Impedans Semion RFEA and Octiv VI probe used to measure Ion Properties and Electrical Characteristics of a 60 MHz Magnetron Discharge

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Introduction

The Impedans Semion RFEA and Octiv VI Probes are vital for optimizing thin film deposition process by providing accurate plasma and RF measurements for real-time monitoring. Octiv VI probes offer cost-effective RF measurements (current, voltage, phase, impedance) in both CW and pulsed RF/DC environments, while Semion RFEA probes measure ion flux and energy distribution reaching the substrate. These critical measurements provide valuable insights into tool performance and enable the correlation of electrical variables with key process parameters, such as ion flux and deposition rates driving process efficiency and quality improvements.

A recent publication in Plasma Science and Technology discusses the use of Impedans Semion RFEA and Octiv Suite VI probes in very high frequency magnetron sputtering tools. Semion measurements were crucial in determining the optimal power range for depositing Silicon films with improved crystal structure and higher growth rates. Additionally, Octiv measurements provided valuable electrical discharge characteristics, enhancing the understanding of electron and ion behavior within the plasma.

Experimental setup

In the experiment, a 13.56 MHz RF ICP discharge was used to produce a pre-ionized plasma to assist the 60 MHz VHF magnetron discharge at low pressure. Figure 1 shows the schematic diagram of the experimental set up. The Argon was used as the discharge gas. The operating pressure was chosen as about 1Pa and 5Pa. The Si target was powered by 60 MHz source while the substrate holder was electrically floated.

The ion velocity distribution function (IVDF) and ion flux density to the substrate were measured using the Impedans Semion HV-2500 retarding field energy analyzer (RFEA). The Impedans Octiv Suite V–I probe, connected between the matching box and Si target, was used to measure the electric characteristics, including the discharge current, discharge voltage, discharge power, and discharge impedance.

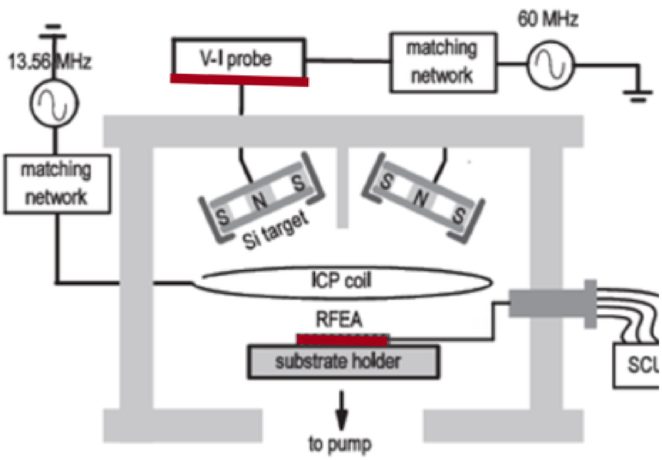

Figure 1 Schematic diagram of the 60 MHz VHF magnetron sputtering assisted by the 13.56 MHz ICP discharge.

Results

Figure 2 shows the variation of ion flux density with the sputtering power for the magnetron discharge. It is seen that by reducing the discharge pressure, the ion flux density of VHF magnetron discharge can be increased largely.

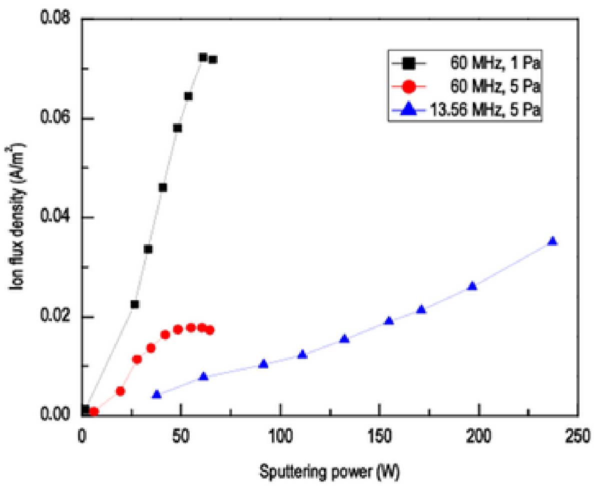

Figure 2 Variation of ion flux density with sputtering power increase for the magnetron discharge at 60 MHz and 1 Pa, 60 MHz and 5Pa as well as 13.56 MHz and 5Pa.

Figure 3 shows the variation of maximum ion energy with the sputtering power. The energy difference between 1 and 5 Pa discharges is about 13.7–16.7 eV. For the 13.56 MHz magnetron discharge at 5Pa, the maximum ion energy is found to vary between 15.9 and 17.7eV, showing a slight increase as sputtering power rises from 38.0 W to 237.2 W. This indicates that lowering the discharge pressure significantly enhances the maximum ion energy in the VHF magnetron discharge.

Therefore, by incorporating the ICP-assisted discharge, a pre-ionized VHF magnetron discharge can be achieved at low pressure, leading to a substantial improvement in ion properties for the VHF magnetron discharge.

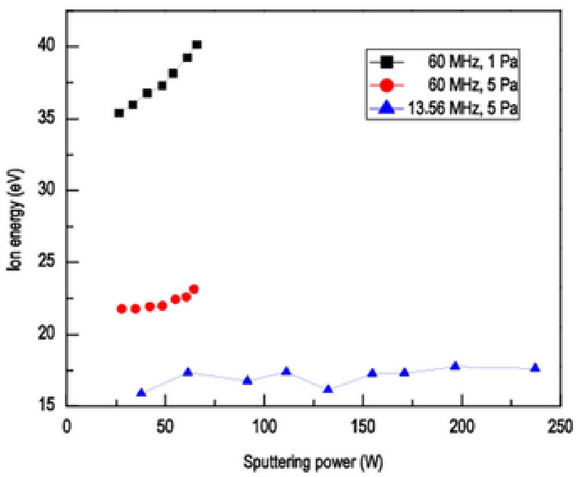

Figure 3 Variation of maximum ion energy with sputtering power increase for the magnetron discharge at 60 MHz and 1Pa, 60 MHz and 5Pa as well as 13.56 MHz and 5Pa.

The electrical characteristics of the VHF magnetron discharge were further examined using V–I probe measurements. Figure 4 presents the power–current (P–I) characteristics of the magnetron discharge. The near quadratic dependence of power on current ($P \propto I^2$) indicates that the VHF and RF power is primarily dissipated in the ions within the sheath region.

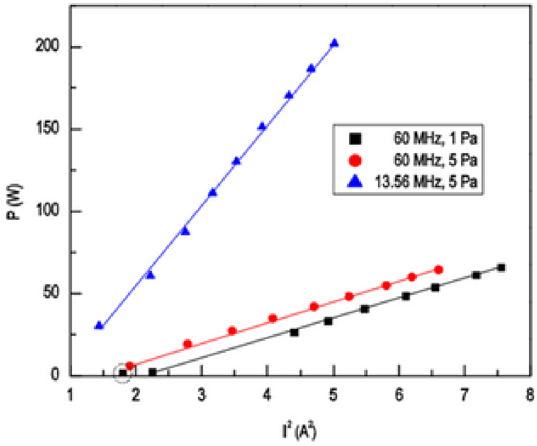

Figure 4 P– I² curves of 60 MHz VHF sputtering at 1 and 5 Pa as well as 13.56 MHz RF sputtering at 5Pa.

Summary

Semion measurements enabled researchers to gain insights into the ion properties of the VHF magnetron discharge. Meanwhile, Octiv's electrical measurements provided a deeper understanding of electron and ion dynamics, essential for stable discharge operation at very high frequencies.

Using both Impedans Semion and Octiv probes in sputtering discharges at frequencies like 60 MHz offers valuable data, aiding in the deposition of films with dense, smooth surfaces, well-defined crystalline structures, and higher growth rates.