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反応性プラズマにおけるプラズマ揺らぎとラジカルとナノ粒子成長の関係
Relationship between plasma fluctuation, radicals and growth of nano-particle in reactive plasma

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Investigation of relationships between plasma fluctuation, radicals, growth of nano-particles in reactive plasma of leads to to the improvement of the fabrication technology of nanomaterials for IoT devices. Amplitude modulation (AM) method can control the plasma fluctuation level in reactive plasma [1,2]. Here, we report these relationships in reactive plasmas studied using an *in-situ* laser-light scattering (LLS) method [3].

Experiments were performed using a capacitively-coupled rf discharge reactor with a LLS system. $Si(CH_3)_2(OCH_3)_2$ gas was supplied to the reactor at a flow rate of 0.2sccm, diluted with Ar at a flow rate of 40sccm. Total gas pressure was 166Pa. The rf discharge power was 30W and rf frequency was 60MHz for a discharge period of t = 8s. The AM method was applied as sine-wave modulation (the frequency f_{AM} = 100Hz) at the all discharge time. The LLS intensity is proportional to the nanoparticle density n_p and the sixth power of size d_p ($\propto n_p d_p^6$) [1,3]. The LLS intensity between the upper grounded electrode (dia. 60mm) and the powered rf electrode (dia. 60mm) was obtained using a high-speed camera with a frame rate of 1000 s^{-1}. Here, (r, z) = (0mm, 0mm) and (0mm, 20mm) were the center of the upper surface of the powered electrode and of the powered rf electrode, respectively. The fluctuation level is derived from standard deviation/average value of LLS intensity

Figure 1 shows the time evolution of the LLS intensity with and without AM for f_{AM}=100 Hz and AM Level = 0-50%. It can be seen that although the LLS intensities under each condition increase with time, they are suppressed by the presence of AM. At t = 8s, the AM level for AM level =10, 30, 50 % cases are 0.58, 0.18, 0.05 times that without AM. These results suggest that the suppression ratio of growth of nano-particles depends on the fluctuation level. Figure 2 shows the time evolution of emission intensity of ArI750.4nm with and without AM for AM level =10-50%. It can be seen that although the emission intensities with and without AM start to increase from t ~ 1s and t ~ 4s, their values with AM are larger than ones without AM. At t = 8s, the Emission intensity for AM level =10, 30, 50% cases are 2.6, 5.8, 7.2 times that without AM. These results show that the AM discharge with higher fluctuation level influences on the plasma parameters related with ArI emission more efficiently.

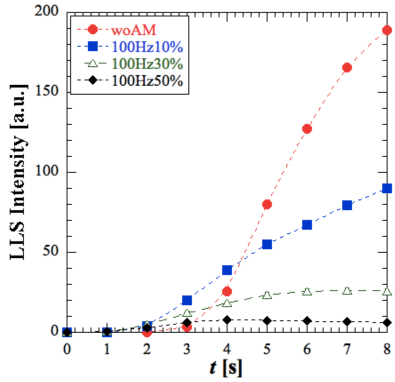

Fig.1. Time evolution of the LLS intensity with and without AM at (r, z) = (0 - 5 mm, 4 - 16 mm) region for f_{AM}=100Hz and AM Level = 0-50%.

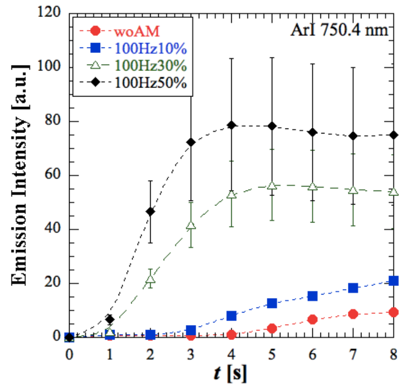

Fig.2. Time Evolution of Emission Intensity of ArI750.4nm intensity with and without AM at (r, z) = (0 - 5 mm, 4 - 16 mm) region for f_{AM}=100 Hz and AM Level = 0-50%.

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[3] S. Nunomura *et al*., : J. Appl. Phys. **99** (2006) 083302.