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Active Species Spatiotemporal distributions and energy transfer mechanism in nanosecond pulsed discharge plasma base on the air pollution control

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It has been proposed that dielectric barrier discharge can be used as a non-thermal plasma source to improve the air quality[1-2] by removal of volatile organic compounds, bacterial pollution, particulate matter, etc. In the non-thermal plasma, large number of reactive species, such as electrons, ions, atoms, radicals, and excited particles, are existing and impacting for each other, which lead to the high complexity and uncertainty of energy transfer, generation of byproducts, and kinetic process. In recent years, numbers of studies are focused on the temporal evolution of plasma temperatures and active species in the time scale of nanoseconds[3-4]. In our work, the controlling of energy relaxation and physicochemical processes in non-thermal plasma are studied by the spatiotemporal characteristics diagnosis and chemical kinetics calculation in the application of air pollution control.

Firstly, different types of excitation voltage used in the non-thermal plasma sources are investigated. Both nanosecond pulse and sine AC voltage was employed to generate an atmospheric air diffuse discharge. Discharge images, electrical characteristics, optical emission spectra, and plasma gas temperatures were compared and the discharge stability during long operating time were discussed. It is found that the nanosecond pulsed discharge can generate a more homogenous and stable plasma with high energy efficiency compared with sine AC discharges, as shown in Fig.1.

Secondly, fast exposure images, evolution for electrical behavior, and spatiotemporal resolved spectra are measured to study the instantaneous characteristics of the nanosecond pulsed dielectric barrier discharge plasma and to understand the mechanisms of discharge processes. The time and space distributions of reduced electric field E/N, plasma vibrational & rotational temperatures are calculated by the spatiotemporal optical emission spectra, shown as Fig. 2. It is found that a diffuse structure with high density plasma concentrating in the region near the needle tip can be presented in nanosecond pulsed discharge, and an obvious energy transfer from electronic energy to vibration energy can be observed in each discharge pulse.

Thirdly, the kinetic mechanisms of physiochemical processes of active species conversion and HCHO degradation are described for the pollution control. The metastable nitrogen molecules play an important role in the generation of high energy level state excited particles of N_2 ($C^3\Pi_u$, $C^5\Pi_u$) in nitrogen, in the generation of active species of O, H and OH, and in the degradation of HCHO. The oxygen mole fraction has an obvious influence on the variety and number density of active species. Corresponding for the mechanisms of HCHO degradation and byproducts generation, the uniform discharges excited by high frequency have a distinct advantage in by-production (O_3, NO_x, etc.) control. Also it is shown the radicals OH and H are the dominate particles at low oxygen mole fraction (< 2%), and the atom O becomes the dominate species when the oxygen mole fraction is higher than 5%.

References

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Figures

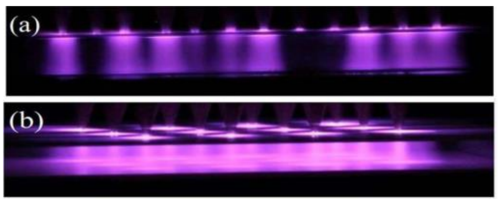

Fig.1. Images of discharges excited by sine AC voltage and nanosecond pulse voltage

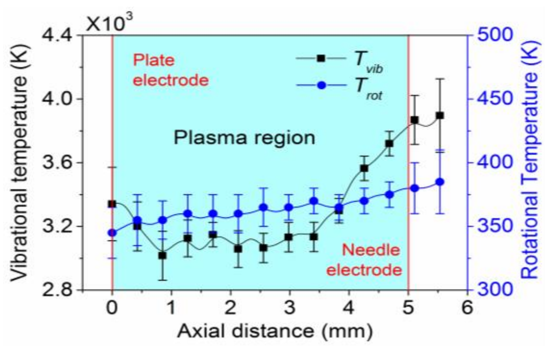

Fig. 2. Space distributions of plasma vibrational & rotational temperatur