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Study on microwave propagation and uniform plasma generation in an ECR plasma etching reactor

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Electron cyclotron resonance (ECR) plasma source is widely used for semiconductor manufacturing [1] because it has many advantages, as shown below.

(1) Plasma contamination and the erosion of reactor wall can be minimized because plasma generation region can be located away from the reactor wall.
(2) It is easy to control plasma distribution by the external static magnetic field.
(3) By using the ECR method, plasma can be stably generated under very low pressure e.g., 0.1Pa or less.
(4) Uniform plasma generation can be achieved on the large wafer whose diameter is 300mm or more [2].

However, it is not well understood concerning the mechanism of uniform plasma generation because microwave analysis in the ECR plasma source is difficult.

Remarkable progress of computer hardware and the numerical calculation method like finite element method (FEM) in last few decades enabled large calculation of microwave vector analysis. We analyzed microwave distribution in the ECR plasma utilizing these technologies and found very complicated and fine patterns in the ECR plasma etching reactor [3]. We first suspected the fine patterns came from spurious solution, however, we identified the pattern was originated from TG waves by the condition of appearance and the dispersion relation.

We newly developed an ECR plasma simulation tool utilizing the validated microwave calculation tool combined with plasma generation and plasma diffusion analysis. Moreover we validated the simulation tool by comparing the results with the experimental ones of plasma density distribution. The tool can simulate plasma distribution, microwave distribution, and plasma generation region in the ECR reactor.

By using the simulation tool, we analyzed a typical ECR reactor and found microwaves cannot enter high density region of $\omega_{pe}/\omega>1$, where ω_{pe} is plasma angular frequency, ω is angular frequency respectively as shown in Fig.1. However, this phenomenon conflicts the ordinary propagation characteristics of Right Hand Polarized (RHP) waves in free space.

It is well known that RHP waves can propagate in high density plasma of $\omega_{pe}/\omega>1$ in strong magnetic field under the condition of $\omega_{ce}/\omega>1$, where ω_{ce} is electron cyclotron angular frequency. To solve the conflict, we theoretically investigated microwave propagation characteristics in plasma filled waveguide with static magnetic field [4]. The results of normalized wave number in the waveguide are shown in Fig.2 for weak ((a) ω_{ce}/ω=0.8) and strong ((b) ω_{ce}/ω=1.2) magnetic field. We found that mode transformation from RHP to Left

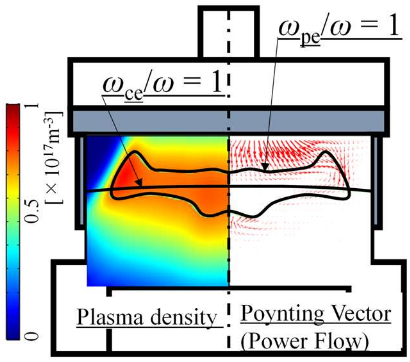

Fig.1 Plasma density and power flow

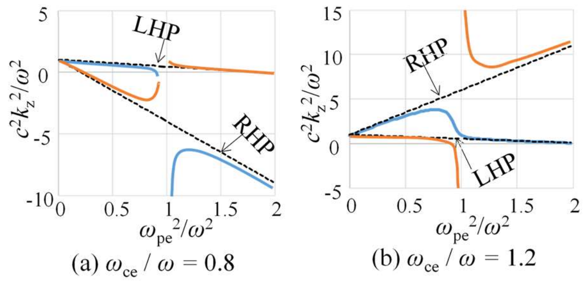

Fig.2 Wave number in plasma filled waveguide with static magnetic field

Hand polarized (LHP) wave near the region of ω_{pe}/ω=1.0 for strong ((b) ω_{ce}/ω=1.2) magnetic field in consideration of waveguide wall. We could explain the phenomenon observed in the simulation result by mode transformation. In this talk, we will discuss about uniform plasma generation and mode transformation in consideration of the chamber wall effect.

References

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