Mg-implanted Vertical GaN Superjunction Barrier Schottky Rectifiers with Extremely Low On-Resistance, High Breakdown Voltage, Low Turn-On Voltage and Avalanche Capability

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We report the first experimental demonstration of vertical gallium nitride (GaN) superjunction (SJ) devices. The SJ concept [1] was applied in the GaN Schottky barrier diodes (SBDs) to improve the trade-off between the breakdown voltage (BV) and specific on-resistance (R_{ON}) as well as to reduce the leakage currents. The SJ barrier Schottky (SJ-JBS) diode structure was formed by implantation of Mg ions into a 10 µm thick Si-doped GaN drift layer (with electron concentration 3-4x10^{16} cm^{-3}) grown on a free-standing n-type GaN (0001) substrate under the <0001> channeling conditions with 180 keV energy, as shown schematically in Fig 1. The Mg ions were activated via the ultra-high-pressure annealing process. We fabricated the SJ-JBS diodes with a different n-GaN channel width: L_n=1 and 1.5 µm (see Fig. 1a). The SJ-JBS diodes depending on L_n exhibited R_{ON} of 0.58-0.67 mOhm cm^2 (see Fig. 1b-c) which is a record low value for vertical GaN SBDs and high BV of 647-675 V (Fig. 2b). The leakage currents in SJ-JBS diodes were relatively low (10^3-10^4 lower than conventional GaN SBDs) and stable (low leakage slope) as shown in Fig. 2d. Moreover, the SJ-JBS diodes exhibited the low turn-on voltage (V_{ON}) of 0.7 V and the reverse avalanche capabilities against the rapid increase of the reverse current over 2.5 orders of magnitudes. This result shows that the vertical GaN SBDs based on the SJ structure can realize extremely low R_{ON} and low V_{ON} simultaneously keeping high BV, which makes them a strong candidate for ultra-low loss power switching applications.

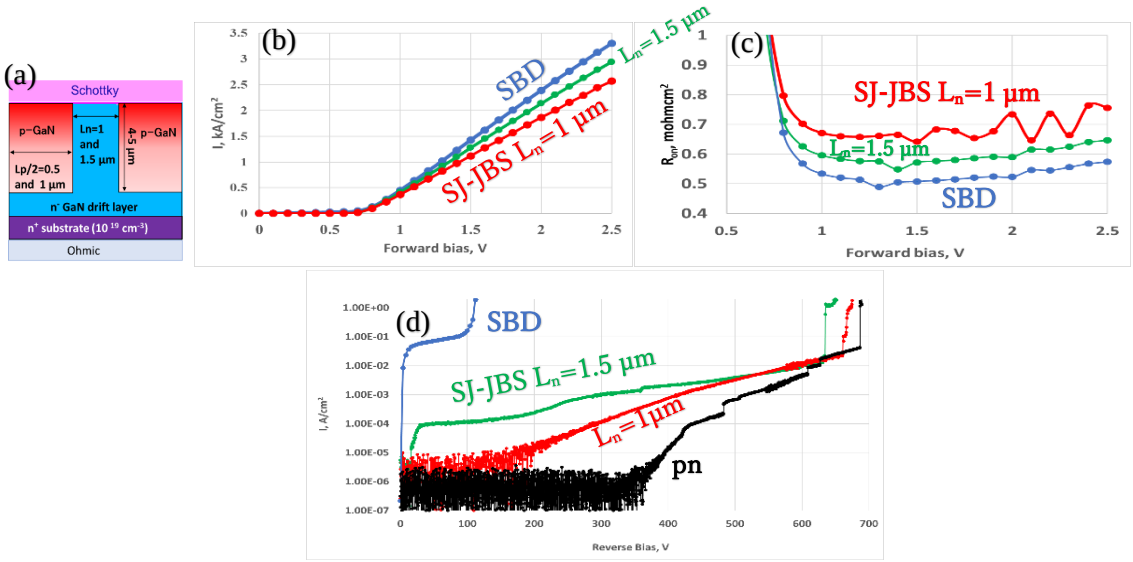

Fig. 1 Schematic illustration of SJ-JBS (a), forward I-V characteristics (b), R_{ON} vs. forward bias (c) and reverse I-V (d).

This work was supported by MEXT-Program for Creation of Innovative Core Technology for Power Electronics Grant Number JPJ00977.

[1] T. Fujihira, Jpn. J. Appl. Phys., Part 1 **36**, 6254 (1997).

We acknowledge Dr. Tetsuo Narita from Toyota Central R&D Labs. Inc for epitaxial structures.