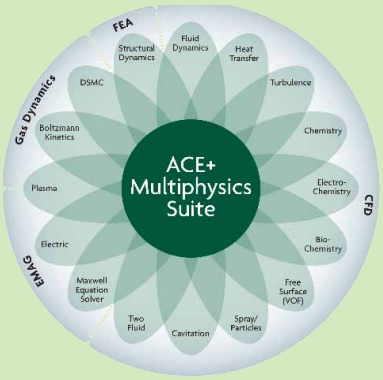
get it right®

ELECTROMAGNETIC WAVE EFFECTS IN CCP REACTORS

WITH ACE+ SUITE

KEY BENEFITS

- 0D, 1D, 2D, and 3D modeling
- Hybrid meshes
- Parallel computation
- ICP, CCP, discharge models
- Maxwellian and non-Maxwellian EEDF
- Databases for reaction mechanisms
- Material properties
- Coupling with external circuit models (SPICE)



ACE+ Suite is a leading multiphysics platform with a wide range of capabilities.

ACE+ Suite couples electromagnetic solutions with plasma models for comprehensive CCP (capacitively coupled plasma) reactor design and optimization tools. Electromagnetic wave effects can influence plasma distribution in CCP reactors. The use of higher frequencies and larger wafers necessitates the consideration of coupled phenomena for reactor modeling and design.

Solving CCP reactors using traditional Poisson Equation:

- This approach involves solving the Poisson equation to obtain the electric field distribution that is then applied to solve charged particle equations in a time marching schema. This approach is acceptable for low frequencies (e.g. 13.56 MHz) and small wafers (e.g. 2" in diameter).

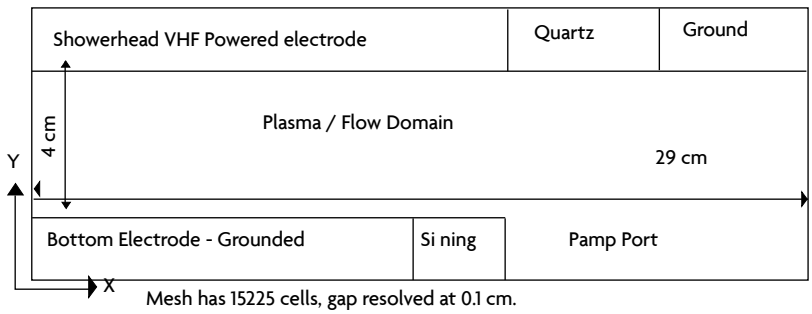
Solving CCP reactors using coupled electromagnetic and plasma models:

- This approach couples a full wave electromagnetic solver with plasma models resolving wave effects and their influence on charged species distribution. ACE+ Suite complements the traditional approaches and computational theories to enable accurate modeling of generic large area high frequency plasma reactors.

ACE+ Suite validates the modeling results against experimental and published data and enhances robustness to address scaling issues in large area reactor modeling.

The enhanced ACE+ Suite implementation is being developed and initial results are presented here. The new models are expected to be released with V2011.0

GEOMETRY AND CONDITIONS

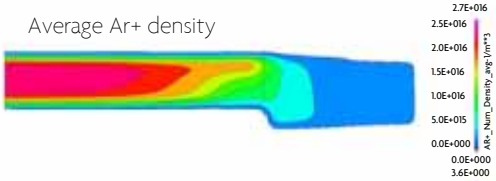


Geometry: 3-D sector CCP reactor shown on X-Y plane in the figure.

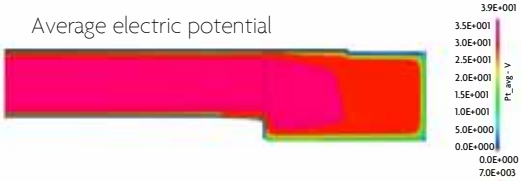
Boundary Conditions: Outer walls and pump port are assumed grounded. At material interfaces with perfect electrical conductors, tangential component of A is zero. Symmetry conditions at both the vertical faces of the 3-D sector are along the center axis.

BASE CASE

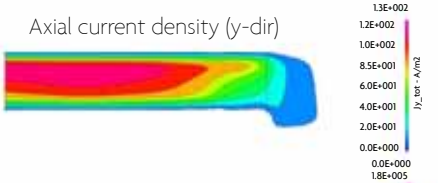
Average Ar+ density



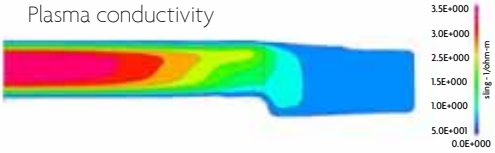
Average electric potential



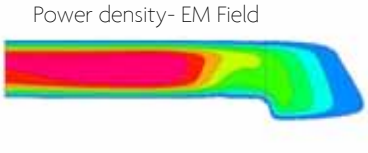
Axial current density (y-dir)



Plasma conductivity



Power density- EM Field

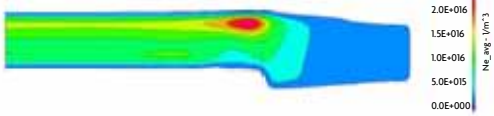


Power density- ES Field

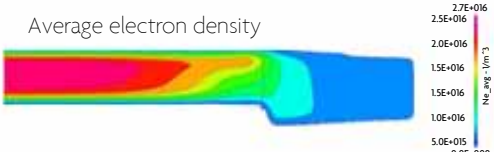
Cycle-averaged plasma density peaks at the center of the reactor due to significant inductive power deposition into electrons from the electromagnetic field. Electrostatic power deposition is localized near the sheaths. Applied RF electric potential is scaled to match specified total power absorption into electrons and ions.

SOLUTION COMPARISON

Average electron density



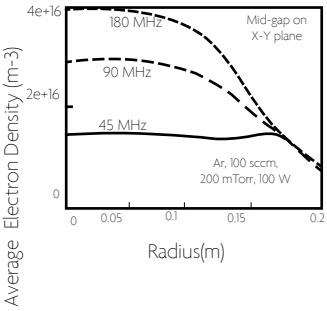
Average electron density



Base case conditions Poisson solution: Typical edge peaked electron density profile due to field enhancment.

Including wave effects: Center peaked electron density profile.

EFFECT OF FREQUENCY

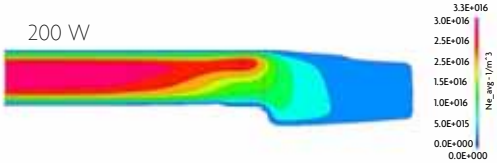


As applied frequency is decreased, wave effects are less pronounced, leading to an almost flat profile at 45 MHz.

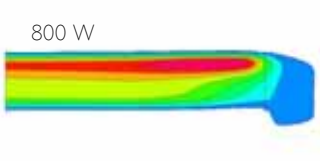
This is attributable to inductive power deposition contribution scaling with the square of the applied frequency.

EFFECT OF POWER

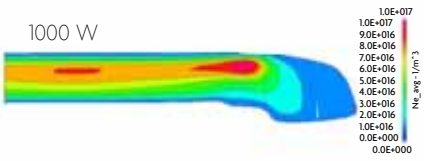
200 W



800 W



1000 W



The peak in average electron density shifts from the center to the electrode edge as RD power is increased holding other conditions fixed to base case conditions. This is due to greater inductive power deposition that occur closer to the electrode edge and this trend is in agreement with published results.

ACE+ Suite is a computational modeling platform to perform scientific analysis and guide industrial design of reactors and processes in the industry. In particular to enable multi-dimensional plasma modeling, fluid dynamics, heat transfer, Boltzmann kinetics, gas and surface reaction mechanisms, electromagnetic and external circuitry are coupled. The platform is capable of handling curvilinear reactor geometries, mixed meshes and offers modest parallel computation scale up capabilities in order to address real-world models for industrial design or scientific analysis.

To learn more about ACE+ Suite, visit www.esi-group.com/ace+suite

ABOUT ESI GROUP

ESI is a pioneer and world-leading provider in virtual prototyping that takes into account the physics of materials. ESI has developed an extensive suite of coherent, industry-oriented applications to realistically simulate a product's behaviour during testing, to fine-tune manufacturing processes in accordance with desired product performance, and to evaluate the environment's impact on performance. ESI's solutions fit into a single collaborative and open environment for End-to-End Virtual Prototyping, thus eliminating the need for physical prototypes during product development. The company employs over 800 high-level specialists worldwide covering more than 30 countries.

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