Particle in Cell Modeling of Low Pressure Capacitively Coupled Plasmas

Shahid Rauf

Capacitively coupled plasmas (CCP) are widely used for thin-film etching and deposition in the semiconductor industry. CCPs are operated at low pressure (mean free path comparable to gap) for many applications, where kinetic phenomena dominate the plasma behavior. Even though fluid and hybrid plasma models are the primary modeling tools in the industry for plasma system design, analysis of these low-pressure CCPs requires kinetic techniques. Particle-in-cell (PIC) is one of the most attractive options for kinetic plasma modeling due to its simplicity and accuracy. PIC simulations can, however, be slow and PIC is limited in the range of problems it can address. This presentation is an overview of some of the PIC modeling our team at Applied Materials has done in recent years. We first describe out PIC modeling code, in particular the aspects that make PIC simulations faster as well as practical in 2D cylindrical geometry. Several 1D PIC studies of He, Ar, and O_2 plasmas are next discussed with a focus on model validation and verification. The last section of the presentation deals with the 2D modeling of several capacitive plasmas. These 2D modeling studies examine transport in low-pressure CCPs, the effect of low-frequency bias voltage waveform on plasma uniformity in dual-frequency CCPs, and capacitively coupled hollow cathode discharges.

Coauthors: Jun-Chieh Wang, Han Luo, Peng Tian, Kallol Bera, Jason Kenney, Ihor Korolov and Julian Schulze

Bio of Shahid Rauf:

Shahid Rauf is the managing director of plasma technology at Applied Materials (Sunnyvale, California, USA). He joined Applied Materials in 2006, where he has held responsibility for plasma and electromagnetic modeling, plasma diagnostics, and plasma source development. Dr. Rauf received his Ph.D. from the University of Wisconsin, Madison in 1995 based on theoretical research on nonlinear plasma waves. He spent the following 3 years in Mark Kushner's lab at the University of Illinois, Urbana-Champaign focusing on the modeling of low-temperature plasmas, plasma processing, and plasma displays. Dr. Rauf joined the Semiconductor Products Sector of Motorola Inc. (subsequently renamed Freescale Semiconductor) in Austin, Texas in 1998, where he worked until 2006 on plasmas applications in semiconductor manufacturing and modeling of microelectronics devices. Dr.

Rauf has contributed to > 100 journal papers, > 80 patents, and > 250 conference presentations, most on topics related to the physics, applications, and modeling of plasmas.