Compact Helicon Plasma Source for III – N Semiconductor Growth

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.

OBJECTIVES

- 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 and species flux to the substrate as well as on pre-nitridation of the substrate and substrate temperature.
- 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 and the substrate temperature.

MOLECULAR NITROGEN SPECIES

ENERGETIC DIAGRAM

\[ I \nu' \nu = \text{const} \times S(\nu' \nu) N \nu q_\nu \nu' R_\nu (T_{\nu' \nu})^2 / \lambda_{\nu' \nu}^2 \]

A survey spectrum of nitrogen helicon discharge showing the N first positive band system (left), a detail of it showing partially resolved rotational structures of the \( B'\Pi_1 \rightarrow A'\Sigma^+ \) band (center), and a relative vibrational distribution of the \( A'\Sigma^+ \) state obtained from the emission spectrum.

Discharge parameters: \( P = 200 \text{W}, p = 20 \text{ mTorr}, B = 900 \text{ G}, f = 14.2 \text{ MHz} \).

OPTICAL EMISSION SPECTROSCOPY IN HELICON GENERATED NITROGEN PLASMA

SUMMARY

- The strong first positive emission spectrum indicates a large population of the \( B'\Pi_1 \) state and implicitly a high population of the \( A'\Sigma^+ \) metastable level. Taking into account the relatively long lifetime of this state and the fact that all upper excited levels will cascade down to this state, it is possible that in the MBE chamber, at the growing surface, to obtain a nitrogen plasma flux with a large concentration of molecules in \( A'\Sigma^+ \) state.
- The Boltzmann type vibrational distribution of \( B'\Pi_1 \) state indicates that vibration - translation and vibration – vibration energy exchange processes in helicon nitrogen plasma prevail over electron excitation processes.