Improvement of process uniformity in recessed gate AlGaN/GaN HFET by selective etching of in-situ Si$_x$N$_y$ on AlGaN

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Abstract
In this research, the effect of the in-situ Si$_x$N$_y$ etching was investigated on the uniformity of threshold voltage in recessed gate AlGaN/GaN HFET devices. By varying O$_2$ ratio, etch rate of Si$_x$N$_y$ and AlGaN was changed and etching condition with the highest selectivity of Si$_x$N$_y$ / AlGaN was obtained. At this optimized condition, the standard deviation of threshold voltage in AlGaN/GaN recess gate HFET in 6inch wafer was decreased from 0.60 to 0.18.

1. Introduction
In the AlGaN/GaN HFET, the passivation layer is important to improve AC characteristics, for example, dynamic Ron. However, AlGaN/GaN HFET devices have a problem called “current collapse” and Si$_x$N$_y$ and other dielectric films are need to be deposited on the AlGaN surface to lessen the electric field on the gate edges.[1, 2] Among the various deposition methods, in-situ passivation by MOCVD is chosen to reduce the interface contamination and surface traps effectively after growing AlGaN. In-situ Si$_x$N$_y$ is easy to be grown by MOCVD but unconventional gas mixture and etching condition of etcher was required to etch in-situ Si$_x$N$_y$ that has high density.

In this paper, we focus on the selectivity of in-situ Si$_x$N$_y$ / AlGaN to improve the process uniformity of threshold voltage in AlGaN/GaN recess gate HFET in 6inch wafer.

2. Experimental
Al$_{0.25}$Ga$_{0.75}$N/AlN/GaN (30/1/3000 nm) HFET structure was grown by metal-organic chemical vapor deposition (MOCVD) system on 6-inch Si (111) substrate. Si$_x$N$_y$ was grown as the top layer after the AlGaN growth for in-situ passivation. Si$_x$N$_y$ etch process was performed to define isolation, ohmic contact region and gate recess region. Ti/Al-based ohmic contacts were used as source and drain. And gate recess process was carried out by using inductively coupled plasma-reactive ion etch (ICP-RIE) with Cl$_2$/N$_2$ gas mixture. Gate dielectric layer was deposited by sputtering process and gate was fabricated by e-beam Ni/Au lithography.

The various gas mixture like as F-, Cl-, Ar- and O- base gas were used as to obtain the high etch rate and selectivity of in-situ Si$_x$N$_y$ / AlGaN. To improve the selectivity of Si$_x$N$_y$ / AlGaN was used as an additive gas varying 0-100% in the total gas flow in fluorine-based gas mixture.

3. Results and discussion
In order to optimize the etch selectivity of in-situ grown Si$_x$N$_y$ / AlGaN, the experiments that varying O$_2$ ratio in total gas flows were performed. Fig.1 shows the results of selectivity and the etch rate of Si$_x$N$_y$ and AlGaN. The highest selectivity is obtained with 30% O$_2$ ratio in total gas flow and selectivity was increased from 5:1 to 100:1. The etch rate of AlGaN was reduced by adding O$_2$ in gas mixture due to the formation of AlOx and GaOx on the surface during etching process [3]. The etch rate of in-situ Si$_x$N$_y$ was decreased with increasing O$_2$ ratio. By this relationship, the optimized gas ratio with high selectivity was obtained.

![Fig. 1 The etch rates and selectivity between Si$_x$N$_y$ and Al$_{0.25}$Ga$_{0.75}$N as a function of O$_2$ ratio.](image)

The etching depth was increased by using fluorine and argon gas only (Fig. 2). Also etching depth was saturated with O$_2$ addition to the gas mixture.

Fig. 3 shows the cross-sectional SEM images of Si$_x$N$_y$ and AlGaN recess etching profiles. Sample A using fluorine and argon has non-uniform recess etching depth between center and edge in wafer, while sample B using O$_2$ addition to gas mixture has uniform etching profile.
4. Conclusions

In conclusion, we have investigated the impact of the in-situ Si$_x$N$_y$ etching by comparing the uniformity of threshold voltage in recessed gate AlGaN/GaN HFET devices. It has been found that O$_2$ addition in the gas mixture improves the uniformity of Si$_x$N$_y$ etching. By varying O$_2$ ratio, etch rate of Si$_x$N$_y$ and AlGaN was changed and etching condition with the highest Si$_x$N$_y$ / AlGaN etching selectivity was obtained. This optimized etching condition improves uniformity of threshold voltage in fabricated AlGaN/GaN recess gate HFET devices, and this would enhance the performance of the device effectively.

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References