Growth rate dependent near ideal vertical-type Schottky barrier diodes fabricated on MOCVD-GaN/GaN substrates

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GaN has attracted much attention for their potential applications in power electronic devices, benefitting from its superior properties, such as wide band gap, high electron mobility, large breakdown field and high thermal conductivity. A vertical structure is believed to be more suitable for high-power applications than lateral devices since high current and voltage can be achieved simultaneously with reduced on-resistance and less effect from surface/interface states. Moreover, the fast development of free-standing GaN substrates with low threading dislocations (TDs) density (on the order of 10^6 cm^{-2} or less) in recent years opens up an opportunity for the GaN vertical-type power conversion applications. Compared to PN junction diodes, the Schottky Barrier diodes (SBDs) are expected to achieve both low on-resistance and turn-on voltages since they do not have minority carrier storage issue and have higher electron mobility. To obtain high-performance power electronics, carbon incorporation during MOCVD growth is an important issue. Although there is a few investigations on the carbon doping in SBDs, a proper doping level and how to control the growth parameter is still unclear.

During MOCVD epitaxial growth, many parameters, such the V/III ratio, growth temperature, and pressure, could affect the unintentional carbon incorporation. Nevertheless, all these parameters can be attributed to the variation of growth rates. Therefore, in this study, we detailed investigate the effect from growth rates of the GaN drift layer on free-standing GaN substrate by changing the TMG flow rates. It was found that, nearly all the characteristics, including the yellow band intensity, mobility and morphology of the GaN drift layer, the Schottky properties, such as ideality factor, barrier height, specific on-resistance, turn-on voltage, were strongly dependent on the growth rates. An optimized growth rates from 2.62 to 7.78 um/h was observed for a high-quality drift layer with high mobility (>1000 cm^2/Vs) and SBDs with near ideal Schottky property (n=1.03) with low on-resistance (0.75 m Ω cm^2) and turn-on voltage (0.69 V).

Table I. Key SBDs parameters extracted from electrical property

	Growth rate (μm/h)	Ideality factor	Φ (eV) From I-V	Φ (eV) From C-V	Free carrier Density (cm^{-3})	R_{on} ($m\Omega \cdot cm^2$)	Mobility ($cm^2/V \cdot S$)
A	2.61	1.12	0.935	0.969	6.35E+15	0.75	1371
B	4.45	1.03	0.934	0.948	2.30E+15	2.63	1008
C	7.78	1.04	0.854	0.905	3.10E+15	2.90	638
D	8.08	1.59	0.693	0.713	4.59E+16	0.83	279