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Thin film deposition using rarefied gas jet

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The rarefied gas jet of Aluminium is studied at Mach number Ma = (U_j / \sqrt{kb T_j / m}) in the range 0.01 < Ma < 2, and Knudsen number Kn = (1 / (\sqrt{2} \pi d^2 n_d H) in the range 0.01 < Kn < 15, using two-dimensional (2D) Direct Simulation Monte Carlo (DSMC) simulations, to understand the flow phenomena and deposition mechanisms in a physical vapor deposition (PVD) process. Here, H is the characteristic dimension, U_j and T_j are the jet velocity and temperature, n_d is the number density of the jet, d is the molecular diameter, and kb is the Boltzmann constant.

The variation of local flux along the stream-wise direction away from the jet are studied. The qualitative nature of the local flux at high Mach number (Ma = 2) is similar to those in the incompressible limit (Ma = 0.01). These include the initial fast decay, then slow variation, and finally rapid decay near the substrate. However, there are important differences. The amplitudes of the local flux increase as the Mach number increases. There is significant velocity and temperature slip ((Pradhan and Kumaran, JFM-2011); (Kumaran and Pradhan, JFM-2014)) at the solid surfaces of the substrate.

An important finding is that the capture width (cross-section of the gas jet deposited on the substrate) is symmetric around the centerline of the substrate, and decreases with increased Mach number (Ma from 0.01 to 2) due to an increase in the momentum of the gas molecules. DSMC simulation results reveals that at lower Knudsen number ((Kn = 0.01) ; shorter mean free paths), the atoms experience more collisions, which direct them toward the substrate. However, the atoms also move with lower momentum at low Mach number (Ma = 0.01), which allows scattering collisions to rapidly direct the atoms to the substrate. At high Knudsen number ((Kn = 15); longer mean free paths), the atoms travel greater distances without depositing onto the substrate.

Keywords
Thin film
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