PhD Defense Presentation

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2219 Engineering

SELF-CONSISTENT MODELING OF HYDROGEN-BASED PLASMAS IN MICROWAVE PLASMA-ASSISTED CHEMICAL VAPOR DEPOSITION REACTORS AT MODERATE PRESSURES

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ABSTRACT

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Microwave Plasma-Assisted Chemical Vapor Deposition (PACVD) systems are used in the deposition of high quality diamond films. These systems have traditionally been operated at less than 20% atmospheric pressure (atm), resulting in growth rates of up to 5 µm/hr. Under such conditions, the system operation and plasma behavior are well-understood and have been successfully modeled. Recent experiments at pressures approaching 40% atm have demonstrated faster growth rates and better quality samples. At these increased pressures, the system operation and plasma behavior are not completely understood, with unusual plasma behavior sometimes observed. Experimental measurements within these systems can be difficult, making numerical models attractive for aiding in understanding this behavior. This thesis presents a self-consistent multi-physics numerical model of Microwave PACVD systems, which is accurate under these operating conditions. Electromagnetic field propagation, chemical reactions, species diffusion, thermal processes, energy transfer, and convective flows are all included in the self-consistent model. The model is verified against canonical problems, and validated against both experimental data and similar, previously-developed numerical codes at lower pressures. Numerous plots of substrate temperature distributions, species densities, and plasma temperature are provided at several operating conditions. Extensive numerical results of the convective flow patterns and their effects on the plasma behavior are also detailed. These results suggest the average gas flow is primarily upward directed inside the plasma at these increased pressures. Convective forces are always present in the plasma, and become more significant as the gas flow speed increases. Finally, further physical models to be added to future versions of the simulation are also recommended.
JOURNAL ARTICLES


JOURNAL ARTICLES IN PREPARATION


C. S. Meierbachtol, T. A. Grotjohn, B. Shanker, Modeling of Near Substrate Effects in Microwave Plasma-Assisted Chemical Vapor Deposition Reactors at Moderate Pressures, 2013.

THESAUS


CONFERENCE PROCEEDINGS


T. A. Grotjohn, C. S. Meierbachtol, B. Shanker, Modeling of Moderate Pressure Mi-


INVITED TALKS


CONFERENCE PRESENTATIONS


J. C. Myers, K. Y. Park, C. S. Meierbachtol, P. Chahal, Planar Surface Plasmonic Structures for Terahertz Waveguides and Devices, 2012 Michigan State University College of


C. S. Meierbachtol, T. D. Brown, Surface Plasmon Enhanced Electromagnetic Fields within a Prism Coupler - Al$_{0.2}$Ga$_{0.8}$N/GaN High Electron Mobility Transistor System at Resonance, AVS Michigan 36th Spring Symposium, East Lansing, MI, 2009.