Effect of secondary electron emission on atmospheric pressure oxygen dielectric barrier discharges

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Dependence of secondary electron emission coefficient on atmospheric pressure dielectric barrier discharges has been analyzed using two dimensional fluid model. The discharge characteristics are significantly affected by the secondary electron emission coefficient. Number of filaments (number of streamers) decreases with decreasing of secondary electron emission. While, electron density increases with the decreasing of the coefficient. And it is found that with decreasing the coefficient, a minimum point exists on ozone generation rate curve.

One of the applications of atmospheric pressure gas discharge is ozone generation. Generation of ozone from pure oxygen using dielectric barrier discharge (DBD) at atmospheric pressure has many advantages than other generation method. One of the well known advantages is efficient ozone generation by streamers in DBD. However, since 1990s[1], so call “ozone-zero phenomena[2]” have been reported. To clear the mechanism of ozone-zero phenomena, understanding of discharge development in atmospheric pressure oxygen DBD is important. In this paper, the effect of secondary electron emission on atmospheric pressure oxygen DBDs have been examined using multi-filament two dimensional fluid model[3].

The amplitude of 7.5kV and frequency of 200kHz sinusoidal voltage is applied at the electrode at x=0.2 cm[4]. Oxygen gas is considered and its pressure is 760Torr. The initial electron and ion density of $10^6 cm^{-3}$ are located at (x, y)= (0.1cm, 0.3cm) in the middle of discharge space. Secondary electron emission coefficient due to ion bombardment and photo emission have been varied from γ_i=0.3 and γ_p=0.03 to γ_i=0.01 and γ_p=0.001, respectively.

Fig.1 and Fig.2 show the spatial distributions of electron density. As the secondary electron emission coefficient decreases the number of filaments(primary streamers) decreases. For the high coefficient case, the filaments are formed in fine forms and the spread of surface discharges are slightly seen. For the low coefficient case, the filaments are formed in thick shape and the spread of surface discharges are obtained significantly. At the heads of surface discharge, the positive space charges are slightly neutralized by the lower electron emission from the dielectrics, this induces the wide propagation of surface discharges. Fig.3 and Fig.4 show the spatial distributions of ozone generation rate. The ozone is generated mainly where the filaments exist. But for the high coefficient case, also the ozone is generated where the filaments are not formed. It is because the small streamers generate oxygen atoms which are formed between the filaments[3]. As a result, ozone is generated in the discharge space and near the dielectrics. On the other hand, for the low coefficient case, the spread of surface discharges generate oxygen atoms($O(^3P)$), the precursor of ozone, so the ozone is generated mainly in the vicinity of the dielectrics. But in the vicinity of the dielectrics, the gas temperature increases by the surface discharges, so the less oxygen molecules density prevent generation of ozone ($O(^3P) + O_2 + O_2 \rightarrow O_3$) as shown in Fig.5. Fig.6 shows the secondary electron emission coefficient dependence on ozone generation rate. As the coefficient decreases, the ozone generation rate decreases, because of the significant surface discharges spread and increase of gas temperature. But it is found that there is a minimum value on the curve as shown in the figure. The increase of the ozone generation rate occurs by the thickened filaments. As the coefficient decrease, the number of the filaments decreases, but the radius of the filaments increases. As a result, the high electron density region almost bridges between the dielectrics. In the middle of the discharge space, the gas temperature is not so high, so the high electron density affect to the increase of ozone generation rate significantly. Ozone-zero phenomena usually occurs after the long operation of ozone generator, this means the surface of dielectrics is severely damaged and it might decrease the secondary electron emission coefficient of the dielectric surface.

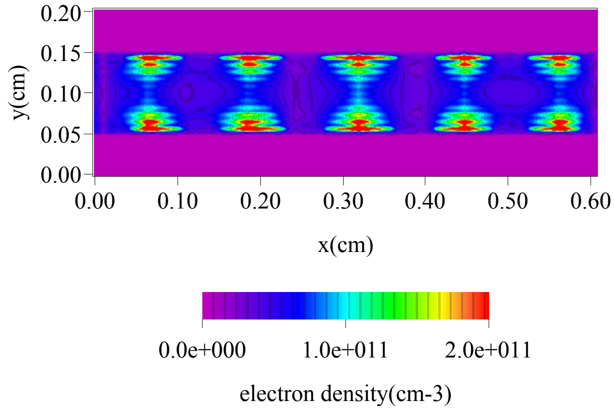

Fig. 1. Spatial distribution of electron density averaged by one cycle for γ_i=0.2 and γ_p=0.02.

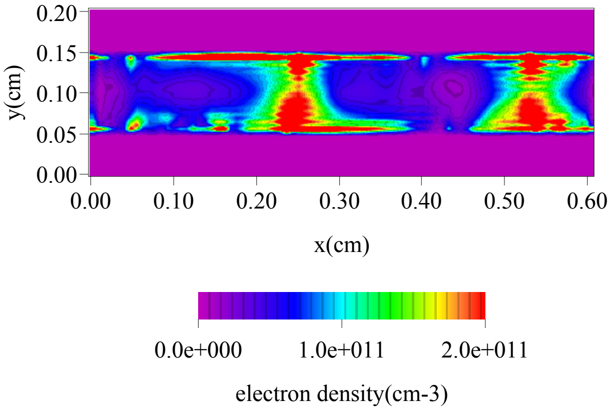

Fig. 2. Spatial distribution of electron density averaged by one cycle for γ_i=0.01 and γ_p=0.001.

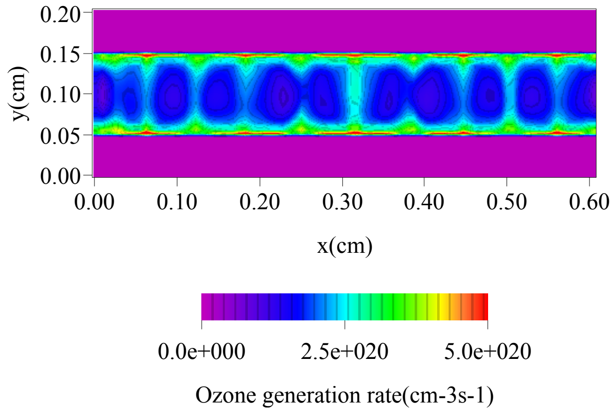

Fig. 3. Spatial distribution of ozone generation rate averaged by one cycle for γ_i=0.2 and γ_p=0.02.

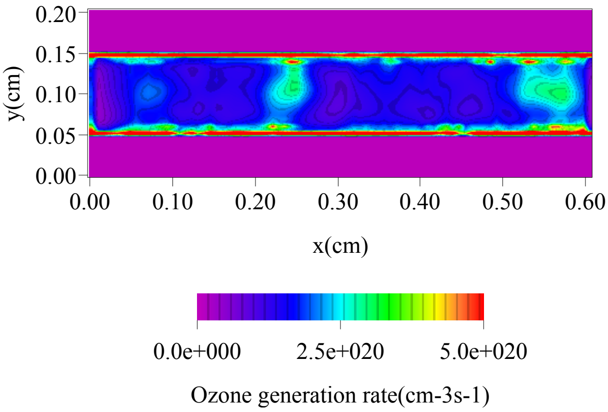

Fig. 4. Spatial distribution of ozone generation rate averaged by one cycle for γ_i=0.01 and γ_p=0.001.

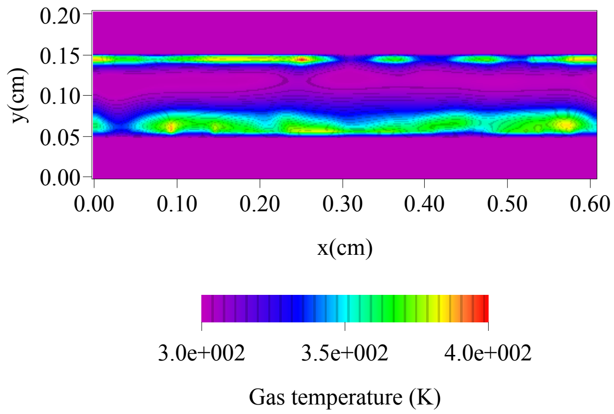

Fig. 5. Spatial distribution of gas temperature by one cycle for γ_i=0.01 and γ_p=0.001.

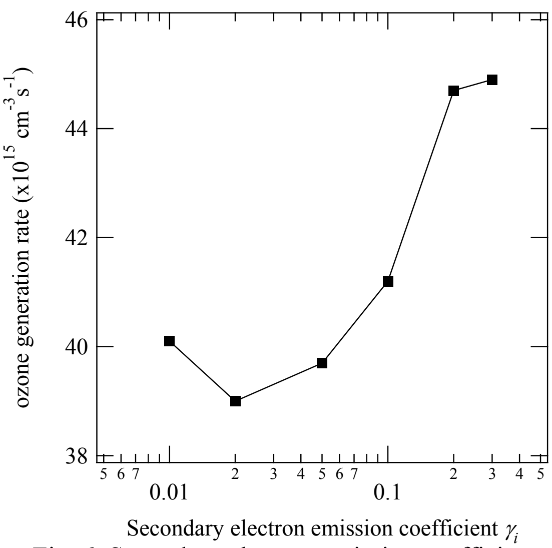

Fig. 6. Secondary electron emission coefficient dependence on ozone generation rate.

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