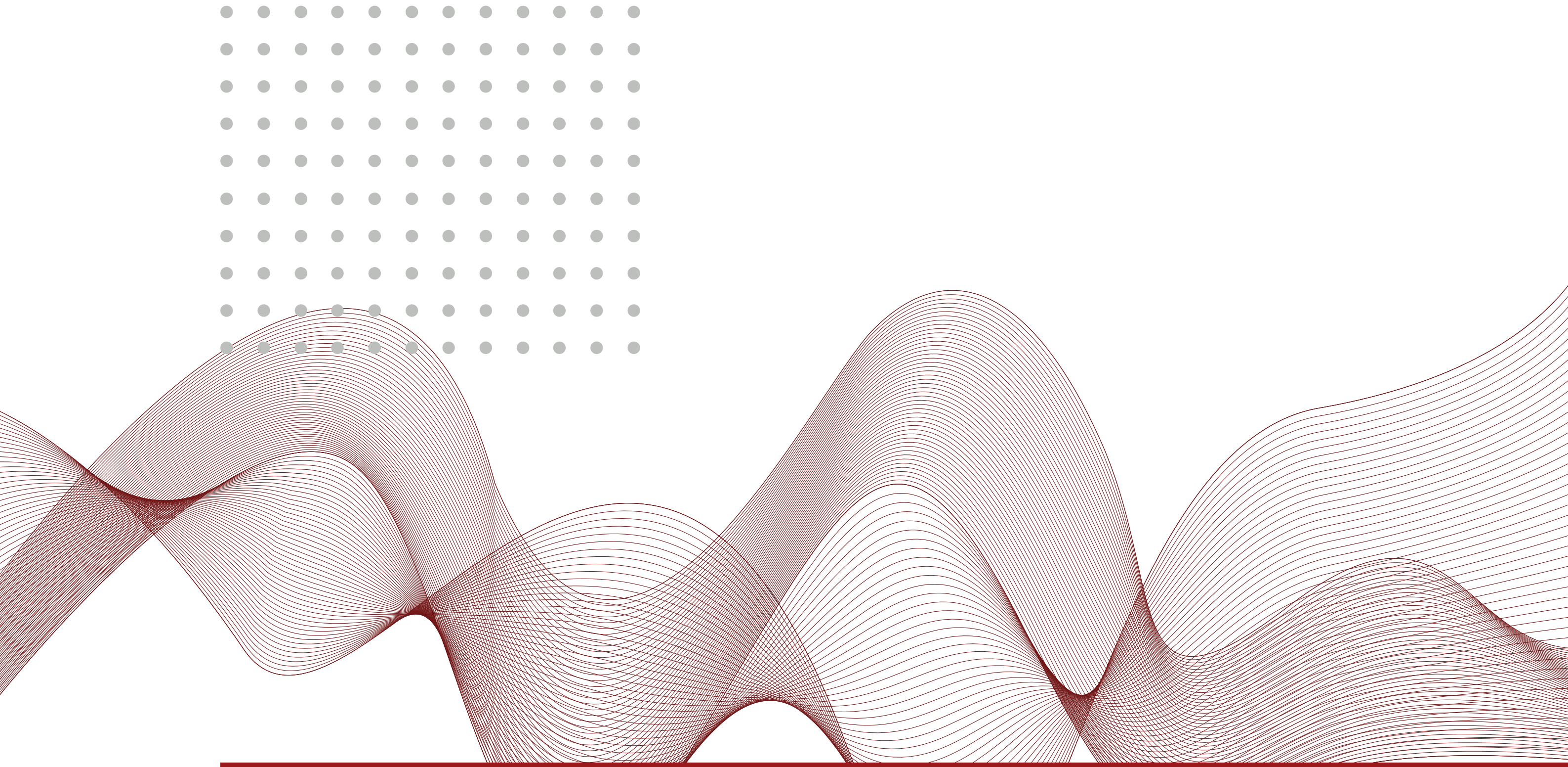

Impedans Langmuir probe used in the optimization of thin film deposition process employing microwave assisted reactive HiPIMS.

Published in Science Direct

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Introduction

Impedans Langmuir probes are versatile diagnostic tools employed in various applications to monitor and characterize plasma parameters. These probes provide valuable information about the electron density, electron temperature, and other plasma properties, which is crucial for optimizing and controlling the processes. Some of the application include thin film deposition using high power impulse magnetron sputtering (HiPIMS), plasma enhanced chemical vapor deposition (PECVD), plasma assisted atomic layer deposition (ALD) processes etc.

A recent paper published by Science Direct highlights the application of Impedans Langmuir Probe in the deposition of InN thin films through reactive HiPIMS. Utilizing Impedans Langmuir probes measurements on plasma parameters they addressed the challenges of maintaining uniformity, thickness, and stoichiometry in the deposited thin film.

Experimental setup

The deposition chamber for this study was the HEXL Modular Deposition System, equipped with a single magnetron in an unbalanced configuration. Aura-Wave ECR coaxial plasma sources from SAIREM were utilized to generate microwave volume plasma. InN thin films were fabricated using both R-HiPIMS and MAR-HiPIMS methods. Impedans Langmuir single probe measurements were employed to gather information about Ar/N2 plasma properties near the substrate during sputtering and microwave plasma conditions. Characterization of microwave plasma was conducted in time-averaged mode, while MAR-HiPIMS was analyzed in time-resolved mode.

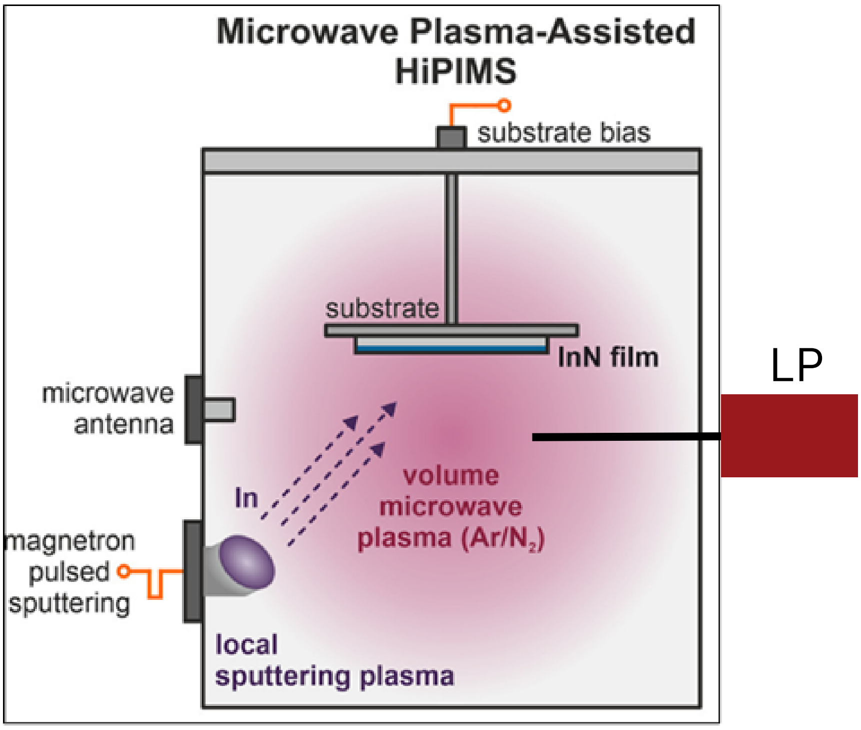


Figure 1 Schematic diagrams of the HIPIMS system

Results

Measurements using Langmuir probes were performed under microwave plasma conditions to evaluate the influence of different nitrogen flows and microwave powers on plasma potential (Vp), electron temperature (kTe), electron density (Ne), and ion density (Ni).

The results (Fig 2 A-C) disclosed clear distinctions between pure argon plasma and argon/nitrogen mixtures, irrespective of nitrogen flow. In pure argon plasma, Vp initially surged with increasing microwave power before stabilizing at 18 V, while nitrogen-containing plasma exhibited a rapid increase, stabilizing at 22 V. Electron temperature (kTe) was notably influenced by the addition of nitrogen, with the highest values observed in pure argon plasma (up to 2.4 eV). However, kTe decreased with nitrogen addition due to vibrational collisions with plasma electrons. Ne and Ni exhibited minimal variation with nitrogen addition and followed trends similar to pure argon plasma with increasing microwave power.

In the substrate region, time-resolved Langmuir probe measurements (Fig 2 D-F) under MAR-HiPIMS conditions revealed alterations in plasma properties upon initiation of HiPIMS pulses. Plasma potential (Vp) decreased from 13 V to 5 V, while electron temperature (kTe) increased from 1 eV to 3.5 eV during the HiPIMS pulse. Reductions in ion and electron density at the substrate height during the HiPIMS pulse were attributed to charged species being attracted toward the magnetron owing to the high electric field generated.

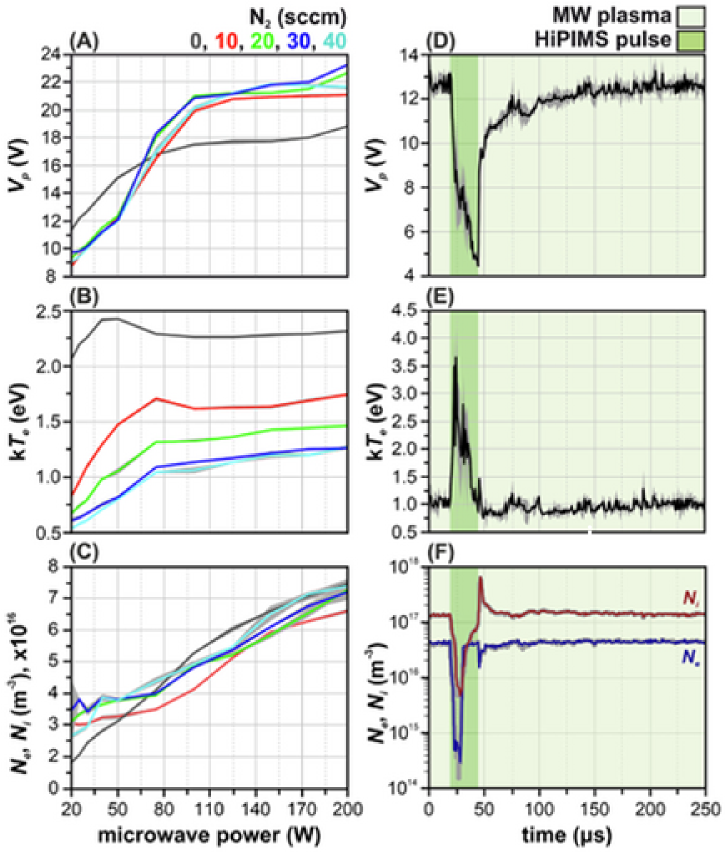
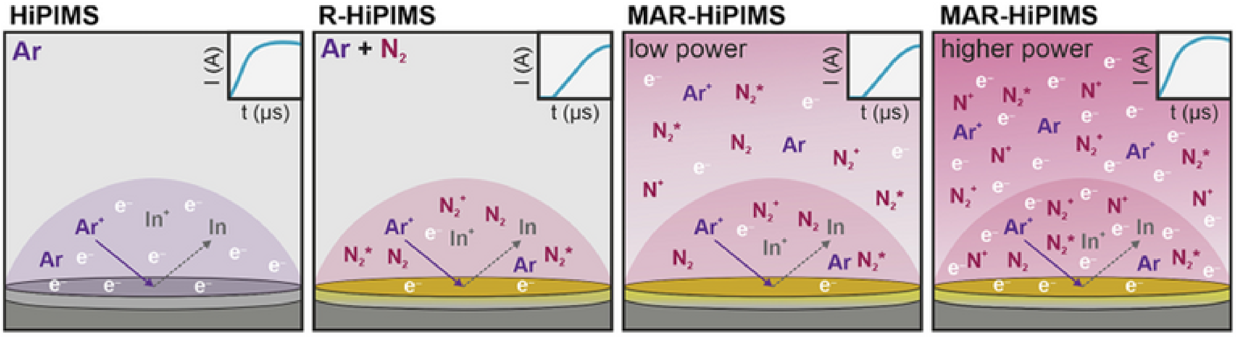


Figure 2 (a) I-V discharge curves of HiPIMS mode and DCMS mode during sputtering, (b) EEDF results of second derivative from I-V curves



- Ar plasma-forming gas
- enough electrons to sustain the discharge

- Ar/N$_2$ plasma-forming gas
- target poisoning, γ_{see} decrease
- too few electrons to sustain the discharge

- Ar/N$_2$ plasma-forming gas
- increase in reactive nitrogen
- too few electrons to sustain the discharge

- Ar/N$_2$ plasma-forming gas
- increase in reactive nitrogen
- enough electrons supplied by the MW plasma to sustain the discharge

Figure 3 Schematic representation of nitrogen reactivity vs electron generation during In sputtering via HiPIMS, R-HiPIMS, low and higher MW power MAR-HiPIMS

Summary

Langmuir probe measurements were used to observe plasma properties in HiPIMS plasma with and without microwave-assisted background plasma. The microwave plasma was examined to understand the background plasma. However, it's crucial to comprehend pulse characteristics to uncover plasma conditions in HiPIMS. Time-resolved Langmuir probe measurements were conducted to monitor changes in electron density, temperature, and plasma potential over time during and after each pulse. These measurements offered insights into the times of charge buildup and decay, aiding in understanding particle interactions during and after each pulse. This information proved valuable in optimizing thin film deposition processes and controlling film structure.

Impedans Langmuir probe measurements offer a dynamic perspective that enhances the characterization of HiPIMS and microwave plasmas. By tracking the temporal evolution of plasma properties, researchers can gain insights into the underlying processes, optimize plasma conditions, and improve the control of various applications such as thin film deposition, surface modification and material processing.

To know more about Impedans Langmuir Probe click here.