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A RESURF Structure with Nano-trenches and Fins for AlGaN/GaN Devices

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Abstract

The surface electric field (*E*-field) optimization of the AlGaN/GaN devices is very important because the 2DEG channel is located extremely close to the surface. In this work, a novel RESURF structure comprising size-modulated nano-trenches and fins (NTFs) is proposed and demonstrated. The effectiveness of the NTF-structure in reducing the surface *E*-field is confirmed by the TCAD simulation and the experiment. Benefitting from the NTF-structure, the Schottky junctions on AlGaN/GaN exhibit improved performance including leakage and electron trapping under reverse bias.

1. Introduction

The REduced SURface Field (RESURF) technology [1] is widely used to prevent the lateral power semiconductor devices from premature breakdown. For AlGaN/GaN heterostructures, they are typical lateral structures with the 2DEG channel located extremely close to the surface. Therefore, it is very important to optimize the surface electric field (*E*-field) of the AlGaN/GaN devices. Several RESURF schemes have been proposed for the AlGaN/GaN devices including field plate [2], recessed gate edge [3], ion implantation [4], et al. In this work, a novel RESURF structure comprising size-modulated nano-trenches and fins (NTFs) is proposed and experimentally demonstrated. Moreover, the NTF- structure can be used not only as a termination but directly as a gate structure for HEMTs or an anode structure for diodes.

2. NTFs design, fabrication, and characterization

As shown in Fig. 1, the 2DEG density is dependent on the thickness of the AlGaN barrier and the width as well as the height of the Fin-AlGaN/GaN [5]. Based on these principles, the NTF-structure (Fig. 2) is specifically designed to achieve a lateral-gradient distribution (LGD) of the 2DEG. As summarized in Table I, the depths and the widths of the nano-trenches are gradually decreasing while the fin widths are gradually increasing.

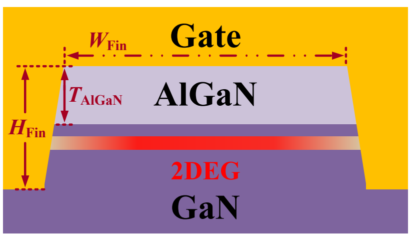

Fig. 1 Schematic cross section of the Fin-AlGaN/GaN.

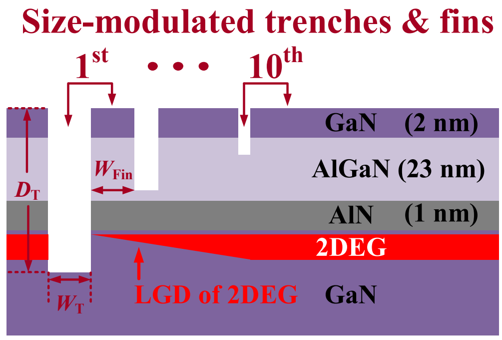

Fig. 2 Schematic cross section of the NTF-structure.

Table I Key Sizes of the NTF-structure

No.	Trench Depth D_T (nm)	Trench Width W_T (nm)	Fin Width W_F (nm)
1	30	700	150
2	29	500	170
3	28	150	200
4	27	120	220
5	25	100	240
6	22	90	260
7	15	70	280
8	11	60	300
9	9	50	300
10	6	40	500

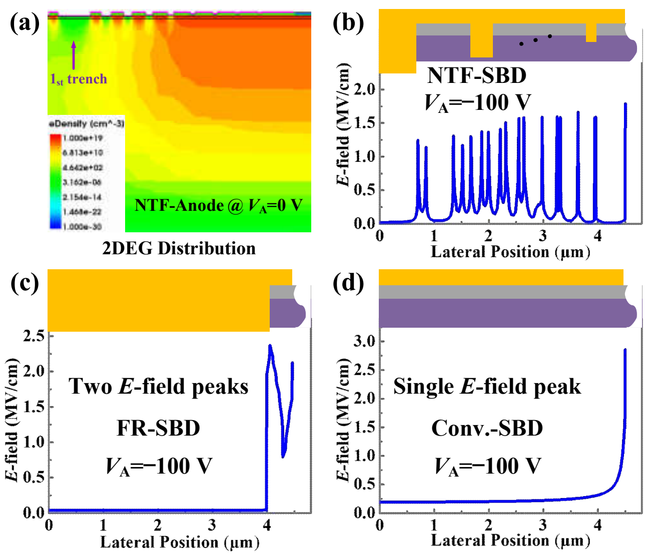

Fig. 3 TCAD simulated (a) 2DEG distribution in the NTF-anode at V_A=0 V, *E*-field profiles in the anodes of (b) the NTF-SBD, (c) the FR-SBD and (d) the Conv.-SBD at V_A =−100 V.

TCAD simulation was performed to investigate the LGD of the 2DEG as shown in Fig. 3(a). The simulated E-field profiles of the SBDs with NTF, Fully Recess (FR), and conventional anode structures are compared in Fig. 3. Under reverse bias, due to the LGD of the 2DEG, the single E-field peak in the Conv.-SBD is decentralized into multi E-field peaks in the NTF-SBD while the maximum E-field peak is also remarkably reduced. Such uniform E-field distribution is favorable for enhancing the reverse blocking characteristics.

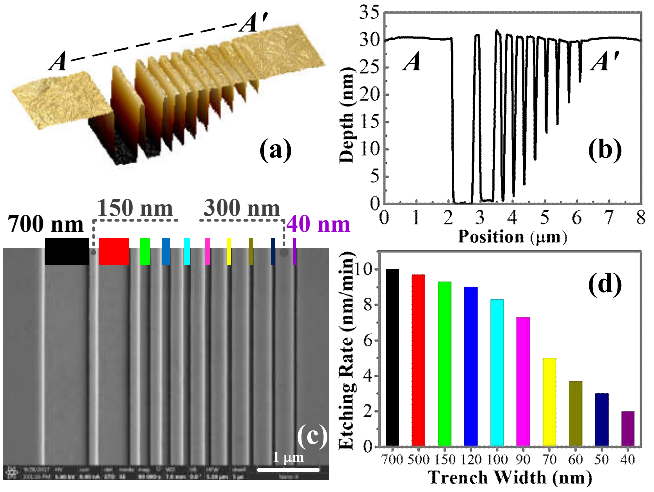

Fig. 4 (a) 3D AFM image of the NTF-structure. (b) Trenches depths profile along the *A-A′* direction. (c) Top view SEM image of the NTF-structure. (d) Trench-width dependent etching rates.

The NTF-structure fabrication commenced with the nano-trenches patterning by e-beam lithography, followed by single-step Cl_2/BCl_3-based inductively coupled plasma (ICP) etching. Fig. 4(b) shows the measured trenches depths profile along the *A-A′* direction, manifesting that the depth and the width of the nano-trenches are gradually decreasing. It is worth noting that the depth gradient decreasing is achieved in a single ICP etching step due to the etching rate is trench-width dependent as summarized in Fig. 4(d).

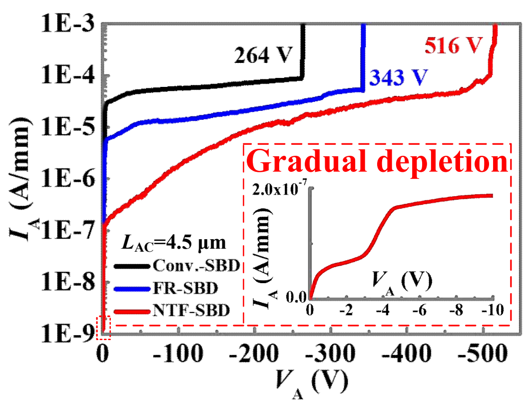

Fig. 5 Reverse bias *I-V* curves of the (NTF, FR, Conv.)-SBDs. Inset: 10 V reverse bias *I-V* curve of the NTF-SBD.

As shown in the inset of Fig. 5, three turning point at V_A of −0.6, −3 and −4.6 V are observed in the small reverse bias *I-V* curve of the NTF-SBD, suggesting a gradual depletion of the 2DEG which is related to the LGD effect. Such gradual depletion process results in more efficient depletion of the drift region. The leakage of the NTF-SBD is the lowest among the three types of SBDs as shown in Fig. 5.

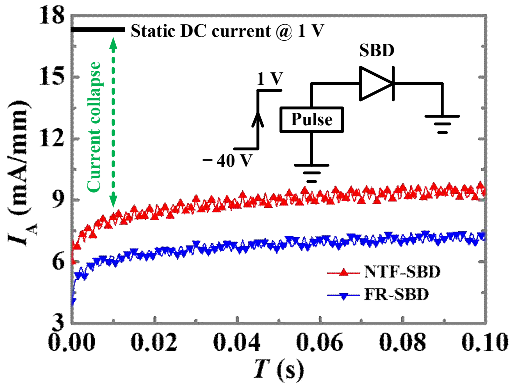

Fig. 6 Transient forward current of the stressed (NTF & FR)-SBDs. Inset: schematic measurement setup for the transient forward current.

High E-field at the cathode-side Schottky contact edge during reverse stress could result in electron trapping which leads to current collapse. The NTF-SBD exhibits a mitigated current collapse compared with the FR-SBD. This is attributed to the reduced surface E-field.

3. Conclusions

In conclusion, a NTF-structure with inherent LGD of the 2DEG is proposed and successfully demonstrated. Benefitting from the NTF-structure, the reverse leakage and the current collapse of the AlGaN/GaN SBD are improved. The NTF-structure is also feasible for the gate design towards normally-off GaN HEMTs and the edge termination of high voltage GaN power devices.

References

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