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Plasma Etching of the Group-III Nitrides

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Interest in the wide band-gap group-III nitrides continues to increase as growth and process technologies improve and device demonstrations of blue, green, and ultraviolet emitters and detectors, and high temperature electronics are reported.[1-3] Realization of more advanced devices; including lasers, requires dry etch processes which are well controlled, smooth, highly anisotropic and have etch rates approaching 0.5 μm/min. Laser facet fabrication is especially dependent upon dry etching since the majority of epitaxially grown group-III nitrides is on sapphire substrates which inhibits cleaving the sample with reasonable yield.

GaN etching has been reported in reactive ion etch (RIE) systems with etch rates approaching 600 Å/min at dc-biases greater than -400 V.[4] The high rates and anisotropic profiles achieved with RIE are attributed to the acceleration of energetic ions from the plasma to the wafer. However, this energetic ion-bombardment of the surface can damage the sample and degrade both electrical and optical device performance. Attempts to minimize such damage by reducing the ion energy or increasing the chemical activity in the plasma often results in a loss of etch rate or anisotropy which significantly limits critical dimensions and reduces the utility of the process for device applications requiring vertical etch profiles. It is therefore necessary to develop plasma etch processes which couple anisotropy for critical dimension and sidewall profile control and high etch rates with low-damage for optimum device performance.

A great deal of interest has been generated in low-damage etch processes based on high-density electron cyclotron resonance (ECR) plasmas. Due to the magnetic confinement of electrons in the microwave ECR source, high density plasmas are formed at low pressures with low plasma potentials and ion energies. Therefore, less damage than that produced by RIE plasmas has been observed during ECR etching of III-V materials. Most ECR etching of GaN has been performed using Cl_2/H_2-based plasmas with etch rates exceeding 2800 Å/min at dc-biases ranging from -150 to -250 V.[5,6] In this paper, we report etching of GaN in a Plasma-Therm SLR 770 ECR etch system using both the ECR/RIE mode and the RIE-only mode. We also review group-III nitride ECR etching as a function of plasma chemistry, power, temperature, and pressure.

In Fig. 1, GaN etch rates are shown as a function of rf-power for the ECR/RIE and RIE-only modes. As the rf-power and dc-bias increased the GaN etch rates increased. The etch rates were much higher for the ECR/RIE mode at rf-powers ≥ 50 W due to the higher ion densities generated in the ECR/RIE mode. In the ECR/RIE mode, the GaN etch rate was ≤25 Å/min without rf-power suggesting that the etch products did not desorb efficiently at low ion-bombardment energy or that a thin surface oxide was present which was not sputtered off to allow chemical etching.

In Fig. 2, the etch rates for GaN, InN, and AlN are shown as a function of ECR microwave power. As the microwave power increased, the ion density increased and the etch rates increased. The etch rate

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for InN increased by approximately a factor of 3.5 whereas the GaN and InN etch rates increased by less than a factor of 2 as the microwave power increased.

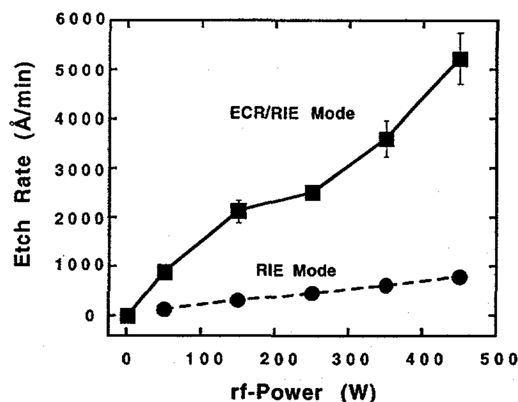

Fig. 1. GaN etch rates as a function of rf-power for ECR/RIE and RIE-only modes.

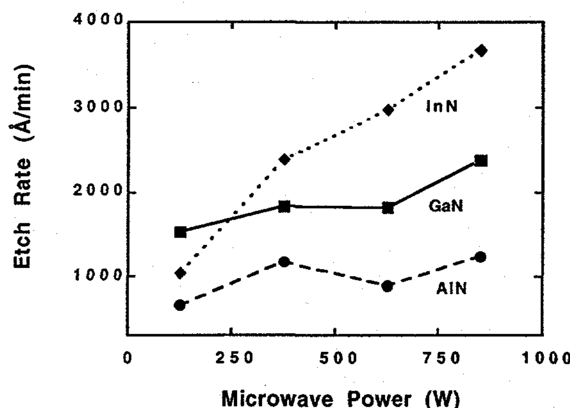

Fig. 2. GaN, InN, and AlN etch rates as a function of microwave power in the ECR/RIE mode.

GaN etch rates exceeding 6500 Å/min have been observed in the ECR/RIE mode and will be reported. Variations in surface morphology and near-surface stoichiometry were also investigated using atomic force microscopy and Auger spectroscopy and will also be discussed.

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