Effect of Coulomb Collisions on Low Gas Pressure Plasmas

K.Nanbu, T.Furubayashi

K. Nanbu, Institute of Fluid Science, Tohoku University, Katahira 2-1-1, Aoba-ku, Sendai.

T. Furubayashi, Graduate school of Tohoku University

Plasma processing has been used for fabricating semiconductors. The requirement of high aspect ratio etching is satisfied by using low gas pressure and high density plasmas. When simulating high density plasmas ($n_{\rm e} = 10^{17} - 10^{18}{\rm m}^{-3}$), collisions between charged particles should also be taken into consideration. Generally, in simulating plasma using the particle model, we consider only electron - molecule collisions and ion - molecule collisions. In this study, we consider not only such collisions but also electron - electron collisions using Bobylev and Nanbu method[1] because it is most probable that Coulomb collision have effect on the electron energy distribution. We examined the effects of Coulomb collision on plasma parameters. Especially, the effect on electron energy distribution function(EEDF) is important because it influences reaction rate of radicals production and hence, affects the etch rate.

$$k_{\rm r} = \int_{\varepsilon_0}^{\infty} \sqrt{\frac{2\varepsilon}{m}} \sigma_{\rm r}(\varepsilon) E(\varepsilon) d\varepsilon, \qquad (1)$$

where ε is kinetic energy of electron, m is the mass of electron, $\sigma_{\rm r}(\varepsilon)$ is the reactive collision cross section for the electron - molecule collision that results in a production of a radical, ε_0 is the threshold energy of the reactive collision, and $E(\varepsilon)$ is the electron energy distribution function . $E(\varepsilon)$ in equilibrium is the Maxwellian distribution

$$E(\varepsilon) = \frac{2}{\sqrt{\pi}} \frac{\sqrt{\varepsilon}}{(kT_{\rm e})^{3/2}} \exp(-\frac{\varepsilon}{kT_{\rm e}}), \qquad (2)$$

where k is the Boltzmann counst and $T_{\rm e}$ is electron temperature.

In this study, we simulated argon plasma and oxygen plasma using the Particle in Cell/Monte Carlo (PIC/MC) method considering two species, e^- and Ar^+ for argon plasma, and considering four species, e^-, O^+, O_2^+, and O^- for oxygen plasma. In case of the argon plasma, we found that the electron - electron collisions have a small effect on the electron temperature but little effect on the EEDF[2]. On the other hand, in case of the oxygen plasma, we have found that the electron - electron collisions have a clear effect on electron number density and the EEDF. This is because the ionization energy for electron - oxygen collision is much lower than that of argon.

The discharge condition is as follows. The electrode distance is 30 mm, the gas pressure is 30 mTorr, the deriving frequency is 100 MHz, and the voltage amplitude at the powered electrode is 300V.

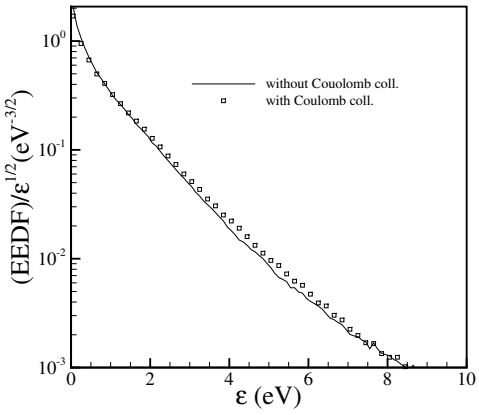

Figure. 1: EEDF in oxygen plasma

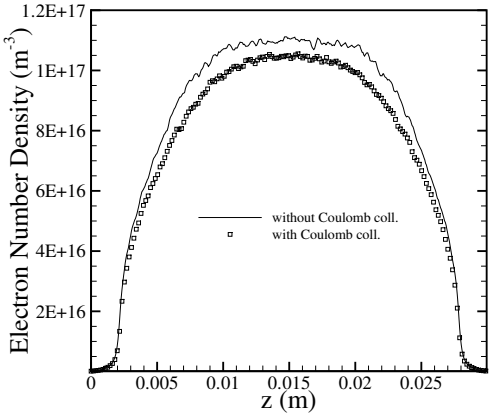

Figure. 2: Electron Number Density in oxygen plasma

Reference

[1] A. V. Bobylev and K. Nanbu, Phys. Rev, E, Vol.61(2000), pp. 4576 - 4586

[2] K. Nanbu, T. Furubayashi and H. Takekida, Thin Solid Film(to be published)