Student Paper

Current Collapse Suppression in AlGaN/GaN HEMTs by Means of Slant Field Plates Fabricated by Multi-layer SiCN

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AlGaN/GaN high electron mobility transistors (HEMTs) are promising as high frequency and power transistors because of the two dimensional electron gas (2DEG) with high saturation velocity and high carrier concentration as well as high critical breakdown field of GaN. In general, field effect transistors under high operation voltage suffer from high electric fields at the drain edge of the gate leading to the breakdown of transistors [1]. In order to reduce the maximum electric field intensity, field plate structures are widely used. Furthermore, the slant field plate has been suggested as a way to effectively suppress the RF dispersion and the parasitic capacitance [2]. However, the fabrication of the slant field plate with a designed shape is still challenging. In this paper, we report a fabrication technique of the slant field plate by means of the multi-layer SiCN dielectric film. Each layer of the SiCN film exhibits a different dry etching property by changing the deposition condition in the plasma enhanced chemical vapor deposition (PECVD) [3]. The control of the sidewall shape is demonstrated. Then this approach is applied to the fabrication of the slant field plate in AlGaN/GaN HEMTs. The pulsed I-V characteristics indicate that the current collapse is successfully suppressed by the field plate.

The device structure of the AlGaN/GaN HEMT with a slant field plate is shown in Fig. 1. The process flow of the field plate is shown in Fig. 2. SiCN film is deposited by PECVD with hexamethyldisilazane (HMDS) vapor [4]. Hydrogen and ammonia are introduced to the reactor as carrier gases in addition to the HMDS vapor. The mixture ratio of carrier gases (H_2:NH_3) determines how deep lateral etching goes when the SiCN film is etched by reactive ion etching (RIE). During the SiCN deposition, the mixture ratio can be changed with deposition time. The SiCN layers are first etched anisotropically by C_2F_6 RIE after the gate pattern is defined by e-beam (EB) lithography, and then the sidewall of the SiCN film for the field plates is shaped by the lateral etching during the SF_6 RIE. Finally, Ni/Au gate metal is evaporated on the gate window and the SiCN sidewall.

Figure 3 shows the scanning electron microscope (SEM) images of the SiCN sidewall. The corresponding mixture gas flow during PECVD is also shown as a function of deposition time. In Fig. 3(a), only hydrogen is used as a carrier gas in PECVD. The gate opening in the SiCN has vertical sidewalls. In Fig. 3(b), the carrier gas is changed from hydrogen to ammonia during the PECVD. The resulting cross sectional shape exhibits a clear plateau in the middle of the sidewall. In Fig. 3(c), the mixture ratio H_2:NH_3 is gradually changed in 10 steps during PECVD. The slant sidewall is observed in the SEM image.

The DC and pulsed I_d-V_{ds} characteristics measured for the device with gate length of 230 nm are shown in Fig. 4. The pulse width and the pulse period are 0.5 ms and 10 ms, respectively. The device without the field plate is shown in Fig. 4(a) as a reference. To fabricate the field plate, the carrier gas in PECVD is changed from hydrogen to ammonia in (b) 3 steps, (c) 4 steps, and (d) 10 steps. The total thickness of SiCN is the same for (b)-(d). The results indicate that the current collapse is suppressed by field plates and the device with 10-step SiCN slant field plate exhibits the greatest suppression effect (Fig. 4(d)).

Acknowledgment: The authors thank Prof. T. Matsuoka for his support on the GaN-based process. This work was supported by the JSPS KAKENHI Grant #24560392 and the Research Institute of Electrical Communication (RIEC) at Tohoku University. The device fabrication has been carried out at the Laboratory for Nanoelectronics and Spintronics in RIEC.

References

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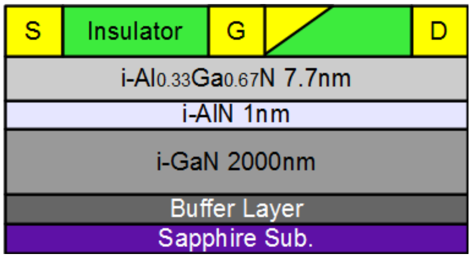


Fig. 1: Device structure of AlGaN/GaN HEMT with slant field plate.

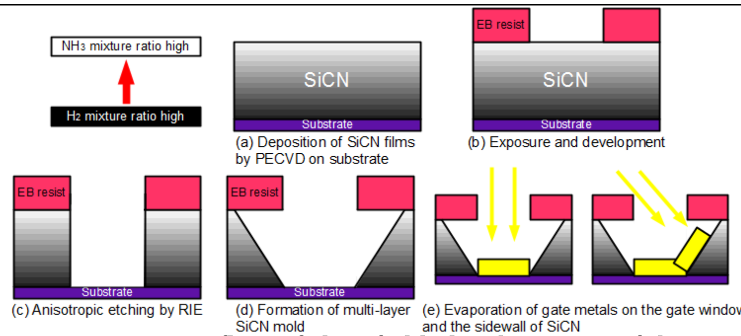


Fig. 2: Process flow of slant field plate by means of the multi-layer SiCN film.

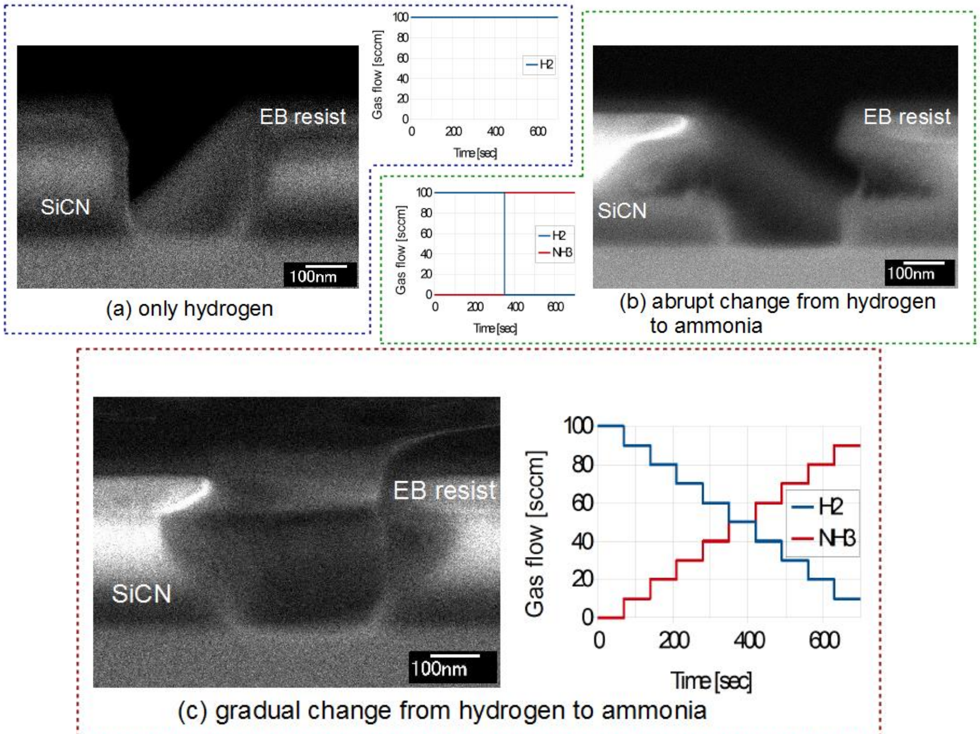
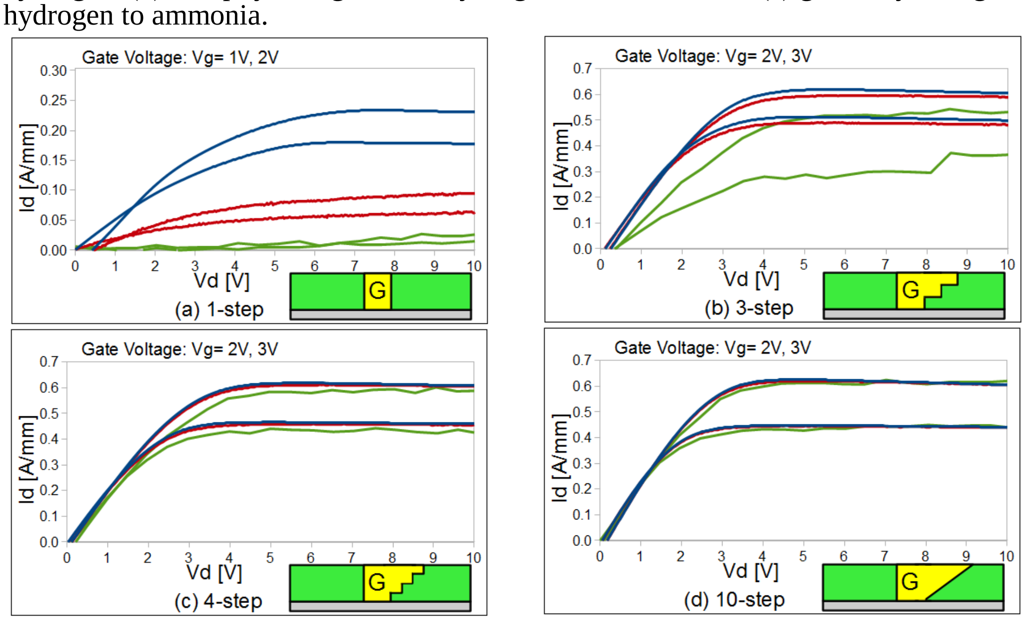


Fig. 3: Cross section of SiCN and carrier gas flow in PECVD. Carrier gas is (a) only hydrogen, (b) abruptly changed from hydrogen to ammonia and (c) gradually changed from hydrogen to ammonia.



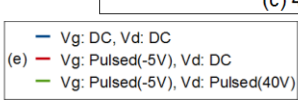


Fig. 4: I_d-V_{ds} characteristics of AlGaN/GaN HEMTs (a) without field plate and with (b) 3-step field plate, (c) 4-step field plate and (d) slant field plate (10-step). The legend is shown in (e).