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Three dimensional investigation of activated species in O_2/Ar nonequilibrium atmospheric pressure plasma

O_2/Ar非平衡大気圧プラズマにおける活性種の3次元気相反応解析

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In this research, three-dimensional gase phase diagnosis of the atmospheric pressure plasma that generated in nitrogen atmosphere was performed. Atomic oxygen radical density and ozone density were measured. Oxygen density was measured by Vacuum Ultra Violet Absorption Spectroscopy (VUVAS) and ozone density was measured by Ultra Violet Absorption Spectroscopy (UVAS). For three-dimensional measurement, the plasma source was moved in the direction of the gas stream (Z) and the direction of the diameter from the gas stream center (R).

1 Background

Nonequilibrium atmospheric pressure plasma, can achieve extremely high plasma density compared with low pressure plasma. Therefore, it has a potential for higher speed processing than low pressure plasma. Moreover, plasma-exposure liquid or living processes which are impossible at low pressure condition become possible because it is enable us to generate under the condition of atmospheric pressure. The activated species such as atomic or molecular radicals, excited molecules and so on are deeply related to the performance of these plasma processes.　So it is necessary to understand and control the behavior of radical in the plasma process for realizing the more high performance.

But the density distributions of activated species in atmospheric pressure plasma are localized, because the recombination and quenching effects are more higher compared with those at low pressure. Moreover, the atmospheric pressure plasma processes are generally carried out in the remote plasma region. Therefore, for understanding the spatial distributions of radicals in atmospheric pressure plasma process, we have to consider about the recombination and transportation of radicals with gas stream. In this study, it was considered about the transportation of activated species by gas flow and a chemical reaction in gas phase based on the quantitatively-measured results.

2. Experimental

In this study, atmospheric pressure plasma was generated by introducing the gas from the gas nozzle of 1 mm in the inside diameter between the opposite electrode that were impressed 60 Hz high voltage. Atomic O radical and O_3 distribution in the nonequilibrium atmospheric pressure plasma was examined by various gas flow rates. Atomic O radical density was measured by using vacuum ultra-vioret absorption spectroscopy(VUVAS)**[1,2]**, and O_3 density was measured by using ultra-vioret absorption spectroscopy(UVAS)[3]. The xenon lamp and micro hollow cathode lamp were used as UV source and VUV source. For the three dimensional measurement the plasma source was able to be move to the probes. The plasma source was moved in the direction of the gas stream (Z) and the direction of the diameter from the gas stream center (R).

3.Result

Figure 1 shows the O radical density as a function of the distance from electrode to probe center. The O radical density has been 4.1×10^{14} cm^{-3} at the gas flow rate of 1.0 slm and the distance from electrode to probe center of 10 mm. The O radical density was decreased with increasing of the distance from electrode to probe center (Z). And the amount of a decrease of the radical to the distance grows when flow rate is small.

Figure 2 shows the O_3 density as a function of the distance from electrode to probe center. The O_3 density has been 1.6×10^{14} cm^{-3} at the gas flow rate of 1.0 slm and the distance from electrode to probe center of 37 mm. The O_3 density was increased with the value of Z.

The chemical reason for reduction of atomic oxygen radical is considered because the atomic oxygen radicals became ozone or oxygen molecules by a reaction with the oxygen molecules or ozone in gas as follow.

$$O + O_2 \rightarrow O_3$$

$$O_3 + O \rightarrow 2O_2$$

However, the activated species in oxygen plasma exist besides atomic O radical and ozone, and these species are related also to a reaction with an atomic O radical and ozone. More detailed plasma diagnosis is required to get to know the details of oxygen plasma. Moreover, it is necessary to take into consideration density change of the particles resulting from diffusion. At the presentation I will talk about this topics.

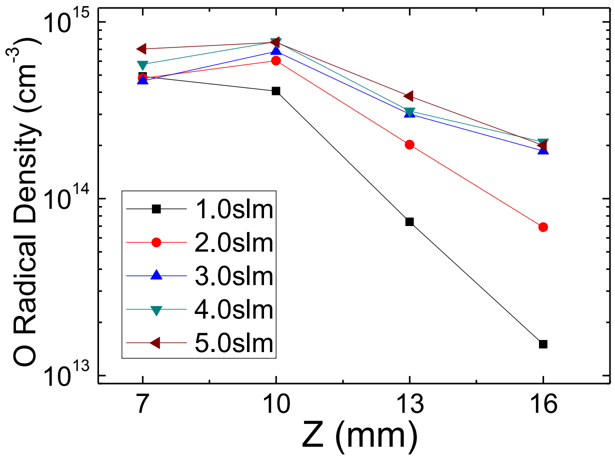

Fig. 1 atomic O radical density as a function of the distance from electrode to probe center

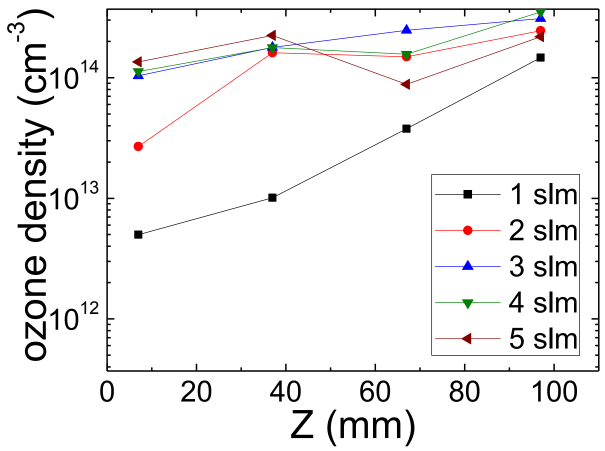

Fig. 1 Ozone density as a function of the distance from electrode to probe center

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