Ion beam assisted chemical vapor deposition of hybrid coating

Process diagnostics and mechanisms

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Introduction

Ion beam assisted chemical vapor deposition (IBA-CVD) is a promising thin-film fabrication method that employs an ion source discharge to decompose organic monomer molecules. The liquid monomer Hexamethyldisiloxane (HMDSO) was used as a model precursor for the fabrication of low index optical coatings. Assessment of the discharge parameters were performed using Impedans Langmuir Probe named as Plato probe. **Correlation between the discharge parameters, ion beam density and precursor flow rate were established to understand the plasma polymerization process.**

Experimental setup

Experiments were conducted to apply HMDSO films onto Si wafers using an ion beam-assisted chemical vapor deposition process within the Boxer Pro pilot box-coater deposition system by Leybold. The primary deposition chamber, featuring a rectangular shape with a 70 × 70 cm^2 base and 85 cm height, was employed. The experimental setup is illustrated in Figure 1. The end-Hall ion source (KRI eH-2000) served as the plasma source. A carrier gas mixture of Ar (10 SCCM) and O2 (10 SCCM) facilitated the discharge operation. A controlled flow of HMDSO (2–20 SCCM) was introduced into the deposition chamber via a gradually heated gas line positioned approximately 30 cm above the ion source.

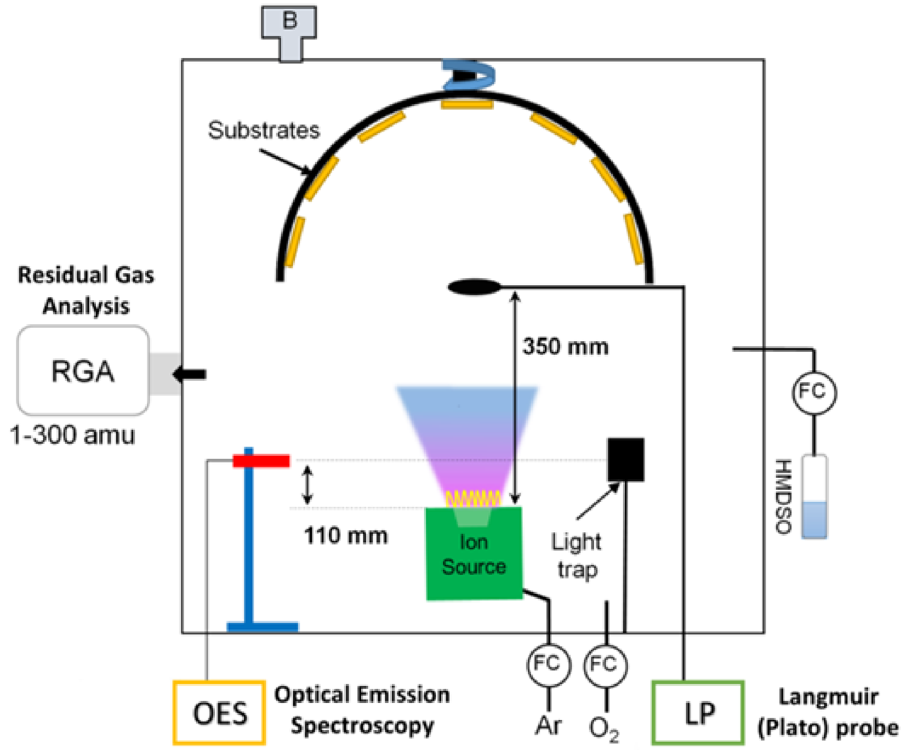

Figure 1 Schematic representation of the deposition system, including the configuration of the diagnostic equipment.

The plasma parameters were assessed using a planar Langmuir Probe (LP) referred to as the Plato probe, manufactured by Impedans Ltd. This probe was specifically designed for in situ analysis of the plasma within an organic working gas mixture, capable of reliable operation even with dielectric layers up to 50 μm in thickness.

Results

The Langmuir Probe (LP) measurements revealed the patterns of two crucial ion source discharge parameters, namely electron temperature (Te) and ion flux (Ji), depicted as functions of discharge current and the flow of HMDSO in Fig. 2. It was observed that Te remains relatively low, not exceeding 4.5 eV at a distance of 350 mm from the ion source's top plate. The behaviors of Te and Ji exhibit a strong correlation. As illustrated in Fig. 2(a), an increase in discharge current (Id) results in a linear growth of both ion flux and electron energy, aligning well with our previous findings in precursor-free discharges. Conversely, the monomer flow exerts an inverse effect: it causes a linear reduction in both ion flux and electron energy as the flow increases from 2 to 20 SCCM. This behavior indicates the significant inelastic interactions between discharge species and monomer molecules.

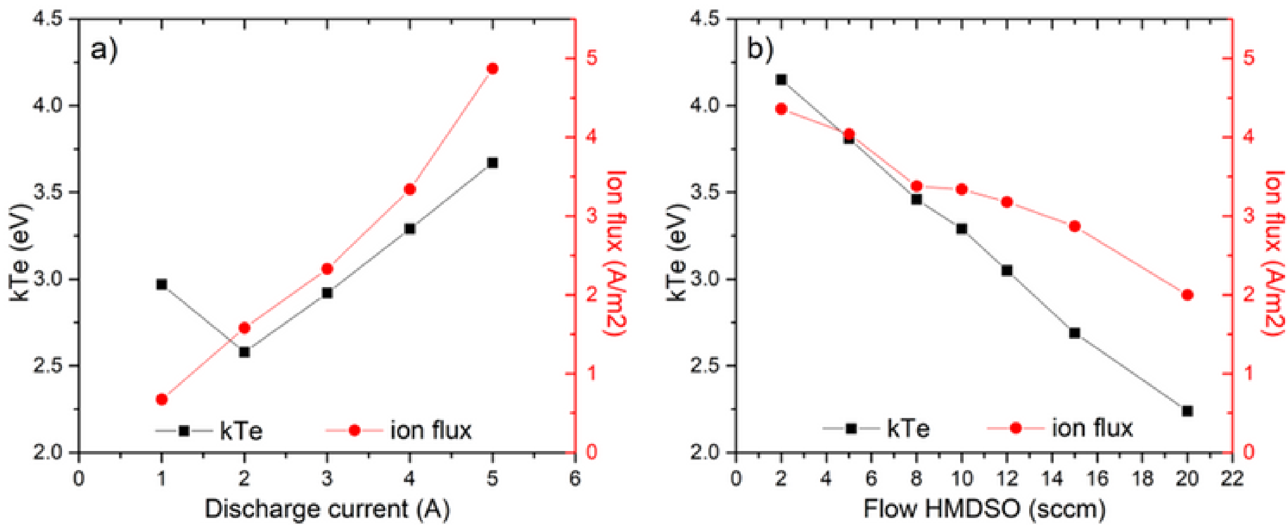

Figure 2 Electron energy (kTe) and ion flux as a function of discharge current (a) and precursor flow (b).

Summary

The utilization of the Langmuir probe diagnostic aimed to elucidate the gas-phase kinetics involved in the ion beam-assisted chemical vapor deposition process. The liquid precursor HMDSO served as the model monomer. **The results of the detailed characterization of the discharge characteristics revealed that the initiation of monomer molecules could be triggered by both ions and electrons, with ions expected to exert a dominant influence due to their significantly higher energy.** This distinctive aspect marks a notable difference between the ion beam-assisted chemical vapor deposition process and plasma-enhanced chemical vapor deposition (PECVD), where electrons are typically regarded as the primary species in plasma polymerization.