AAPPS DPP

8th Asia-Pacific Conference on Plasma Physics, 3-8 Nov, 2024 at Malacca

PIC-MCC simulation of Rectangular Amplitude Modulated Radio Frequency Capacitively Coupled Plasma

Yuma Yamamoto[1], Kohei Yamashita[1], Kunihiro Kamataki[1],
Naoto Yamashita[1], Naho Itagaki[1], Kazunori Koga[1], Masaharu Shiratani[1]
[1] Kyushu University
e-mail:y.yamamoto@plasma.ed.kyushu-u.ac.jp

State-of-the-art modern semiconductor devices need often formation processes of high aspect trenches and holes by reactive ion etching (RIE) as well as sidewall deposition in the structures by plasma-enhanced chemical vapor deposition (PECVD). Difficulties of such processes are increasing sharply, because of higher aspect ratio and narrower opening such structures. Novel process tuning knobs are required to overcome the difficulties.

For a new process tuning knob, we proposed amplitude modulation (AM) discharge voltage for sustaining plasma. We demonstrated control of ion angular distribution function (IADF) using sinusoidal AM of RF capacitively coupled plasma (CCP) by experiments and numerical simulations [1, 2]. In this method, the amplitude of 13.56 MHz RF voltage applied to the electrodes is modulated sinusoidally as shown in Fig. 1(a). This method improves film qualities and coverage of sidewall of trenches in SiO_2 deposition using TEOS-PECVD. Furthermore, we carried out Particle-In-Cell Monte-Carlo-Collision (PIC-MCC) simulations [3] for sinusoidal AM RF CCP and found that the method offers time modulation of IADF, electron density, and electron temperature with AM cycles.

So far, effects of amplitude modulation using other modulation waveforms on plasma parameters have not been fully clarified yet. In this study, we performed PIC-MCC simulations (PEGASUS Software Inc.) of RF CCP for rectangular AM as shown in Fig. 2(a).

Figures 1(b) and 2(b) show spatial profiles of electron density in one AM period obtained for sinusoidal and rectangular AM for AM frequency 10 kHz and 50% modulation depth, respectively. Figures 1(c) and 2(c) show the electron temperature profiles for sinusoidal and rectangular AM discharges, respectively.

Although the discharge voltage of rectangular AM is bi-stable, time evolution of spatial profiles of electron density and electron temperature has not bi-stable feature but gradual change. This is because the characteristic time of electron temperature and that of electron density are several μs and several tens μs for 10 mTorr.

Effects of rectangular AM RF CCP on other plasma parameters, such as IADF, will be discussed at the conference.

References
[1] I. Nagao, *et al*., MRS Advances, **7**, 911 (2022).
[2] K. Kamataki, *et al.*, AIP Advances, **12**, 8 (2022).
[3] http://www.psinc.co.jp/

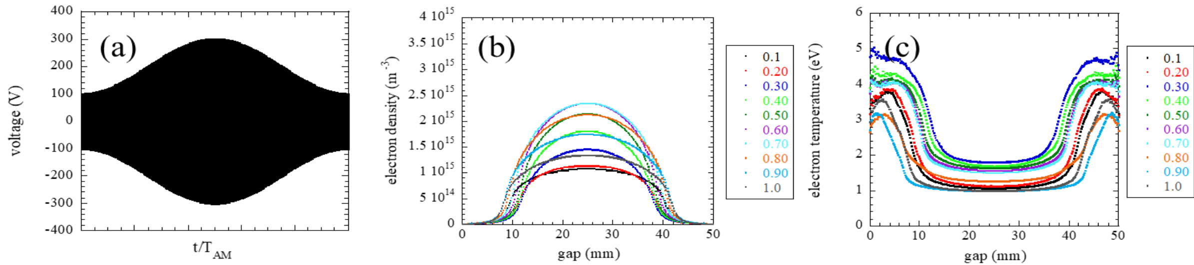

Fig.1 (a) voltage waveform, (b) electron density profile, and (c) electron temperature profile in a sinuaoidal AM discharge (AM-10 kHz, 50%)

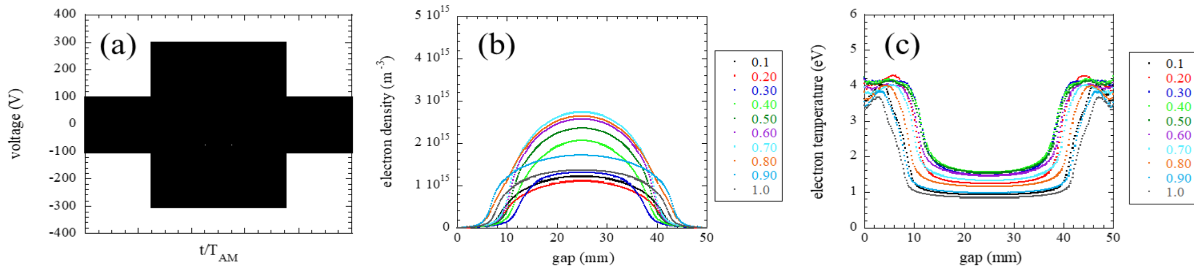

Fig.2 (a) voltage waveform, (b) electron density profile, and (c) electron temperature profile in a rectangular AM discharge (AM-10 kHz, 50%)