A-P6 AAPPS-DPP2019

3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Trajectory simulations of negative ions for developing novel plasma processing

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Currently, three-dimensional nanoscale fabrication is required in a multidisciplinary field of research at the semiconductor, energy, biomedicine, etc. Atomic layer process such as atomic layer deposition and formation of ultra-thin films is used to realize fine processing. However, with conventional plasma processing techniques, it is difficult to precisely control a collective behavior of ions, radicals and electrons contained in a plasma. The behavior of the ions especially cannot be controlled and damages a processed substrate surface. As the result, to process the surface in a desired precise shape has been a technical bottleneck. Such plasma processing techniques also cause a crucial problem that various particles such as ions, radicals, and electrons are irradiated simultaneously, and therefore it cannot identify the specific particle species to play an important role in the dry process. In order to fundamentally eliminated this problem, we have been developing a novel dry plasma processing with low damage at a low temperature. In basic concept of this study, the plasmas containing no impurities are generated by using inductively coupled electrodeless discharge, and then only one particle species is electrostatically extracted from the generated plasmas. After that, it is transported to a reactor chamber away from the plasma source while focusing and deflecting its trajectory, and controlling its energy with electromagnetic fields.

We now consider a negative oxygen ion, O^-, the so-called anion radical as the specific particle species. Several reports have indicated that O^- ions can cause strong oxidation compared with positive oxygen ions [1]. According to a recent study on plasma processing using an oxygen plasma, O^- ions are suggested to play a key role in promoting oxidation [2]. In order to investigate the dependence of the amount of O^- ions flux and temperature on the oxidation, we have developed a flat oxygen plasma source containing a magnetic filter, and successfully produced O^- ions via dissociative electron attachment to oxygen [3]. By using the SIMION 8.1 software [4], we are now performing O^- ion trajectory simulations to optimize the geometry of an apparatus which extracts O^- ions from the plasma source and then transports to the reactor chamber, and investigate some of O^- ion beam characteristics. The apparatus consists of four parts: plasma and intermediate electrodes, einzel lens, two sets of magnetostatic quadrupole lens and a set of steering coils. The plasma and intermediate electrodes extract O^- ions from the plasma source. The einzel lens that consists of three electrodes focuses without changing the energy of the beam. The quadrupole lens that consists of four coils corrects the astigmatism and controls the beam shape in the reactor chamber. The steering coils deflect the beam. Figure 1 shows the arrangement of the apparatus and the typical simulation result of O^- ion trajectory. It is found that O^- ion beam extracted from the plasma source travels through each component, and then converges at the center of the reactor chamber. The amount of current and the beam diameter at this position are 8.0 μA and 8.5 mm, respectively. In this conference, we report the detail of O^- ion trajectory and its characteristics.

References

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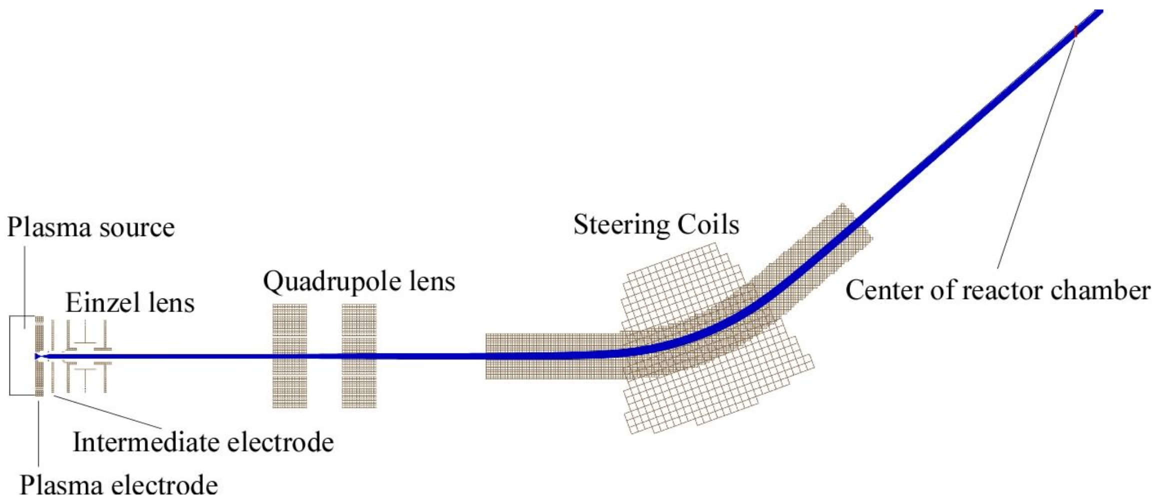

Fig.1 Typical O^- ion trajectory in the simulation at the acceleration voltage of 7 kV.