Helicon Discharge with Selectable Nitrogen Reactive Species Production as a Plasma Source for III–group Nitride Growth by MBE

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MOTIVATION

Investigate the production of reactive nitrogen species in a helicon discharge with the objective using a helicon source for Molecular Beam Epitaxy (MBE) growth of GaN while modifying and controlling the relative fractions of various nitrogen states (molecular, atomic, and ionic) in the plasma.

Required Steps:
- Determine which plasma species are most favorable for GaN film growth, how their kinetic energy can be controlled, and if they survive long enough to be transported from the plasma source to the growth surface.
- Generate specific reactive nitrogen species for film growth by controlling the electron energy distribution function in the plasma through fine tuning of the rf driving frequency and the source magnetic field.
- Look for correlation between the dominant species in the plasma flux reaching the substrate, GaN film quality, and GaN film growth rate.
- Explore and understand dependencies of the surface reaction mechanism on nitrogen reactive species, species kinetic energy, and species flux to the substrate as well as on pre-nitridation of the substrate.

CONTROL OF NITROGEN REACTIVE SPECIES

OPTICAL EMISSION SPECTROSCOPY

The intensity of emitted light accompanying the transition $A_1 \rightarrow A_2$ is given by:

$$I = \frac{h c}{\lambda} S(\lambda, \beta) \frac{n_j}{n_i} \int \sigma_j(\epsilon) \psi_j(\epsilon) f(\epsilon) d\epsilon$$

If the electron-impact excitation rate coefficients ($\sigma_j$) are known, the dissociation degree in nitrogen plasma could be inferred from the ratio of an atomic line ($I_{\beta}$) intensity and a molecular line ($I_{\alpha}$) intensity:

$$n_{N_j} = \frac{\lambda_{j\alpha} S(\lambda_{\alpha\beta}) Q_j}{\lambda_{j\beta} S(\lambda_{\beta\alpha}) Q_j} \frac{n_j}{n_i} I_{N_j}$$

SUMMARY

- The increase in the intensity of atomic lines relative to molecular lines as a function of rf power indicates that the mix of atomic and molecular nitrogen species can be readily modified by varying the rf power in a compact helicon source.
- By varying other plasma parameters, such as the neutral pressure, the plasma flux and the kinetic energy of activated nitrogen species impinging on the substrate could also be controlled.