4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

Relations among spatial profiles of plasma parameters, growth of nanoparticles in reactive plasma and properties of fabricated thin films

Kunihiro Kamataki[1], Tomoaki Yoshida[1], Yusuke Sasaki[1], Kohei Abe[1], Daisuke Yamashita[1],
Naho Itagaki[1], Kazunori Koga[1,2], and Masaharu Shiratani[1]

[1]Graduate School and Faculty of Information Science and Electrical Engineering, Kyushu University, [2]National Institute for Materials Science

e-mail (speaker): kamataki@plasma.ed.kyushu-u.ac.jp

A recent paradigm shift of semiconductor manufacturing is a transition from 2D to 3D architecture. 3D power scaling, arranging/orienting transistors vertically rather than horizontally, achieves the rapid density increase with no decrease in transistor size required. There are many impediments to fabrication of such 3D architecture devices in industry: process fluctuations, ultra-multilayer thin film deposition, and etching of ultra-high aspect ratio holes, and so forth. For faster development of ultra-precision nano-fabrication methods for 3D devices, relations among spatial profiles of plasma parameters, growth of nanoparticles in reactive plasma and properties of fabricated thin films must be clarified. Here, we study such relations in reactive plasma using two high speed cameras.

Experiments were performed using a capacitively-coupled RF discharge reactor [1]. A powered electrode with a diameter of 60 mm was set 6 mm above an grounded electrode with a diameter of 60 mm. TEOS ($Si(OC_2H_5)_4$) and O_2 gas were supplied to the reactor at a flow rate of 40 sccm and 180 sccm, diluted with Ar at a flow rate of 160 sccm. The total gas pressure was 6 Torr. The RF discharge power was 30W and frequency was 13.56 MHz for a discharge period of T_{on} = 8 s. Here, (r, z) = (0 mm, 0 mm) was the center of surface of the powered electrode.

For obtaining information of nanoparticles, we applied a 2DLLS method [2]. For this method, a sheet beam of 532 nm laser light was irradiated to the area between the electrodes, and the light scattering intensity from the nanoparticles was measured with a high-speed camera (Photron, 1000fps). The LLS intensity is proportional to nanoparticle density n_p and the sixth power of size d_p ($n_p d_p^6$) in the Rayleigh scattering regime. For the study of relations between growth of nanoparticles and plasma, we measured simultaneously both LLS intensity and emission intensity of Ar I (λ =750.4 nm) with two high speed cameras.

Figure 1 shows the z-profiles of LLS intensity (red line) and emission intensity of ArI (750nm)(blue line) at r = 0 mm and T_{on} = 7s. Nanoparticles grow near the powered electrode and emission intensity of Ar I has two peaks located close to the powered and grounded electrodes. Figure 2 shows the time evolutions of LLS intensity and emission intensity of ArI(750nm) at (r, z) = (0, 2-3 mm) region. The emission intensity of Ar I increases drastically and immediately after turning on plasma, then it gradually deceases and becomes almost
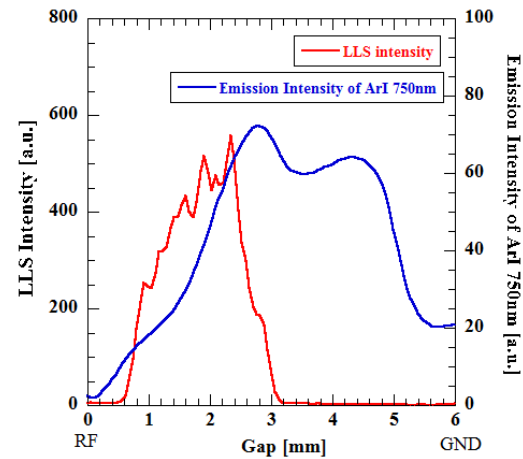

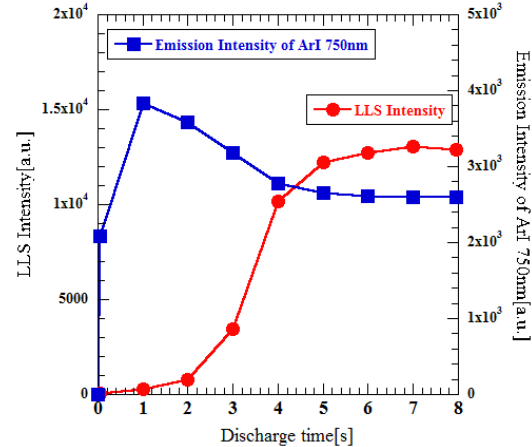Fig.1 z-profiles of LLS intensity and emission intensity of ArI(750nm) at T_{on}=7s.

Fig.2 Time evolutions of LLS intensity and emission intensity of ArI(750nm) at (r, z) = (0, 2-3 mm) region.

constant after 4 s. Nanoparticles grow slowly, then they grow rapidly during 2-5 s and saturate in about 5 s. In recent other our experiments, we have found relations between property of SiO_2 thin film and the spatial profile of emission intensity of Ar I. We will discuss details in the conference. This work was partly supported by JSPF KAKENHI (Grant No. JP19K03809 and JP20H00142).

References
[1] K. Kamataki, et al., J. Instrum., 7, 4 (2012) C04017.
[2] N. Nunomura, et al., J. Appl. Phys. 99 (2006) 08330.