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主　論　文　の　要　旨

論文題目　**Nanorod-Based Vertical GaN-on-GaN Schottky Barrier Diodes Fabricated by Top-Down Approach**
(トップダウン的手法により作製したナノロッド縦型 GaN-on-GaN ショットキーバリアダイオード)

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論　文　内　容　の　要　旨

In this day and age, the concerns on reduction of power dissipation in power conversion systems become significantly urgent towards the sustainable development of society. Silicon (Si)-based power devices, as the essential components in power conversion system, have been widely developed and become indispensable parts in our modern life. Since Si-based power devices have experienced extensive research and sophisticated development for a long-term time, a further improvement of device performance is severely hindered by physical limitations of Si-based materials.

Gallium nitride (GaN) has already become a prevailing candidate for high-performance power electronics owing to its excellent material properties including a wide bandgap, a high critical electric field, a high electron saturation velocity and high temperature endurance. Over the last two decades, lateral GaN/AlGaN heterojunction-based high electron mobility transistors (HEMTs) have witnessed rapid progress with recent large-volume commercialization in a variety of applications such as power supply and fast charger. Meanwhile, as free-standing GaN substrates with a low threading dislocation density ($< 10^6/cm^2$) become more widely available, vertical GaN-on-GaN power devices are attracting widespread attention because of their great potentials in achieving some desirable device performances such as high-power handling capability, improved device reliability, and more efficient thermal dissipation and management over their lateral counterparts.

As an elementary building block in GaN electronics, GaN-Schottky barrier diodes (SBDs) have been extensively studied owing to their low turn-on voltage (V_{ON}) and rapid switching speed. However, the device performance is typically hindered by a high reverse leakage current and premature breakdown. To overcome these shortcomings, a substantial amount of research for high-voltage GaN-SBDs has been devoted to the development of edge termination techniques such as field plate, junction barrier Schottky diode, trench MOS barrier Schottky diode, and others. Nanorod/nanowire

(NR/NW) and Fin structures have enabled the implementation of novel GaN device concepts such as enhancement-mode MOSFETs, FinFETs, and super-junction structure. Furthermore, it is also interesting to note GaN NR-based SBDs whether they could serve as an alternative to high-voltage SBD, because nanostructures can readily make the most of the Reduced Surface Field (RESURF) effect.

In this dissertation, the author studies on NR-based vertical GaN-on-GaN SBDs fabricated by top-down approach. In Chapter 1, the author describes the background, as well as the outstanding issues, and the motivation of this study.

In Chapter 2, the author discusses the feasible methods to fabricate GaN nanostructures and an etching-based top-down approach is regarded as a suitable way for the subsequent fabrication. Moreover, relevant process/characterization facilities, which would be frequently utilized throughout this study, are briefly introduced.

In Chapter 3, by Silvaco TCAD simulations, the author indicates GaN NR/NW-based structures could benefit from the dielectric RESURF effect and be regarded as an alternative for high-voltage SBDs. Furthermore, the practice fabrication of NR (mesa)-SBDs was proceeded by top-down approach. The dielectric RESURF effect on NRSBDs is demonstrated, which corresponds with the simulation results.

However, non-ideal carrier transportation at the Schottky interface was confirmed in the fabricated SBDs, as a result of the adverse effect from CF_4/O_2-based etch-back process. To solve this problem, the optimization, which is based on low-damage etch with a fairly low bias voltage and post annealing process, was carried out for NRSBDs. The recovered device performance proved the effectiveness of this optimization.

In Chapter 4, the author introduces the optimized dry- as well as wet-etching process, and the vertical NRs with high aspect ratio and distinct non-polar sidewall can be obtained by following the optimizations. Furthermore, a more reliable and feasible process flow for NRSBDs fabrication is proposed. The NRSBDs fabricated by new process flow feature improved and competitive device performance. In addition, the evaluation for Schottky barrier heights (SBH) of NRSBDs, and the importance of wet-etching process were systematically studied by both static and dynamic characteristics.

In Chapter 5, the author summarizes this study and shows some future perspectives on GaN nanostructure-based devices.