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Study on uniform plasma generation mechanism of Electron Cyclotron Resonance etching reactor

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Electron Cyclotron Resonance (ECR) plasma sources have been widely used for ultra large scale integration (ULSI) manufacturing processes for many years. ECR plasma source can stably generate plasma even at very low pressure under 0.1 Pa, and plasma distribution can be easily controlled by the static magnetic field distribution. Furthermore, the plasma generation region can be located away from chamber wall, which results in reducing plasma contamination from the wall. In addition, uniform plasma can be generated to achieve uniform plasma process, crucial for large diameter wafer as 300mm or 450mm diameter wafers [1].

To improve plasma uniformity, we first studied microwave analysis. However there are some difficulties to analyze ECR plasma source for semiconductor manufacturing shown below.

(1) The permittivity of magnetized plasma becomes a tensor [2].

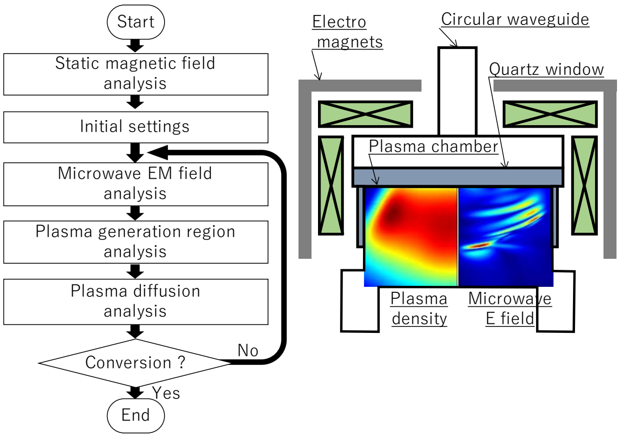
(2) Spurious solutions are sometimes included when ordinary Finite Element Method (FEM) is used [3].

(3) The calculation amount becomes large because microwaves propagate in the process chamber and wavelength near the resonant region becomes very short.

Plasma simulation for various semiconductor manufacturing tools are reported [4-6]. However, ECR plasma simulation for semiconductor manufacturing is limited [7-9] because of reasons mentioned above.

By our developed integrated simulation code, we have studied microwave analysis in ECR plasma etcher and found very complex and fine electric field patterns in the process chamber. First, we suspected the complex patterns were spurious. However, it proved to be Trivelpiece-Gould (TG) waves by careful investigation of the dispersion relation and the emerging conditions of the wave. Thus, we identified validity of the microwave analysis with our code in the process chamber of the ECR etcher [10].

Then, we have conducted ECR plasma simulation of etcher for semiconductor manufacturing combined with 1) microwave analysis in magnetized plasma, 2) plasma generation analysis, and 3) plasma diffusion analysis. Here, we got the consistent solutions in each analysis in a practical calculation time. We measured plasma density profiles in the process chamber and compared it with the simulated results experimentally, and, in addition, estimated the diffusion parameters in the magnetized plasma. Calculation model of typical ECR etcher and procedure is shown in Figure 1 together with an example of simulated results. Furthermore, we will discuss the mechanism of uniform plasma generation in the ECR plasma source by using the simulated results and theoretical consideration of microwave propagation characteristics in waveguide filled with magnetized plasma.



(a) Calculation procedure (b) Typical ECR etcher

Figure 1. Calculation model and procedure with simulated results

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