Emission Characteristics of Surface Microdischarge in Atmospheric-Pressure He/N_2 Mixture

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***Abstract*— The surface microdischarge in atmospheric-pressure He/N_2 mixture is studied with an emphasis on its emission characteristics. It is found that the emission intensity and the pattern shape are strongly dependent on the N_2 concentration. The UV emission intensity increases by a factor of nine with the N_2 concentration up to 5%, after that it decreases moderately. Meanwhile, the luminous pattern expands and then shrinks from grounded mesh edge to the mesh center in the positive half-cycle, while it gradually brightens and then darkens in the central region of a mesh for the negative half-cycle, which is mainly attributed to the distribution of surface charge. In the case of $[N_2] = 2\%$–5%, the UV-Vis emission intensity is stronger and the emission pattern is comparable to spatial homogenous, thus benefiting the light emission applications.**

***Index Terms*— Atmospheric pressure, emission pattern, He/N_2 mixture, surface microdischarge.**

THE SURFACE microdischarge (SMD) is capable of producing large-scale, macroscopic-homogeneous, and stable cold plasmas in a strong reactive feeding gas, thus facilitating various applications like plasma biomedicine [1]. Although much attention has been paid on the SMD in the last decade, the light emission characteristics have little been studied. This character is of importance due to: 1) the potential application of the SMD as a light source and 2) the UV band of light emission has various biological effects.

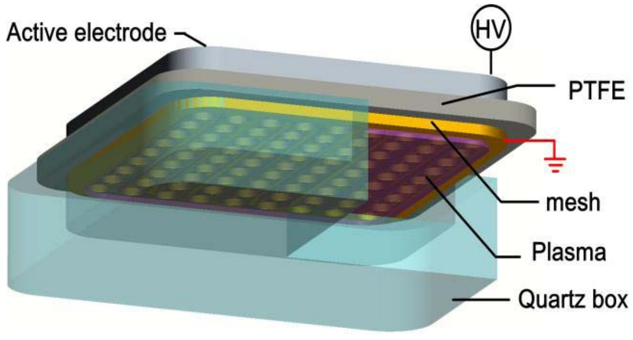

Fig. 1. Discharge device.

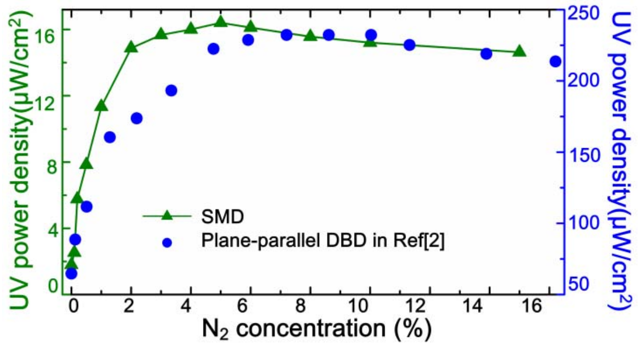

Fig. 2. Dependence of UV emission intensity on the N_2 concentration.

To this end, we present in this paper an experimental study on the emission characteristics of the SMD in atmospheric-pressure He/N_2 mixture. The discharge device is shown schematically in Fig. 1. It contains a plane active electrode, a grounded electrode made by woven wire mesh, a dielectric-slab sandwiched between the two electrodes, and a quartz box to shield the feeding gas from the open air. The grounded mesh has a hexagon shape with each side of 4-mm length and 0.5-mm thickness, and the plasma is generated in each mesh as long as a high voltage is applied. Pure helium (5 N) is fed into the discharge device with a flow rate of 5 L/min, and the concentration of nitrogen, varying from 0% to 15%, is controlled by a gas flow meter. A sinusoidal high voltage ($V_{\rm pp} = 7$ kV, $f = 20$ kHz) is applied on the active electrode, and it is measured by an oscilloscope (Tektronix, DPO3000) with a high-voltage probe (Tektronix, P6015A). The emission pattern is observed by an intensified charge coupled device (ICCD) camera (Andor, DH334T), and the UV power density is obtained by a UV intensity meter (UDT Instrument, Model S471, 200–400 nm, 0.01 μW/cm^2 for sensitivity).

The dependence of the UV emission intensity of SMD on the N_2 concentration is plotted in Fig. 2. The intensity increases sharply when $[N_2] < 2\%$, and then continuous to grow but slightly until $[N_2] = 5\%$, after that it decreases moderately. This trend is similar to that for a plane-parallel DBD, as presented in [2]. The UV emission band of He/N_2 discharge is mostly contributed by the molecular emission of $N_2^+(B^2\Sigma_u^+)$ and $N_2(C^2\Pi_u)$. As these two species are generated mainly by electron impact on N_2 molecules, the increase of N_2 density but corresponding decrease of electron density result in such trend of UV emission intensity [3].

The emission patterns of a full period are shown in Fig. 3(a)–(l). It can be observed that the luminous intensity

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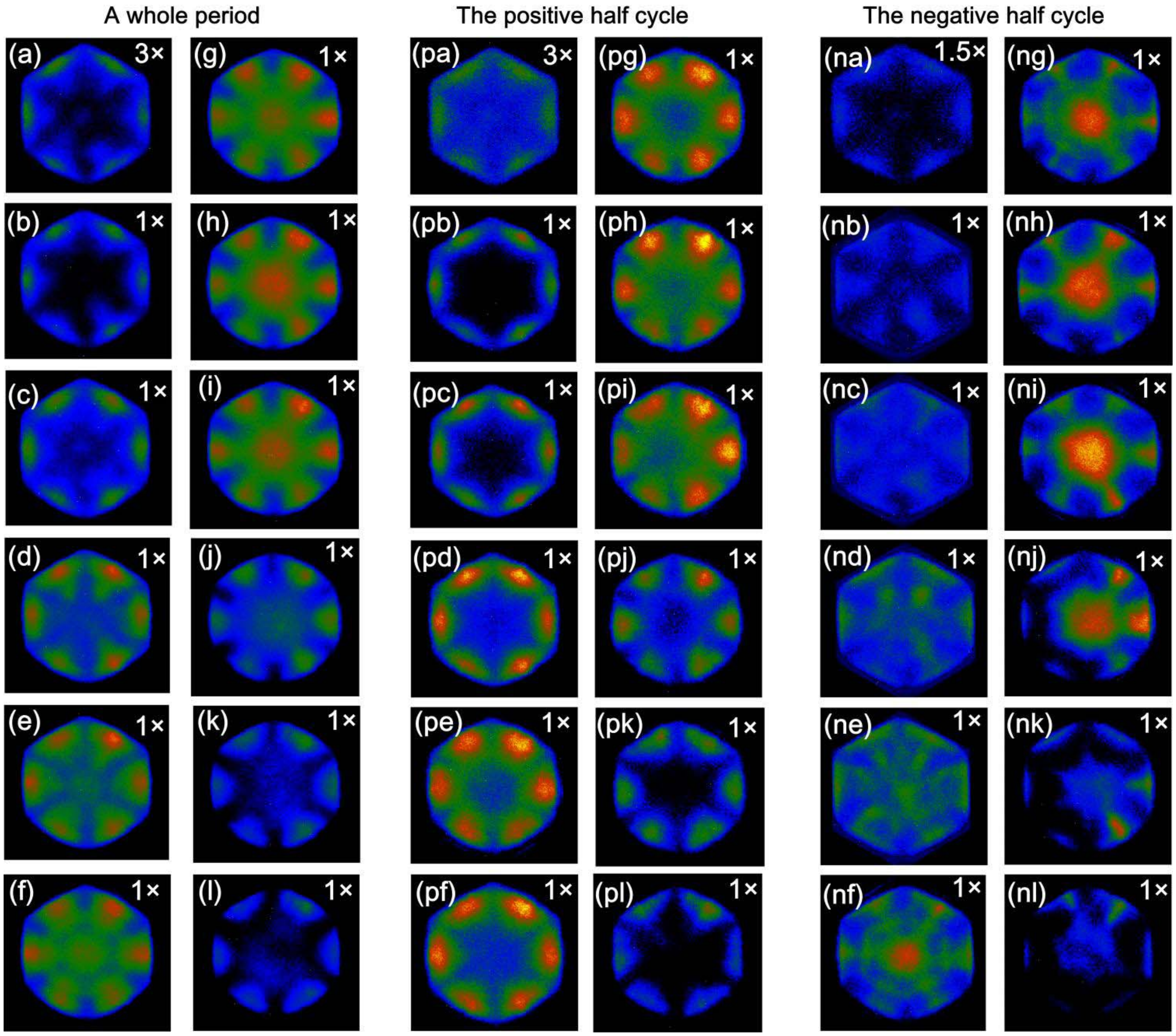

Fig. 3. Luminous patterns of the SMD in He/N_2 mixture for different N_2 concentrations. (a)–(l) Luminous patterns taken for a whole discharge cycle with N_2 concentrations of 0%, 0.1%, 0.2%, 0.5%, 1%, 2%, 3%, 4%, 5%, 6%, 8%, and 15%, respectively. (pa)–(pl) Luminous patterns taken for the positive half-cycle of applied voltage for the same N_2 concentrations as (a)–(l), and (na)–(nl) for the negative half-cycle. The emission intensity is artificially intensified when the image is too weak. For example, when marked with 3× it means that the emission intensity is multiplied by a factor of three.

(λ = 180–850 nm for the ICCDs spectral scope) is most strong when $[N_2]$ = 2%–5%, similar to that for the UV band. Moreover, in that case, the emission pattern is more homogeneous than the others. The full period images consist of the positive and negative half-cycle images, which are also taken by ICCD, as shown in Fig. 3(pa)–(pl) and (na)–(nl), respectively. It can be observed that the emission pattern expands and then shrinks from the mesh edge to the mesh center for the positive half-cycle, while it just gradually brightens and then darkens in the central region of a mesh for the negative half-cycle. This can be mainly attributed to the surface charge that deposited on the Polytetrafluoroethene surface, of which the existing region expands with higher density of nitrogen metastables (Penning ionization) especially when $[N_2]$ = 2%–5% and hence can trigger a stronger reverse breakdown in the negative half-cycle.

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