2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Pulsed oxygen negative ion plasmas produced by RF discharge

Takashi Morioka[1], Haruhiko Himura[1], Norihiro Kodama[1], Deyan Liu[1], Sadao Masamune[1], Akio Sanpei[1],Shigefumi Okada[2], Kingo Azuma[3],Takashi Kanki[4]
[1] Department of Electronics, Kyoto Institute of Technology, [2] Osaka University,
[3] University of Hyogo, [4] Japan Coast Guard Academy
e-mail (speaker): moriok17@nuclear.kit.ac.jp

1. Introduction

In the semiconductor manufacturing process, miniaturization is progressing. Atomic layer process such as atomic layer deposition (ALD) enables extreme processing. In the atomic layer process, precise controlling of the ultra-thin gaps in a few nanometers is recognized as the most key technique. However, ordinal plasma processing cannot control exactly the plasma parameters, especially the ion energy, which causes damages on the thin surface with several nanometers of a target material during the ALD process using plasmas. Similar problem is observed in an atomic layer etching (ALE) process.

It is known that a negative oxygen ion (O^-) exhibits strong oxidizing power [1, 2]. Since O^- is a charge-particle, its energy and orbit can be, in principle, controlled by electromagnetic fields. These properties suggest that an O^- plasma that consists of only O^- ions may develop a new plasma processing without surface damages. This is actually preferable for the ALD and ALE.

In order to experimentally investigate the possibility of developing the new plasma processing using O^- plasmas, we are currently developing a prototype machine in which O^- plasmas are produced and then extracted as an O^- deflecting beam. In this conference, we will present preliminary result of O^- ions along with data of the spatial profile of the electron temperature in the produced oxygen plasmas.

2. Gas injection through pulse valve

To supply oxygen gas into a source where oxygen plasmas are generated by 13.56 MHz radiofrequency, a solenoid valve (VAC-1250, Parker Hannifin Corp.) is employed. A fast-switching circuit using an FET for controlling the opening and closing of the pulse valve is developed in our laboratory. Using the circuit, we test the solenoid valve operation experimentally. In experiments, argon (Ar) gas is used, which flows through the pulse valve and then into a test chamber whose volume is approximately 0.013 m^3. On the other hand, the amount of the Ar gas in the test chamber can be calculated from the pressure difference in the test chamber before and after the gas injection. Figure 1 shows the data that are obtained by changing the back pressure (*bp*) of the Ar gas and the duration of the open time (t_{width}) of the pulse valve. Data show that as either *bp* or t_{width} increases gradually, the total amount of Ar particles increases correspondingly. Since the volume of the plasma source that we have been developing currently is approximately 0.0004 m^3, the number of inflow particles required to attain the gas pressure of ~18 Pa in the plasma source can be estimated to be approximately 1.8×10^{18}. Thus, from Fig. 1, the most reasonable setting values of t_{width} and *bp* would be ~17 ms and ~1.2 MPa, respectively.

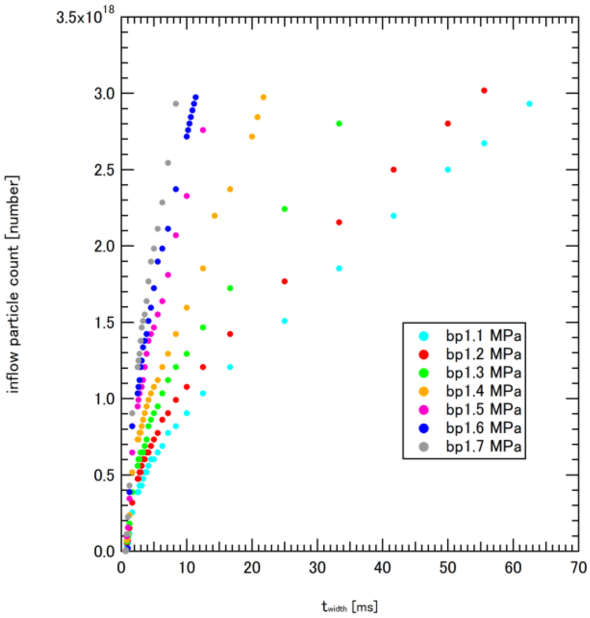

Fig. 1 Dependences of the number of particles charged into a vacuum vessel by a solenoid valve in the open time of it. Differences in color of plotted data correspond to the difference in back pressure.

This work is supported by JSPS Grants-in-Aid for Scientific research, No. 17K18769.

References

[1]K. Hayashi *et al*., J.AM.CHEM. Soc, **124** (2002) 738.
[2]T.Fujii *et al*., Jpn. J. Appl. Phys. **38** (1999) L1466.