Characterization of highly selective dry etching of pGaN over AlGaN

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GaN-based high electron mobility transistors (HEMTs) are a class of devices based on the electron properties of stacks of doped and undoped gallium nitride and AlGaN alloys. Within such structures, a 2D electron gas (2DEG) is formed, resulting in devices with very low resistivity and improved performances.
The basic structure of those devices consists of a GaN-AlGaN junction with with p-doped GaN gates on top. Dry etching of pGaN selectively landing on AlGaN is a common patterning process to define the gate of the transistor in a normally-off device [1]. To preserve the electronic properties of 2DEG, dry etching must be able to safely remove residues without damaging the underlying layer.
The conventional fabrication technique is based on chemically selective etching step [2], landing on AlGaN after most of the pGaN is removed by a faster and non-selective process. The non-selective step is typically obtained with chlorine-based plasma, whereas the selective process is reached by employing Cl_2 and N_2, where the selectivity is provided by a small amount of added O_2. The process is performed in an ICP reactor from Lam, equipped with two RF generators to sustain the plasma and to set up the ion bombardment independently.

In this work, we present a full characterization of the above-mentioned selective steps, mainly focusing on the study of the sensitivity to the process parameters. Process outcome is characterized in terms of residual AlGaN thickness measured by ellipsometry, in-line nondestructive plan view SEM inspection, and cross section by TEM.

Sensitivity to process parameters

Among all the tunable parameters of the selective step, the most critical are Bias Voltage and oxygen flow. As the final electrical properties of the device depend on the integrity of the AlGaN layer, a highly selective step (high oxygen flow) with low plasma damage (low bias voltage) is required. A drawback of reducing BV and increasing O2 flow is that, besides improving selectivity, the etch rate of the step dramatically drops, resulting in residues or even etch stop, even with small variations.
As for the impact of BV, we found a very narrow window around a possible center point. On the one hand, reducing the voltage rapidly leads to residues formation and etch stop; on the other, increasing it produces excessive AlGaN damage and recess, degrading the final device properties.
As for oxygen, despite increasing its flow provides a more selective step, the corresponding reduction of the etch rate is so strong that heavy residues appear. On the other side, a reduction of the flow may be critical due to selectivity loss at lower oxygen concentration. A thorough explanation of the characterization trials will be provided in the final work.

References

1. Giuseppe Greco, Ferdinando Iucolano, Fabrizio Roccaforte “Review of technology for normally-off HEMTs with p-GaN gate”
2. Han, Yanjun, et al. "Highly selective dry etching of GaN over AlGaN using inductively coupled $Cl_2/N_2/O_2$ plasmas." Japanese journal of applied physics 42.10A (2003): L1139

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