분과초청4

Fluctuation in Plasma Nanofabrication

Masaharu Shiratani

Department of Electronics, Kyushu University, Fukuoka, Japan

Nanotechnology mostly employs nano-materials and nano-structures with distinctive properties based on their size, structure, and composition. It is quite difficult to produce nano-materials and nano-structures with identical sizes, structures, and compositions in large quantities, because of spatiotemporal fluctuation of production processes. In other words, fluctuation is the bottleneck in nanotechnology. We propose three strategies to suppress such fluctuations: employing 1) difference between linear and nonlinear phenomena, 2) difference in time constants, and 3) nucleation as a bottleneck phenomenon. We are also developing nano- and micro-scale guided assembly using plasmas as a plasma nanofabrication.1-5) We manipulate nano- and micro-objects using electrostatic, electromagnetic, ion drag, neutral drag, and optical forces. The accuracy of positioning the objects depends on fluctuation of position and energy of an object in plasmas. Here we evaluate such fluctuations and discuss the mechanism behind them. We conducted in-situ evaluation of local plasma potential fluctuation using tracking analysis of fine particles (=objects) in plasmas. Experiments were carried out with a radio frequency low-pressure plasma reactor, where we set two quartz windows at the top and bottom of the reactor. Ar plasmas were generated at 200 Pa by applying 13.56MHz, 450V peak-to-peak voltage. The injected fine particles were monodisperse methyl methacrylate-polymer spheres of 10 μm in diameter. Fine particles were injected into the reactor and were suspended around the plasma/sheath boundary near the powered electrode. We observed binary collision of fine particles with a high-speed camera. The frame rate was 1000-10000 fps. Time evolution of their distance from the center of mass was measured by tracking analysis of the two particles. Kinetic energy during the collision was obtained from the result. Potential energy formed between the two particles was deduced by assuming the potential energy plus the kinetic energy is constant. The interaction potential is fluctuated during the collision. Maximum amplitude of the fluctuation is 25eV, and the average is 8eV. The fluctuation can be caused by neutral molecule collisions, ion collisions, and fluctuation of electrostatic force. Among theses possible causes, fluctuation of electrostatic force may be main one, because the fine particle has a large negative charge of -17000e and the corresponding electrostatic force is large compared to other forces.

Work partly supported by JSPS.

1) M. Shiratani, K. Koga, K. Kamataki, S. Iwashita, G. Uchida, H. Seo and N. Itagaki, Jpn. J. Appl. Phys., 53 (2014) 010201.
2) M. Shiratani, J. Plasma Fusion Res. 90 (2014) 374.
3) M. Shiratani, K. Koga, S. Iwashita, G. Uchida, N. Itagaki and K. Kamataki, J. Phys. D 44 (2011) 174038.
4) T. Ito, K. Koga, D. Yamashita, K. Kamataki, N. Itagaki, G. Uchida and M. Shiratani, J. Phys.: Conf. Ser. 518 (2014) 012014.
5) M. Shiratani, Y. Morita, K. Kamataki, H. Seo, G. Uchida, N. Itagaki and K. Koga, 2014 JPS Conf. Proc. 1 (2014) 5083.

Keywords: nanotechnology, plasma nanofabrication, fluctuation, fine particle