VizEM Application Note

Simulation of 3D Microwave Fields in Semiconductor Processing Reactor Using Frequency-Domain Electromagnetics Wave Solver

This note presents an example simulation of a steady microwave field in a three-dimensional plasma reactor using in semiconductor materials processing. The *Frequency-Domain Electromagnetic Wave Solver Module* of the *VizEM Electromagnetics Modeling Software Package* developed by Esgee Technologies Inc. is used for this problem.

The geometry for the simulation is shown in Figure 1 and comprises a cylindrical processing reactor with an air-filled waveguide port in the top center of the reactor. The waveguide is rectangular in cross section and comprises an L-bend with a 45° mirror surface at the bend. The waveguide connects to a top dielectric window surface through which the wave is launched into the main reactor volume. The top dielectric window is made of quartz with a relative dielectric permittivity of 4 and the main reactor volume has a diameter of 40 cm. The bottom of the reactor has a wafer holder pedestal. The distance between the top dielectric window and the pedestal is 10 cm.

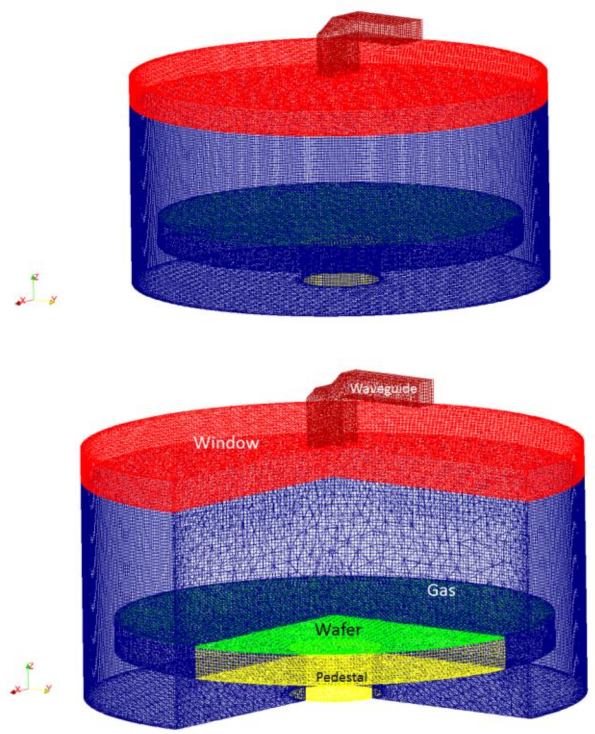

Figure 1: **Geometry description and the unstructured hybrid mesh used for the 3D microwave plasma reactor.**

The entire reactor geometry is meshed with a 3D unstructured mixed mesh comprising a combination of tetrahedral, prismatic, pyramidal, and brick cell volumes that are automatically generated using third-party meshing software. The mesh contains over 1.3 million cells with 6 unknown in each cell (3 real and 3 imaginary components of the wave field) for a total of 7.8 million unknowns in the problem. The overall mesh count, quality, and resolution is determined by not just the geometry, but also the characteristics of the wave. In this case, the wave has a frequency of 2.45 GHz implying that

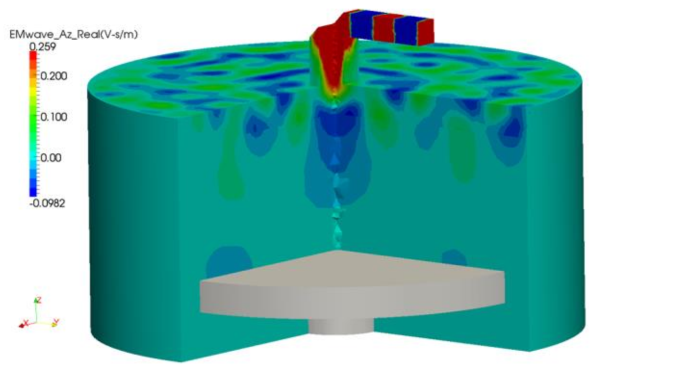

Figure 2: **The *z*-component of the microwave field.**

the vacuum wavelength is about 12 cm and wavelength in quartz is about 6 cm. The resolution of the mesh must therefore be such that at least 20 mesh cells resolve a wavelength (a rule-of-thumb); which means a typical mesh cell dimension about 3 mm or less.

The geometry is divided into 5 physical sub-domains: the *waveguide*, the top dielectric *window*, the *gas*, the *wafer* and the *pedestal*. The bottom panel in Figure 1 shows a 90^{o} cut through the reactor to expose the various components in the reactor. All material boundaries in the geometry are modeled as perfect electric conductors.

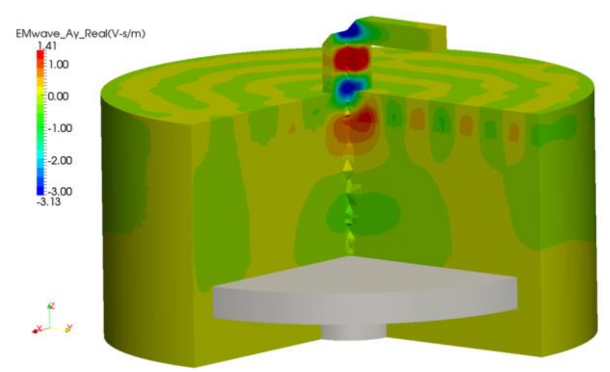

Figure 3: **The *y*-component of the microwave field.**

A uniform microwave field of frequency of 2.45 GHz is launched at the inlet of the waveguide. The wave is polarized with a single non-zero wave component in the *z*-direction (direction along axis of reactor). The wave travels horizontally in the waveguide and reflects of the mirror surface following which it propagates vertically down the reactor axis to the top dielectric window. The wave then travels radially along the thickness of the quartz dielectric and finally launches into the reactor volume, as seen in figure 2. The high dielectric permittivity of the quartz dielectric window "slows" the wave resulting in a lower wavelength in the window (from 12 cm to 6 cm, as mentioned earlier) thereby improving uniformity of the wave field as it is launched into the main reactor volume.

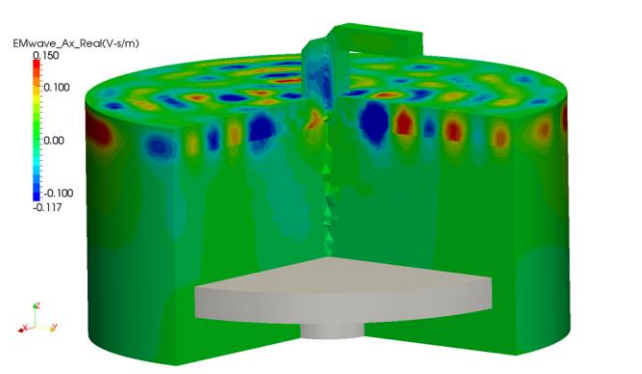

Figure 4: **The *x*-component of the microwave field.**

Figure 2 shows the *z*-component of the microwave field. The wave reflection at the waveguide mirror surface at the L-bend produces a y-component of the wave field as shown in Figure 3. Finally, the wave reflects of the outer walls of the reactor to produce non-zero x-components of the wave field as shown in Figure 4. The three-dimensional geometry therefore results in all three components of the wave field becoming active in the reactor even though only a single non-zero wave field component is launched in the reactor.

The *VizEM* software package provides a very robust environment to solve such problems with quick turnaround. The *VizEM* software is available through the *Overviz* framework. This framework features an easy-to-use interface that provides utilities for problem set-up, problem solution, and post-processing of the solution. Once a mesh is available, the 3D problem discussed in this note can be set-up within a matter of a few minutes. The *Overviz* framework provides "intelligent" default options that the user can trust and use in the absence of additional information.

The different modules within the *VizEM* software package are used seamlessly within the other software packages offered by Esgee Technologies. For example the *Frequency-Domain Electromagnetic Wave Solver Module* used in the above problem can be called by the *VizGlow Plasma Modeling Software Package* to solved coupled electromagnetic wave—plasma problems, such as in microwave reactors and inductively coupled plasma reactor. Examples of such coupled problems are discussed in other Application Notes.

For further information on this application note or details about the *VizEM* and other software packages you may contact us at

Esgee Technologies Inc.
14, North Peak
Austin, Texas 78746, USA
info@esgeetech.com
www.esgeetech.com