Created in COMSOL Multiphysics 5.3

Capacitively Coupled Plasma Reactor

The CCP Reactor

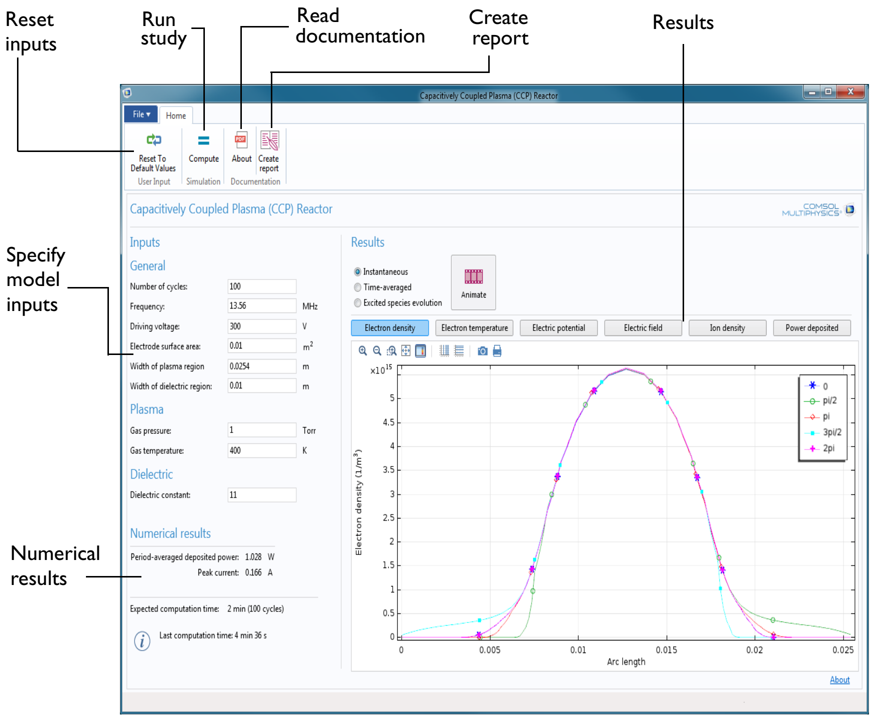
The NIST (National Institute of Standards and Technology) Gaseous Electronics Conference (GEC) CCP reactor provides a platform for studying capacitively coupled plasmas (CCP). However, even the simplest CCP plasma models are quite involved. A 1D example helps in understanding the physics without excessive CPU time. The problem has no steady-state solution, although a periodic steady-state solution is reached after a suitable number of RF cycles (usually >1000).

The operating principle of a capacitively coupled plasma is different when compared to the inductive case. In a CCP reactor, the plasma is sustained by applying a sinusoidal electrostatic potential across a small gap filled with a low pressure gas (typically 1 Torr). This application uses argon because the plasma chemistry is very simple. The mechanism of power deposition into a CCP reactor is highly nonlinear and the system needs sufficient RF cycles in order to reach a periodic steady-state solution.

The application is configured using three panels:

- The **Inputs** panel provides inputs to configure the properties of both the plasma and the dielectric along with general operation inputs such as the physical dimensions of the cell, the number of RF cycles and driving frequency and voltage.
- The graphical simulation results are displayed in the **Results** panel. Plots are available showing time/period averaged data and instantaneous data over the last RF cycle, along with excited species evolution. Animations of the time-averaged data are also available.
- Numerical data are displayed in the **Numerical Results** panel. This data includes the period-averaged deposited power (W) and the peak current (A).

There is also a settings form, shown by clicking on the **Settings** button in the ribbon. This allows you to specify which format to use when generating the report, the options are HTML or Microsoft Word.



The Embedded Model

The embedded model uses several Reaction, Electron Impact Reaction, and Surface Reaction features within the Plasma interface to calculate the evolution of the argon plasma chemistry within the device. A Surface Charge Accumulation feature is used at the plasma/dielectric interface and a Terminal feature is used to drive the system.

MODEL DEFINITION

The model is a simple 1D geometry with a 2.54 cm plasma region adjacent to a 1cm dielectric; the cross-sectional area of the geometry is 0.01 m^2. The initial gas temperature is 400 K and the gas pressure is 1 Torr. A potential of 300V at 13.56 MHz is used to drive the plasma.

Figure 1 shows the concept of the CCP reactor and the representative 1D geometry used in this application.

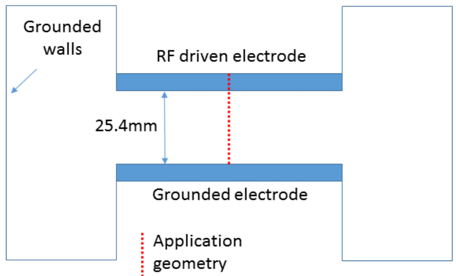


Figure 1: Geometry of the CCP reactor. The dotted red line shows the 1D representative geometry used in this application.

RESULTS

Plots of the electron/ion number densities, electron temperature, the electric potential, the electric field, and the deposited power are available for view in the **Results panel**.

This data can be displayed for instantaneous points or time-averaged over the last cycle.

In addition, the excited species evolution is available to plot. This will show if the CCP reactor has reached steady-state, which can take around 3000 RF cycles.

Animations of the above quantities are available also.

The **Numerical results** panel holds the results of the period-averaged deposited power and peak current evaluations.

APPLICATION NOTES

The modeling and subsequent analysis of capacitively coupled plasmas necessitates the output of many plots, many more than even this application contains. Displaying graphics on forms is a relatively expensive process with respect to the graphics card resources. To avoid potential problems this application has been specifically designed to minimize the number of graphics objects used. To display all 12 results (along with the animations), only 3 graphics canvas objects are used, one for each kind of plot (instantaneous, time-averaged etc). This is achieved by the use of toggle buttons along with a method to dynamically switch the canvases to point to the appropriate model plot groups.

Reference

1. G.J.M. Hagelaar and L.C. Pitchford, "Solving the Boltzmann Equation to Obtain Electron Transport Coefficients and Rate Coefficients for Fluid Models," *Plasma Sources Sci. Technol,* vol. 14, 722–733, 2005.

Application Library path: `Plasma_Module/Applications/ccp_reactor`