The Global Kinetic Model for Laboratory and Space Plasma

Shanti Thagunna[1] (skt0009@uah.edu), Dr. Gary Zank [1], Dr. Vladimir Kolobov[1]

[1] Department of Space Science, University of Alabama in Huntsville , Huntsville, AL 35805

Introduction

Global Model is a numerical method to simulate plasma properties using a space averaging procedure. The simulation method can be applied to problems related to

- Low pressure processing reactors
- Space plasma
- Dusty plasma
- Plasma-liquid interaction
- Atmospheric pressure Plasma jets

Global fluid model for collisional low-temperature plasma:

- The densities of ions and neutral particles are calculated using the particle balance equations
- The electron density is calculated by using quasi-neutrality condition
- The electron mean energy (temperature) is calculated using energy transport equations
- Gas temperature is calculated from Gas Pressure Law.

Global Kinetic Model(GKM), is a hybrid numerical method where a Non-Maxwellian electron energy distribution function is calculated solving Boltzmann equation to find transport properties and electron-induced rate coefficient. With these variables fluid model is solved for plasma parameters.

CFD-ACE+ Suites

CFD-ACE+ Suites is a commercial software which provides

- an integrated geometry and grid generation software,
- a graphical user interface for preparing the model,
- a computational solver for performing the simulation and
- an interactive visualization software for examining and analyzing the simulation results.
(Source: CFD-ACE+ website)

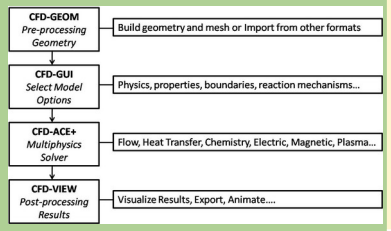

Fig: CFD-ACE+ suites flow chart

Chemistry

- We developed a global kinetic model of hydrogen-based plasmas taking into account electron kinetics, the kinetics of vibrational states of molecules, and non-equilibrium chemistry of Ion and neutral species.
- The key species include the ground state hydrogen atom and molecules, vibrationally excited hydrogen molecules, electronically excited hydrogen atoms, several positive ions, and electrons
- The key chemical reactions are electron induced direct ionization and dissociation of molecules, excitation of vibrationally excited states of molecules and electronically excited hydrogen atoms, step-wise ionization and wall recombination of ions.

No	Equation	Notes	Apf	nf	mf	(Ea/R)f	Apb	nb	mb	(Ea/R)b
1	E+H2->2H+E	Source:...	0	0	0	0				
2	E+H2->H2++2E	Source:...	0	0	0	0				
3	E+H2->H+H*+E	Source:...	0	0	0	0				
4	E+H2->H++H+2E	Source:...	0	0	0	0				
5	E+H2->H2+E	Source:...	0	0	0	0				
6	E+H2->H2+E	Source:...	0	0	0	0				
7	E+H->H+E	Source:...	0	0	0	0				
8	E+H->H++2E	Source:...	0	0	0	0				
9	E+H->H*+E	Source:...	0	0	0	0				
10	E+H2+->2H	Source:...	0	0	0	0				
11	E+H2+->H++H+E	Source:...	0	0	0	0				
12	E+H2+->2H++2E	Source:...	0	0	0	0				
13	E+H3+->2H+H++E	Source:...	0	0	0	0				
14	E+H3+->H2+H	Source:...	0	0	0	0				
15	E+H+->H	Source:...	1.495E-...	-0.64	0	0				
16	E+H+->H*	Source:...	1.213E-...	-0.68	0	0				
17	E+H*->H*+E	Source:...	0	0	0	0				
18	E+H*->H++2E	Source:...	0	0	0	0				
19	3H->H2+H	Source:...	1.38E-44	0	0	0				
20	2H+H2->2H2	Source:...	2.67E-43	-0.6	0	0				
21	H2++H2->H3++H	Source:...	1.587E-...	-0.63	0	-513.76				
22	H2++H->H++H2	Source:...	5.699E-...	1.07	0	282.94				
23	H++2H2->H3++H2	Source:...	3.2E-41	0	0	0				
24	H++H2->H+H2+	Source:...	2.5E-15	0	0	0				
25	H+->H		1	0	0	0				
26	H2+->H2		1	0	0	0				
27	H3+->H2+H		1	0	0	0				
28	H*->H		0	0	0	0				

Fig: List of chemical reactions used for GKM Simulations

Validation and Results

GEC reference cell with radius 80 mm and length 50 mm. (Samuell & Corr,2015).

Power input 100 W- 1200 W.
Pressure 10 mTorr-100 mTorr.

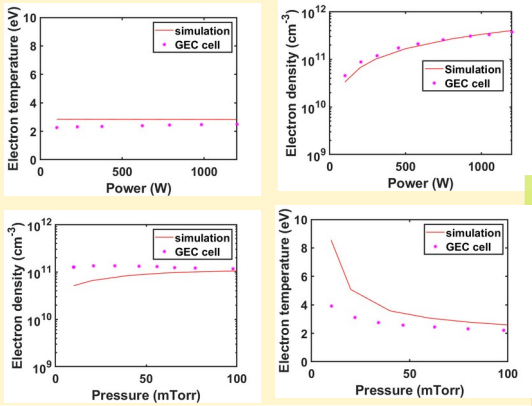

Fig: Electron density and electron temperature as a function of pressure at power of 300 W and power at pressure of 75 mTorr. Solid lines are results from the Global kinetic simulation of molecular hydrogen and asterisk are results from the GEC reference cell (Samuell & Corr, 2015).

Summary

- Base case power and pressure are 300 W and 75 mTorr.
- Energy range for the EEDF calculations is 0 to 40 eV with 400 energy grid points.
- At low pressure, there is an overestimation of electron temperature by a factor of 2 and underestimation of electron density by order of 1.
- This may be because of a reduction in the power coupling efficiency at low pressure.

Future Work

- Testify the model for LTP in Mesosphere.
- Simulate H_2-H_2B_6 for better understanding and control of plasma deposition.

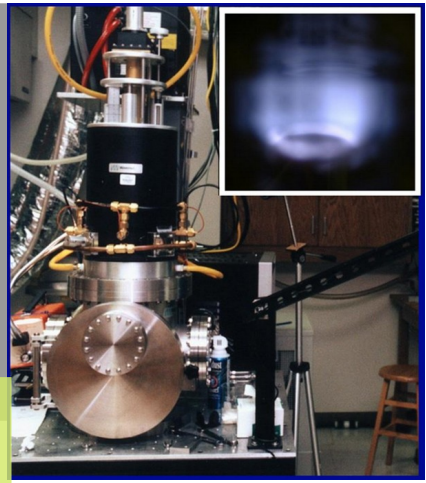

Fig: MPCVD Reactor at UAB Lab

References and Acknowledgment

Samuell, C. M., & Corr, C. S. 2015, Plasma Sources Science and Technology, 25, 015014, Doi: 10.1088/0963-0252/25/1/015014

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