A Study of Fluorine Bombardment on the Electrical Properties of AlGaN/GaN Heterostructures

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AlGaN/GaN high electron mobility transistors (HEMTs) have recently emerged as promising candidates for high-power, high-speed, and RF low noise applications [1]. Multiple performance related issues, such as passivation of the HEMT surface to mitigate current collapse or field-plate to increase breakdown voltage, require the deposition of silicon nitride (SiN). For the fabrication of field-plated devices, the SiN has to be reactive-ion-etched with high aspect ratio to define the gate. SiN is normally etched using fluorine-based chemistry in conventional reactive ion etching or inductively-coupled-plasma systems [Fig. 1]. In order to ensure the complete removal of SiN from the bottom of the gate area prior to metal deposition, a significant over-etch in a fluorine-based plasma (CF_4 or CHF_3) is usually part of the process. Such an exposure to fluorine ion (F^-) bombardment results in a number of significant changes in the electrical behavior AlGaN/GaN heterostructures. For fabricated devices, increased threshold voltage to positive values has been observed due to fluorine bombardment [1]. This is a significant development. A systematic study of the fluorine-induced damage or changes and the effect of the incorporated fluorine species on the two-dimensional electron gas (2DEG) properties is needed in order to design effective processing strategies for the fabrication of AlGaN/GaN HEMTs.

In this work, a comprehensive study of the transport behavior of AlGaN/GaN HEMT layers is presented. The epitaxially grown AlGaN/GaN HEMT layers were treated with in a CF_4 plasma in a conventional reactive ion etching system at different self-bias voltages ranging from 100 V to 450 V. The 2DEG properties, as determined using Hall measurements, exhibited drastic degradations in mobility and sheet concentration after bombardment especially at higher self-bias voltages. Post-etching annealing demonstrates a recovery of up to 90% for short annealing periods. However, a prolonged annealing produced simultaneous decreases in mobility and sheet concentration [Figs. 2 and 3]. This may be due to the diffusion of incorporated fluorine species. Detailed results from Hall measurements, Shubnikov-de Haas measurements, and microanalytical measurements such as time-of-flight secondary ion mass spectrometry (SIMS) will be presented. Implications of such plasma treatments on device performance and methods to alleviate any detrimental effects will also be presented.

[1] Y. Cai, Y. G. Zhou, K. J. Chen, and K. M. Lau, *IEEE Electron Device Lett.* **26**, 435–437 (2005).

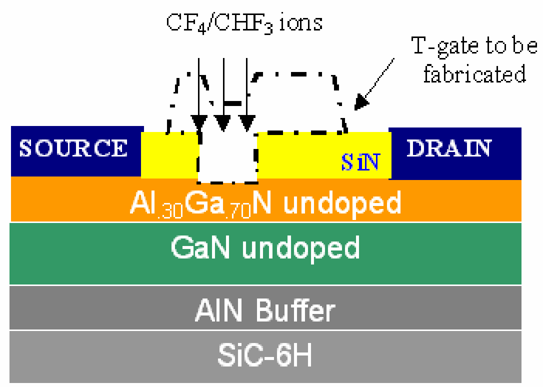

Fig. 1 HEMT structure with a gate opening where ion bombardment is done to study the effect of damage on 2DEG properties and electrical behavior of the HEMT.

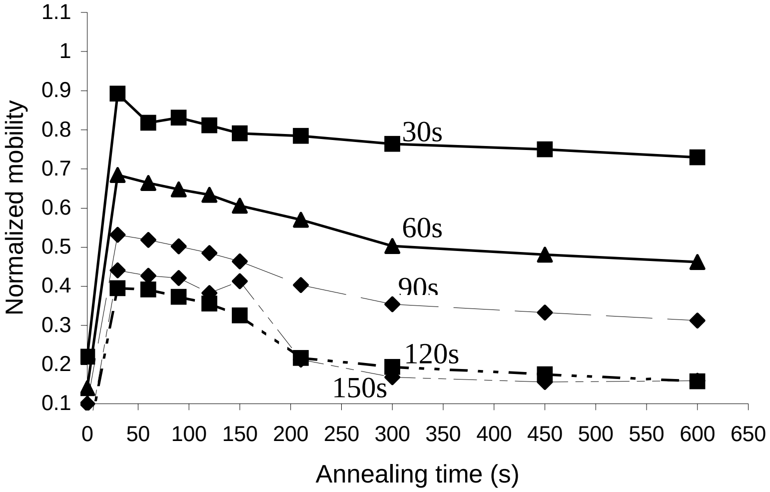

Fig. 2 Variation of mobility (normalized to the unbombarded value) with annealing at 500 °C for different annealing time intervals.

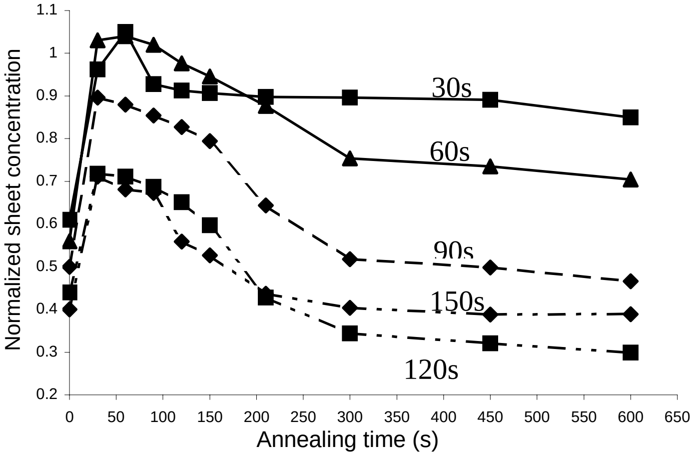

Fig. 3 Variation of sheet concentration (normalized to the unbombarded value) with annealing at 500 °C for different annealing time interval.