGaN layers.\cite{27} Ohmic contact formation is evaluated by circular transmission line measurements (CTLM) on A1 as shown in the inset in Figure 10a, resulting in a contact resistance of 1.2 $\Omega$ mm. The contributions of the ohmic contact resistance and the resistivity of the backside contact layer to $R_{ON}$ are 0.13 and 1.6 m$\Omega$cm$^2$, respectively. In total, these contributions to $R_{ON}$ accumulate to only 1.73 m$\Omega$cm$^2$ and do not seem to be the cause for the anomalously increased $R_{ON}$.

In the absence of evidence, one hypothesis to explain the increased $R_{ON}$ focuses on a nonuniform Si incorporation or defective GaN formation during the initial growth of the regrown pillars. It is well known that the incorporation of impurities strongly depends on the growth direction; supplied Si atoms
are preferentially incorporated on semipolar facets.\textsuperscript{[28,29]} As previously described, the nucleation density and thus the density of semipolar facets during the initial 3D growth are increased at the edges of mask openings possibly also increasing defect densities in this region. At the same time, first GaN crystals near the edges start to coalesce toward the micropillar centers via 2D growth. This may also result in higher Si concentrations at micropillar edges and a depletion of Si in micropillar centers. Overall, we estimate that just a thin defective or nearly compensated GaN layer of 250 nm with $N_{D} - N_{A} = 1 \times 10^{14}$ cm$^{-3}$ and a mobility of 300 cm$^{2}$ V$^{-1}$ s$^{-1}$ is sufficient to account for most of the increased series resistance. The existence of such a layer cannot be confirmed by electrical measurements as the extraction of $N_{D} - N_{A}$ is limited to the first few hundred nanometers below the Schottky contact. Structural analysis like transmission electron microscopy (TEM) would be required for more insight. On the contrary, if real, increasing the silane flow during nucleation and coalescence may compensate this effect and reduce $R_{ON}$ as will be investigated in future experiments.

Breakdown measurements of micropillar Schottky diodes are depicted in a semilogarithmic plot in Figure 10b. The measurements end with sudden and catastrophic breakdowns, presumably originating from a field peak at the edge of the Schottky contact. The average breakdown voltage $V_{BD}$ is 393 V, with a maximum $V_{BD} = 498$ V. With the calculated space charge region width ($w_{SCR}$) at breakdown, the critical electric field ($E_{C}$) is calculated as $E_{C} = 2 V_{BD}/w_{SCR}$. The average and highest breakdown field demonstrated here result in 2.63 and 2.96 MV cm$^{-1}$, respectively. This is among the highest breakdown fields reported for heteroepitaxial GaN, demonstrating the full potential of the proposed SAG approach.

To boost the maximum $V_{BD}$ to values which are not achievable with full-area heteroepitaxy, it is essential to further increase the drift layer thickness. With rising growth time $t_{SAG}$ to 4800 s (A2) and 9600 s (A3), the pillar center height increases to 5.8 and 8.7 μm, respectively, without any cracks or other macroscopic defects. Doubling of $t_{SAG}$ only increases the pillar center height by a factor of $\approx$1.5 mainly due to an increase of superelevation height and width. This increased height of superelevations impedes Schottky contact fabrication. Thus, no electrical characterization was possible. Yet, an optimized mask layout with less masked area and larger mask openings (higher fill-factor) should reduce the size of superelevations and allow for the electrical characterization of micropillar Schottky diodes with drift layer thicknesses clearly exceeding 4 μm in next experiments.

5. Conclusions

In this article, SAG of GaN micropillars has been investigated. Using SiO$_2$ and Si$_x$N$_y$ hard masks and a high $T_{SAG} = 1045^\circ$C, nearly V-pit free micropillars grown with a highly selective growth process have been achieved. The thermal decomposition of the mask materials SiO$_2$ and Si$_x$N$_y$ and the resulting high unintentional $N_{D} - N_{A}$ values have prohibited the fabrication of high breakdown voltage Schottky diodes. AlO$_x$ hard masks have exhibited an inferior growth selectivity, but have enabled a low $N_{D} - N_{A} = 5.2 \times 10^{16}$ cm$^{-3}$ at $T_{SAG} = 1045^\circ$C. Electrical characterization of Schottky diodes on 3.7 μm high micropillars with $r = 85$ μm has confirmed excellent reverse characteristics with $V_{BD} = 393$ V ($V_{BD,max} = 498$ V) and $E_{C} = 2.63$ MV cm$^{-1}$ ($E_{C,max} = 2.96$ MV cm$^{-1}$). It is expected that $V_{BD}$ will scale with increasing pillar height. However, with increased $t_{SAG}$, larger superelevations adjacent to masked areas have impeded Schottky contact deposition. To exploit the full potential of the proposed approach, an optimized mask layout will be developed.

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Conflict of Interest

The authors declare no conflict of interest.

Keywords

GaN, micropillars, metal organic chemical vapor deposition, metal organic vapor phase epitaxy, selective-area growth, selective-area regrowth

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