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Nitrogen Triboplasma Light Emission and Its Applying Method Using Wind Energy for Controlling Agricultural Pest

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Abstract. In this work, the spectrum of nitrogen triboplasma light emission and the influence factors of the light intensity had been investigated by a reciprocating friction experiment platform based on the quartz and polytetrafluoroethylene (PTFE) as the friction pair. The results show that the spectrum of nitrogen triboplasma light emission is 220-470nm and the peak wavelength is 337nm; the friction velocity and friction normal force have a significant effect on the light intensity. The spectrum of the triboplasma light emission with nitrogen as the main working gas is concentrated in the violet and UV regions, which is the sensitive band of most agricultural pests. Therefore a light resource based on the triboplasma emission is constituted through the physical friction process driven by the wind energy. It may supply a new method for light trapping agricultural pest without any pesticides.

Introduction

Low temperature plasma has a special luminous performance, so that it have a very broad prospect in the industrial and agricultural applications. The current researchers always use the dielectric barrier discharge test method to obtain plasma, however, the method to induce the plasma through the friction electrification between the different dielectric materials is rarely studied. Nakayama studied systematically the mechanism of triboplasma generation and the luminescence characteristics under various friction factors by measuring the energy spectrum and two dimensional images of the emitted photons [1, 2]. Recently a deep UV light emission was obtained using triboelectrification induced plasma discharge. By a mechanical friction between polymer and quartz glass, the triboelectric charges cause a changing electric field, which bring plasma discharge of low pressure gas (Ar－Hg) and give out 253.7 nm irradiation[3].

In this paper, the friction plasma emission spectrum and its influencing factors were studied by using a reciprocating friction experiment platform and the aim is to explore a self-driven light source by utilizing windy energy for agricultural pest trapping in the vast field or wild grassland.

Experiment

The triboplasma light emission experiment equipment is schematically shown in figure 1, the sliding friction is generated by the pair of PTFE (6) against on quartz glass tube (5). PTFE is an electret material with excellent charge storage capacity [4]. When PTFE is subjected to reciprocating motion on a quartz glass tube, the PTFE friction surface would gather a large amount of negative charge because the two materials have different friction polarity. In consequence, the tribocharge density on the friction interface of PTFE on the glass is much larger than other glass area, therefore the high charge density could excite the plasma, and cause the emission of the photon by plasma discharge.

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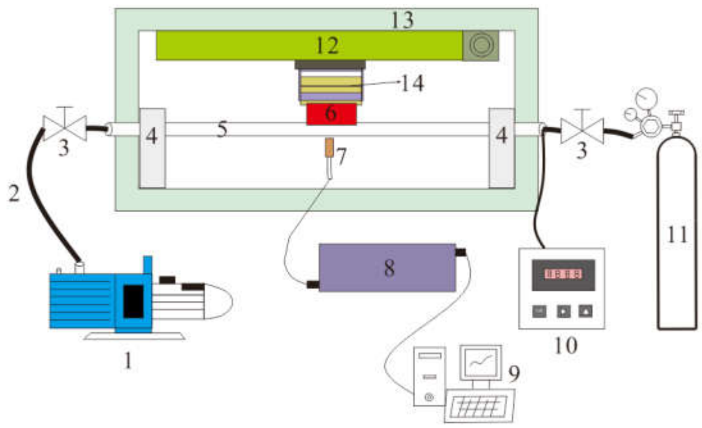


1. Vacuum pump; 2. Gas Guiding Tube; 3. Gas Valve; 4. Support; 5. Glass Tube; 6. PTFE;
7. Detector; 8. Spectrograph; 9. Computer; 10. Vacuum meter; 11. Gas Tank;
12. Lineal reciprocating motor; 13. The frame; 14. Load
Figure 1 Schematics of triboplasma light emission experiment equipment

Results and Discussions

Effect of Load on Luminous Intensity. A violet plasma radiation was found under the friction interface with sliding friction velocity as 0.5m/s and gas pressure as 3000pa, whose main peak is located at 337 nm. Figure 2 shows the intensity of the spectral peak wavelength (337nm) increases with the increase of load that offer the friction normal force. According to the model of triboelectrification, increasing the friction normal force is beneficial to the triboelectric process to some extent. This result indicates a nearly linear correlation between the friction normal force and the triboplasma light emission.

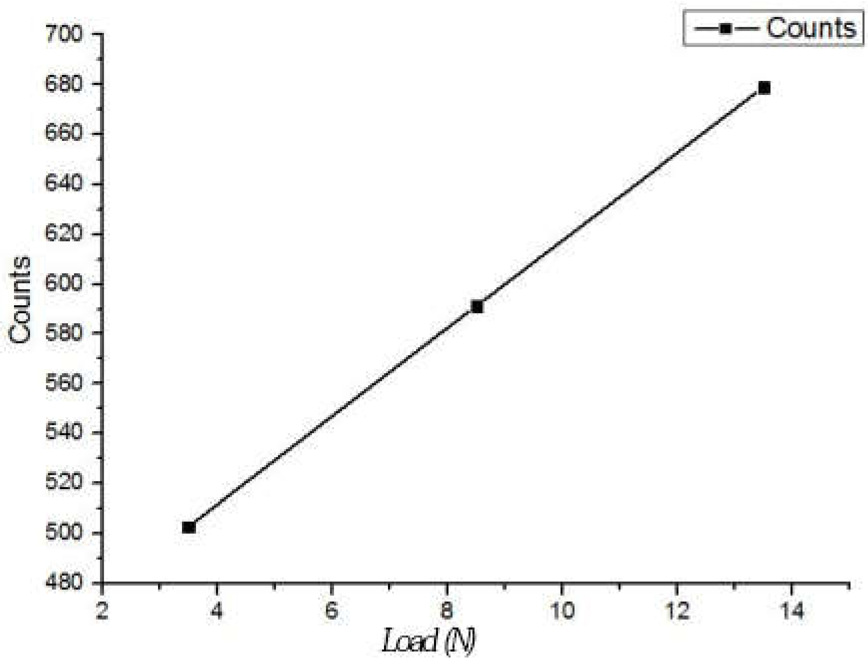


Figure 2 The relationship between peak wavelength intensity and applied load

Effect of Friction Speed on Luminous Intensity. Figure 3 indicates the triboplasma emission spectrum at various frictional velocities from 0.2m/s to 1.0m/s. It can be seen that the luminous intensity is nearly proportional to friction speed, and there is a sharp increase when friction speed from 0.6m/s to 0.8m/s. It is possible that a higher friction speed can produce more charges to increases the electric field intensity in the friction interface, therefore induce more intensity nitrogen plasma in the glass tube. As a result, the luminous intensity increase obviously. It must be mentioned that when the friction is terminated, the plasma emission spectrum also disappears immediately. This shows that the motion of the electric field is a fundamental reason to excite the plasma light emission.

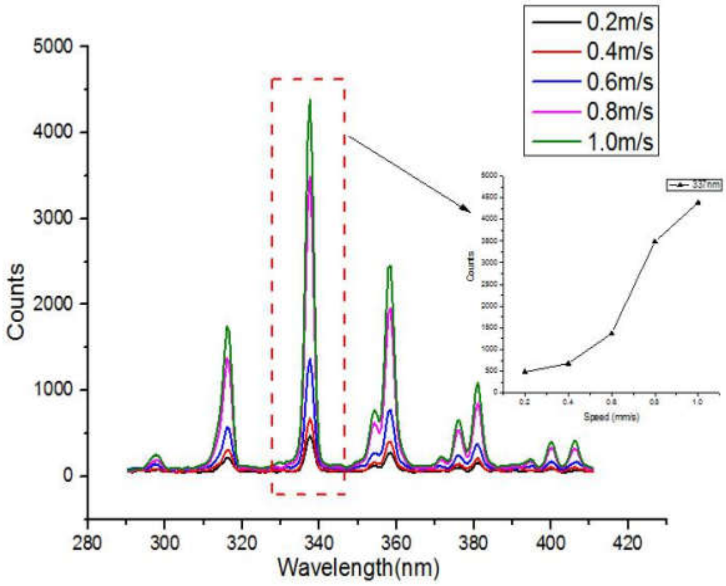


Figure 3 The spectrum at various friction velocities

The Spectrum Analysis of the Nitrogen Triboplasma Light Emission. The spectrum shown in figure 4 was measured under a normal force of 10N and 1m/s sliding friction velocity and the gas pressure is 9000pa. The spectrum of nitrogen triboplasma light emission is composed of several narrow bands in the 220-470nm and the peak wavelength is 337nm, its highest intensity is 22689 counts. The two bands of 220-290nm and 440-470nm present the weak light emission, and they would disappeared when adjust the gas pressure to less than 3000Pa or more than 28000Pa. The excited molecules from nitrogen in the quartz tube include N_2 ($A^3\sum_u^+$), N_2 ($B^3\Pi u$), N_2 ($C^3\Pi u$), and the above spectrum is mainly derived from the transition line of nitrogen molecule ($C^3\Pi u$ - $B^3\Pi u$), that is the second positive band spectrum of nitrogen. In the spectrum, the band of 220-300nm is the γ-band of the NO molecule. The reason may be that the vacuum system is not tightly packed.

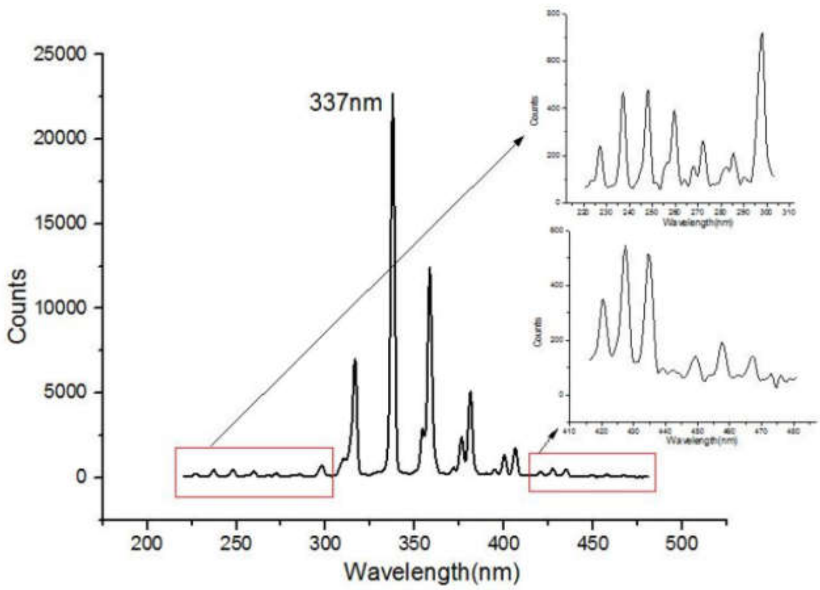
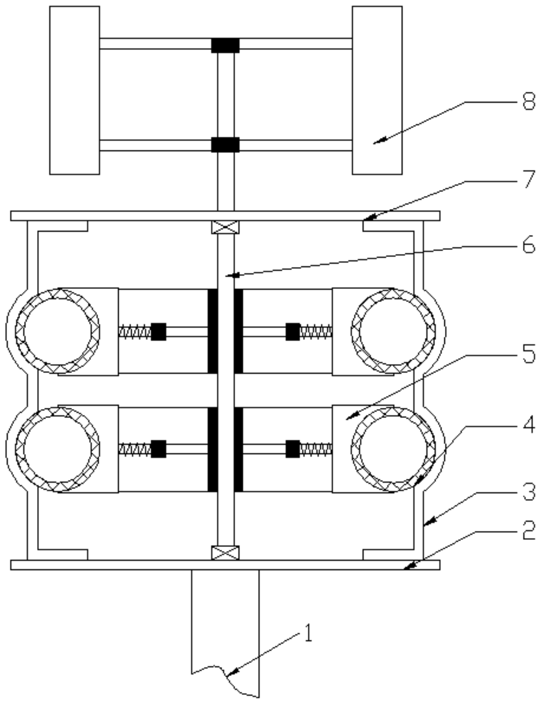


Figure 4 The spectrum of nitrogen triboplasma light emission

The New Applying of the Wind Energy and Triboplasma Emission

Based on the above experimental result, the new applying method using wind energy for controlling agricultural pest was proposed. As shown in Figure 5, a wind-driven triboplasma UV lamp was constituted according to wind turbine driving style and light emitting intensity requirement, it can realize the conversion of wind energy to light source using low-frequency mechanical friction. The rotating motion rubbing part (5) that was directly driven by vertical shaft wind turbine(8) would have a sliding friction on the fixed friction part(4) to emit the desired light. This work provides a novel design to fabricate a wind-driven triboplasma UV lamp realized by the coupling of wind-driven friction and plasma luminescence.



1. Support Pole; 2. Bottom Support Plate 3. Holders 4. Annular Glass Tube 5. PTFE
6. Vertical Center Shaft; 7. Top support Plate; 8.Vertical Wind Turbine
Figure 5 Schematics of a wind-driven triboplasma UV lamp

Conclusions

This work investigated the spectrum of the nitrogen triboplasma light emission and the influence factors of the light intensity, and the following conclusions have been drawn.

Increasing the friction velocity and the normal force of friction pair can improve the luminous intensity of the triboplasma. Under certain friction conditions, adjusting the friction speed and friction normal force can get a better luminous effect.

The spectrum of the nitrogen triboplasma light emission is 220-470nm, which belongs to the violet and UV regions, the main peak wavelength is 337nm, it’s the highest emission intensity is 22689 counts. Most agricultural pests are sensitive to UV rays at wavelengths of 300-400 nm. Therefor the spectrum and light intensity produced by the experiment can meet the requirements of trapping pests.

According to the plasma frictional luminescence effect, a new luminescent unit for pest light trapping is constitute by using wind energy as a friction-driven power, and it is a new method to utilize wind energy, and an expand application of controlling agricultural pest.

Acknowledgements

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