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Kinetic Modeling of Roll to Roll RFCVD Plasma

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ABSTRACT

Roll-to-roll radio frequency plasma enhanced chemical vapor deposition (R2R RFCVD) is a technique for large-scale synthesis of high quality graphitic nanopetals. Graphitic nanopetals are petal-like graphene structures with remarkable electrical and mechanical properties with major industrial applications such as microsupercapacitors. RFCVD uses a non-equilibrium plasma with high energy electrons to catalyze chemical reactions, induce the creation of free radicals, and promote otherwise high temperature chemistry in a low temperature environment. Understanding how bulk plasma characteristics (particularly, power and number densities) vary with changing reactor parameters is an important step towards optimizing synthesis techniques. In our present work we use the particle-in-cell method with Monte Carlo collisions (PIC/MCC) to better numerically investigate plasma characteristics for a setup present at the Birck Nanotechnology center. In order to estimate breakdown voltages near the electrodes a modified Paschen curve calculator was developed using the work by Venkattraman and Alexeenko. To decrease computational time, an analysis was performed on whether resolving plasma sheath thickness was an adequate criterion for PIC/MCC cell size. It was found that power at moderate pressures (1-100 Torr) reached a maximum density of 10^9 W/m^3 . Further, resolving the sheath thickness agreed with the results found by traditionally resolving the Debye length to within 15 percent. These results suggest methods to increase RFCVD reactor efficiency as well as decrease computational time for future simulations of these systems.

KEYWORDS

Plasma,RFCVD,Carbon Nanopetals, Modified Paschen Curve, PIC,MCC, Kinetic Modeling,