9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

Surface reactions of reactive species in low temperature plasma

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Recently, atomic layer processes assisted by low temperature plasma have attracted us much attention. For the low temperature plasma processing, surface reactions due to neutral and charged species generated in the plasma are dominant factors to determine the process feature. Therefore, it is required to understand the reactions for further technological innovation of plasma processes. However, the knowledge about the surface reaction of each species in the plasma process has not been enough yet, and the interaction between neutral species and ions on material surfaces such as substrates and walls are often unknown [1]. In previous studies, the surface loss probabilities of hydrogen (H) atoms on material surfaces have been estimated from measurement results of the density decay of species in afterglow plasmas [2-4]. However, the plasma processes are generally performed under irradiations of not only neutral species but also ions in the steady state of continuous discharge plasma. So, it is important to investigate the surface loss probability under the condition close to the actual process in which plasma is irradiated on the surface of material, and the effects of ion bombardment on the surface reaction of neutral species should be investigated.

In this study, the surface reaction of H atoms on a material under continuously-irradiation of plasma has been investigated from the spatial density distribution of H atom above the material. The experimental apparatus used in this study consists of a chamber equipped with an inductively coupled plasma (ICP) source and a stage made of stainless use steel (SUS) with a circular shape (a diameter of 200 mm). The position of stage was set at 300 mm apart from the ICP source. In this study, hydrogen gas was introduced into the chamber at a flow rate of 50 sccm keeping the chamber pressure, and the ICP was generated by applying an RF (13.56 MHz) power to the ICP antenna. The vacuum ultraviolet absorption spectroscopy (VUVAS) system using a VUV monochromator and a micro discharge hollow cathode lamp (MHCL) as a light source [2,3,5] was equipped to the chamber. The special density distribution of H atom emitted from the ICP was quantitatively measured by the VUVAS system. The absorption line of H atom used for detecting H atom was Lyman α line at a wavelength of 121.56 nm. The VUV light of H atoms at Lyman α line emitted from the MHCL was incident into the space above the stage in the chamber parallel to the stage surface. The absorption length at which the VUV light was absorbed by the H atom inside the chamber was fixed at 221 mm. The light absorption rate due to the H atoms above the stage supplied from the ICP was obtained from the measurement of the intensity of transmitted light, and then the absolute density of H atom was estimated. The measurements of H atom with the VUVAS system were carried out at the positions of 3.5, 10, 20, and 30 mm from the stage surface, and the spatial density distributions of H atom on the stage surface were investigated. Figure 1 shows the measured spatial distributions of H atom density above the SUS and SiO_2 substrates at the pressure conditions of 5, 7.5, and 10 Pa. In the experiments, the RF power was fixed at 200 W. For all pressure conditions, the H atom density decreased with the decrease in the distance from the stage because of surface loss reaction of H atom.

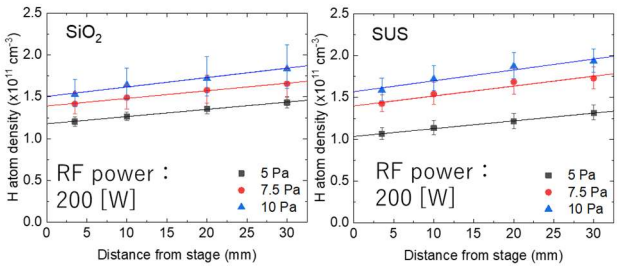

Figure 1. Spatial distributions of H atom density above the SUS and SiO_2 substrates at the pressure conditions of 5, 7.5, and 10 Pa.

From the spatial density distributions of H atoms, the surface loss probability of H atoms on the material surface was estimated on the basis of Milne boundary condition. On the other hand, the ion flux irradiated to the stage was also measured by commercially available retarding field analyzer (SEMION from Impedans). From the results, the surface loss probabilities of H atom on the SUS and SiO_2 substrates were investigated as a function of flux ratio of ion to H atom onto the stage in this study. The surface loss probability of H atom on the materials increased with the relative increase in the flux of ion compared with that of H atom and then was saturated. From the result, it is found that the ion irradiation onto the stage affects the surface reaction of H atom such as recombination and so on. The result is very important knowledge to understand the surface reaction of radicals under the condition close to the actual plasma process.

References

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