NOZZLE OPTIMIZATION FOR DISSOCIATED SPECIES TRANSPORT IN LOW PRESSURE PLASMA CHEMICAL VAPOR DEPOSITION

C. George[1], G. Candler[2], R. Young[3], E. Pfender[1] and J. Heberlein[1]

[1] University of Minnesota, Department of Mechanical Engineering
[2] University of Minnesota, Department of Aerospace Engineering
[3] Westinghouse Electric Corp.
1310 Beulah Road, Pittsburgh, PA 15235

Abstract

Converging-diverging nozzles may be used to transport dissociated precursors in plasma-assisted chemical vapor deposition processes. To assist in system scale-up and optimization, it is important to maximize the transport of chemically active species to the substrate.

In this paper implications for effective nozzle design are discussed. Running a plasma torch off design power can significantly alter power losses through the nozzle wall and subsequently change the species distribution at the nozzle exit. Decreasing the effective nozzle throat diameter can notably decrease atomic concentrations. Small changes in upstream or downstream pressures have a negligible effect on supersonic species transport through the nozzle. Flow separation can be avoided by correctly designing the divergent portion of the nozzle.

A two-dimensional computational model of a supersonic plasma nozzle is described for examining the chemical non-equilibrium of the flow, the effect of different flow parameters, and the effect of different nozzle geometries. A finite volume method, using modified Steger-Warming flux vector splitting, was utilized to solve the governing equations over the flow domain. A three species hydrogen-argon gas mixture was modeled with finite dissociation/recombination rates. Non-equilibrium transport and thermodynamic mixture properties based on species pair collision cross sections were implemented and compared to the semi-empirical formulation of Wilke. It was found that for non-ionized or weakly ionized gases, the Wilke mixing rule is valid. Realistic input plasma profiles were calculated by iterating over known power and mass flow values.