DOE Plasma Science Center Fellowships Report

Romain Le Picard, Dept. of Mechanical Engineering, University of Minnesota, Minneapolis, MN 55455, USA

To foster the collaboration between Girshick's group (University of Minnesota) and Kushner's group (University of Michigan), I visited the Computational Plasma Science group headed by Prof. Kushner from January 14th to 18th, 2013. I am thankful for the long discussions I had with Prof. Kushner and his PhD student Sang-Heon Song.

Project description

Girshick's group developed a 1D model, following the spatiotemporal growth of nanoparticles in RF Argon-Silane plasmas, using a sectional method [1]. Nucleation, coagulation, surface growth, and charging of nanoparticles are solved self-consistently in plasma and aerosol modules. Figure 1 shows a typical nanoparticle distribution in size and charge. The group has decided to extend the model to a broader range of conditions and geometries. Therefore, the Aerosol module created by the group will be implemented in the 2D plasma solver developed by Kushner's group [2], HPEM (Hybrid Plasma Equipment Model). Figure 2 shows typical output from HPEM. The purpose of this visit was to discuss in depth the architecture of both codes and find the most convenient way to merge them together.

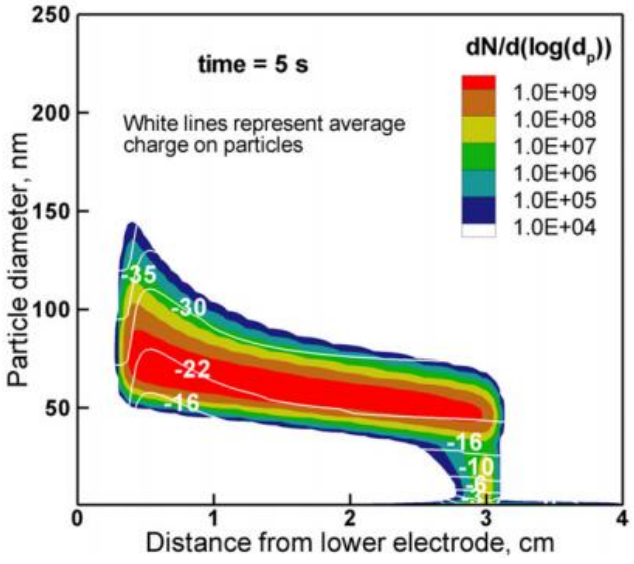

Figure 1 Particle size distribution and average particle charge at t = 5 s

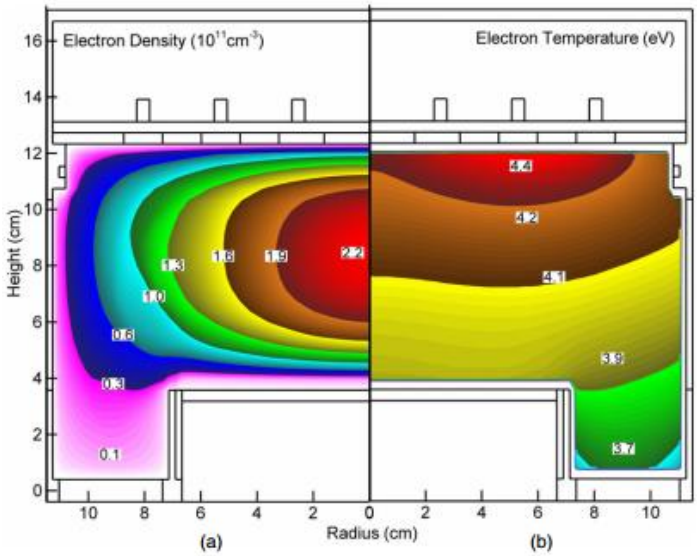

Figure 2 Plasma properties for an Ar/C4F8 ICP with a CCP bias on the substrate. (a) Electron density and (b) electron temperature

Research conducted

Following are the topics treated during the stay:

- **HPEM**

  Discussion with Prof. Kushner and Sang-Heon Song helped me to understand better the structure of HPEM. Exchange of variables using common blocks is now clear and enables me to find the most convenient way to include the Aerosol module making minimum changes to HPEM.

- **Framework**

  A new module called AEROSOL has been added to HPEM. In icp.nam, in which parameters of simulations are chosen, it is now possible to select if (1) nucleation, (2) coagulation, (3) charging, (4), surface growth, (5) ion drag, (6) neutral drag, (7) thermophoresis, (8) gravity will be considered.

- **Dust particles in HPEM**

  A dust particle is defined by a size and a charge. The current version of the Aerosol code studies the evolution over a broad range of size, which implies a broad range of charges. In [1], more than 12,000 different particles are computed at the same time. How to take into account the dust particles in HPEM was discussed.

  It has been decided that for the first version implementing the Aerosol code only a limited number of particles (≈ 50) will be followed. This would be appropriate for cases in which particles do not reach more than 10 nm in diameter. Once the method is validated, a number of changes will be needed to increase the number of dust particles.

References

[1] P. Agarwal and S. L. Girshick, Plasma Sources Sci. Technol. **21** (2012) 055023
[2] M. J. Kushner, J. Phys. D: Appl. Phys. **42** (2009) 194013