Technical-Report

Precise Thickness Control in Recess Etching of AlGaN/GaN-HFET Manufacturing

Gallium Nitride (GaN) and Silicon Carbide (SiC) power devices, the next-generation power devices, enable less energy consumption in smaller device sizes than the silicon-based power devices, and many researchers are now developing commercial grade new-generation power devices. SAMCO is developing the key manufacturing processes necessary for the new-generation power devices:
(1) AlGaN/GaN Heterostructure Field-Effect Transistor (HFET) manufacturing process, i.e., gate recess etching to achieve normally-on and passivation film deposition to prevent current collapse, and (2) SiC power device manufacturing process, i.e., formation of trench, via hole, and passivation film deposition on the gate.
We have developed systems and etching/deposition processes to provide turnkey solutions for power device manufacturing. This report describes precise thickness control technique used in the recess etching of AlGaN/GaN HFET manufacturing for achieving normally-on.

Achievement of "Normally-off" by Precise Thickness Control of AlGaN Layer

AlGaN/GaN-HFET is usually normally-on, but normally-off HFET is suitable for power device applilcation. There are two approaches to enable normally-off and low on-resistance. One is to employ a p-GaN gate (GIT: Gate Injection Transistor). The other is to etch the AlGaN layer in the recess to be less than 5 nm thick, and reduce the amount of two-dimensional electron gas (2DEG) on gate electrodes. Precise thickness control of AlGaN layer in the recess etching is the most challenging part of the AlGaN/GaN-HFET manufacturing, because it affects the Vg-Id characteristics of the device.
Below are our methods for the precise thickness control.

1. Slow Etching Process of AlGaN Layer

As shown in Fig. 1, slow etching of 0.8nm/min was achieved by applying low BIAS RF Power. This slow etching process enabled highly reproducible thickness control.

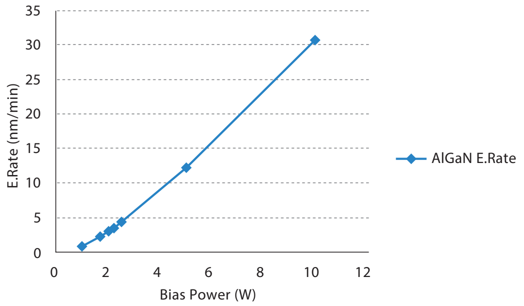

Fig. 1 BIAS RF Power and Etch Rate

As shown in Fig. 2, the AlGaN surface, after low-BIAS etching, was smooth without any micro-trenches, pits, or pillars.
Additionally, the process achieved high uniformity of ± 2.5 % in a φ6inch wafers at an average etch depth of 20nm (within 1 nm variation).

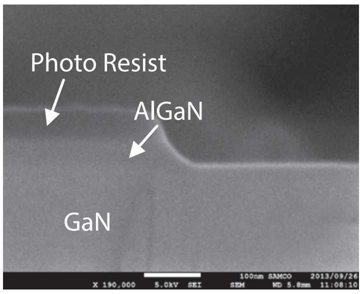

Fig. 2 Cross-section SEM of AlGaN/GaN Layer

2. Thickness Control by Interferometric Endpoint Monitor

An endpoint monitor was used in the AlGaN/GaN etching. The endpoint monitor emits white light onto the wafer, and monitors the interferometric wave of the light reflected by the wafer surface and each boundary of the layers.
Fig. 3 shows the signal intensity of a specific wavelength during AlGaN etching, and shows that the boundary between the AlGaN and GaN layer can be detected. Fig. 4 shows the result of AlGaN remaining thickness monitored by our new algorithm. We have successfully stopped AlGaN etching at 5nm thick on the 25 nm AlGaN layer.

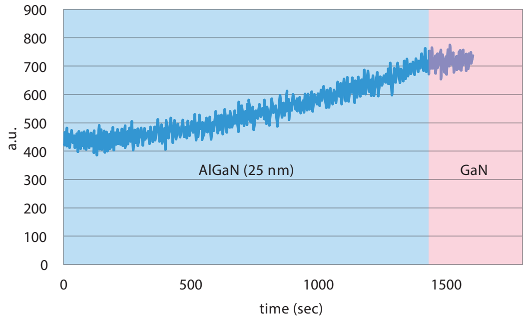

Fig. 3 Signal Intensity of a Wavelength during AlGaN Recess Etching

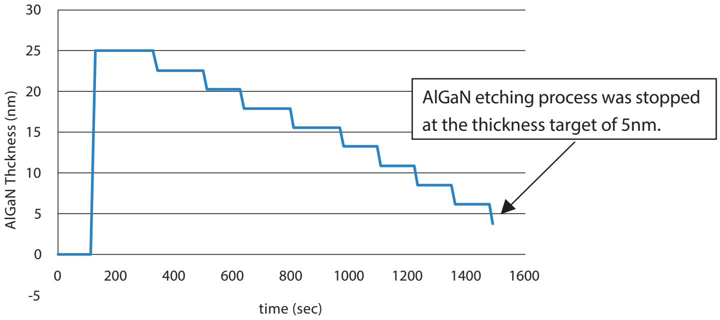

Fig. 4 AlGaN Thickness Monitoring with Our New Algorithm

Atomic Force Microscope (AFM) measurement confirmed that the our new method kept exact etching depth of 20nm.

As stated above, our recess etching process, which combined the slow recess etching process and the optical interferometric end point monitor, enabled the precise thickness control of the AlGaN layer within the range of ±1nm.