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Development of 146nm Vacuum UV Light Source

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Abstract

The principle of dielectric-barrier discharge (DBD) producing 146nm vacuum ultraviolet (VUV) light is introduced in this article. MgF_2 and Kr are used as the output window and the discharge gas, respectively, in the VUV light source. Fairly wide, narrow-bandwidth UV light could be generated with peak wavelength of 146nm and a full width at half maxima of 12nm. In addition, the impact of air pressure, voltage amplitude and frequency to the light source is also analyzed.

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Keywords: Dielectric-barrier discharge; VUV light source; Microdischarge; Intensity

Dielectric-barrier discharge (DBD) is the gaseous discharge in discharge cavity inserted the dielectric barrier. Within the range of high atmospheric pressure and wide frequency, low-temperature and non-equilibrium plasmas with high energy could be generated with DBD. Accordingly, at present, DBD is widely applied in ozone generation, fingerprint extraction, surface treatment, pollution control, high power CO_2 lasers, ultraviolet excimer lamps, and flat large-area plasma display panels[1,2].

In this article, 146nm VUV light source stimulated by DBD is presented, whose ultraviolet spectrum is tested and analyzed. The 146nm ultraviolet light, in the vacuum ultraviolet spectrum range, has high photon energy. As a kind of special light source, it has a very broad application prospect in testing fluorescent powder, enhancing luminous efficiency of plasma display panels and aviation field, etc.

1 The discharge principle

DBD is the electrical discharge between two electrodes separated by the dielectric barrier. Dielectric could be covered on the electrodes or hanged in discharge cavity. When enough high AC voltage is applied across the electrodes, the gas between two electrodes will be broken down to generate DBD. The discharge, uniform, dispersed and stable, looks like glow discharge in low atmospheric pressure. Nevertheless, in fact, current through discharge cavity is made up of large numbers of subtle fast-pulse channels. Theses current filaments, random distribution in discharge space and time, are called as microdischarges. Each microdischarge lasts only less than 10ns. Its current density is 0.1~1kA/cm^2, diameter roughly 0.1mm[3].

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In high atmospheric pressure DBD, an atom, stimulated to the high electronic energy level, collides with an atom in the ground state or a molecule and becomes another molecule. Then, transferring part of energy with the help of the third particle, the molecule relaxes from the high vibrational excited state to the low state and becomes a relatively stable molecule - excimer. Some people call excimer as triple-collision nonradiative bond or atom collision state.

Excimer, mostly in excited state, would radiate UV or VUV within several nanoseconds to release energy[4].

As to Kr, specific reactions are as follows:

$$e + \mathrm{Kr} \rightarrow e + \mathrm{Kr}^*$$

$$\mathrm{Kr}^* + 2\mathrm{Kr} \rightarrow \mathrm{Kr}_2^* + Kr$$

$$Kr_2^* \rightarrow 2Kr + 146nm \text{ VUV}$$

2 The design and production of 146nm UV light source

Configuration of the light source is shown in Figure 1. The output window to extract the radiation is made of MgF_2 single crystal. Controlled-expansion Kovar, tractable and whose coefficient of expansion is close to ordinary soda-lime glass's, is used to accomplish sealing.

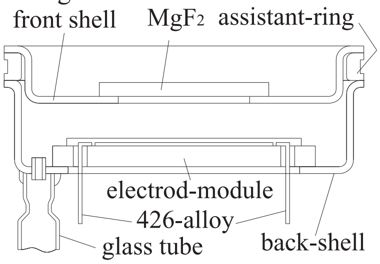

Fig.1 Configuration of 146nm VUV lamp

The light source adopts the surface discharge form. Electrodes graphic (Figure 2) is printed on the soda-lime glass substrate by screen printing processes. The width of discharge electrodes and the gap between electrodes is about 0.3mm and 0.7mm, respectively. Comparing with the opposite discharge, the surface discharge has the merits of low discharge voltage and not affecting UV transmissivity.

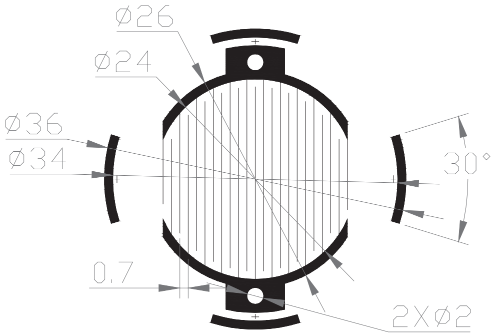

Fig.2 Electrodes graphic

3 Spectral detecting and analysis

3.1 The structure and principle of detecting apparatus

UV-spectrum detecting system is made up of vacuum pump, vacuum sample room, optical system, monochromator and UV-PMT (Figure 3). The detecting process is as follows. First of all, the lamp was put in vacuum sample room, and then the detecting system was pumped air to 10^{-2}Pa with vacuum pump. VUV light radiated by the lamp went through optical system room and entered into spectrophotometer room. Then homogeneous light separated from optical grating went through output split and entered into PMT. Afterwards, interface circuit transformed optical signal into electric one and transmitted it to a computer. At last, spectrogram of the VUV light source was shown on the screen of computer.

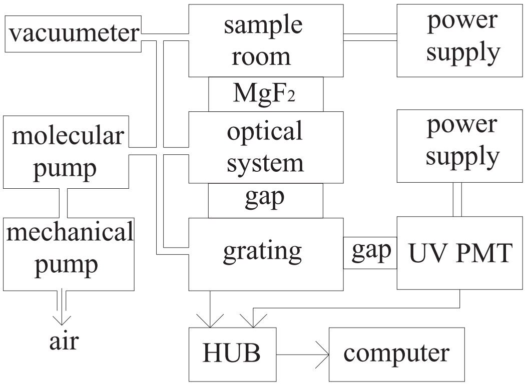

Fig. 3 UV-spectrum detecting system

3.2 The effect of gas pressure to 146nm UV intensity

In this article, related parameters of spectral detecting system are set as follows, the voltage amplitude 328V, the input-split width of monochromator and PMT 1.2mm and 1.0mm respectively, the negative high voltage of PMT -700v, integral time 500ms, scan interval 2nm. When the gas pressure of pure Kr in UV light source are 15KPa, 30KPa and 50KPa respectively, spectral detecting results (Figure 4, 5 and 6) imply that the preferred gas pressure of the lamp should be set as about 30KPa in order to get 146nm VUV light with higher intensity.

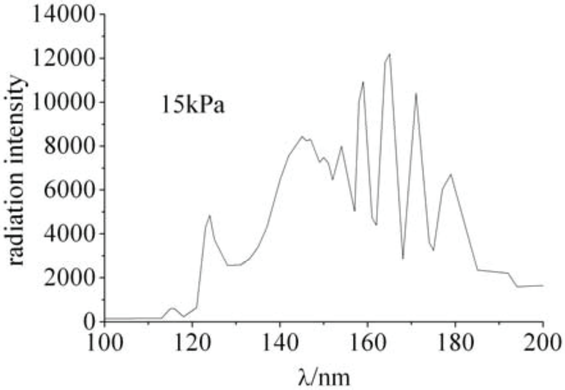

Fig.4 Spectrogram of the VUV lamp when the gas pressure is 15kPa

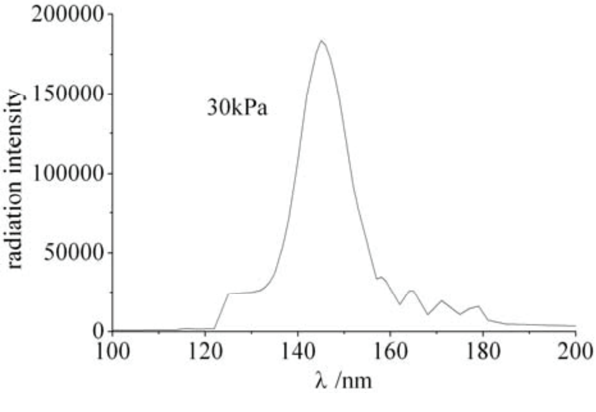

Fig.5 Spectrogram of the VUV lamp when the gas pressure is 30kPa

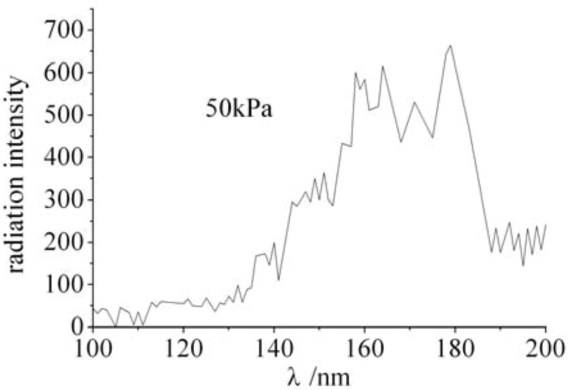

Fig.6 Spectrogram of the VUV lamp when the gas pressure is 50kPa

3.3 The relation among 146nm VUV intensity, voltage amplitude and frequency

When sinusoidal power supply is applied in the light source, the relation among 146nm VUV intensity, voltage amplitude and frequency is shown in Table 1 and Figure 7.

Tab. 1 The relation of luminous characteristic parameter of 146nm UV light source

A.1. Dial of the power A.2. /division	*A.3. Voltage amplitude A.4. /V*	*A.5. Frequency A.6. A.7. /kHz*	*A.8. 146nm UV intensity*	*A.9. 308nm UV intensity*
A.10. 1	*A.11. 280*	*A.12. 69.5*	*A.13. 70989*	*A.14. 9492*
A.15. 2	*A.16. 328*	*A.17. 63.5*	*A.18. 83767*	*A.19. 11489*
A.20. 3	*A.21. 310*	*A.22. 62.2*	*A.23. 65385*	*A.24. 10025*
A.25. 4	*A.26. 356*	*A.27. 55.4*	*A.28. 82055*	*A.29. 22660*
A.30. 5	*A.31. 368*	*A.32. 51.9*	*A.33. 105185*	*A.34. 35902*
A.35. 6	*A.36. 376*	*A.37. 49.1*	*A.38. 67027*	*A.39. 42349*
A.40. 7	*A.41. 392*	*A.42. 46.9*	*A.43. 50399*	*A.44. 53511*

A.45. 8	*A.46. 428*	*A.47. 44.2*	*A.48. 31962*	*A.49. 65836*

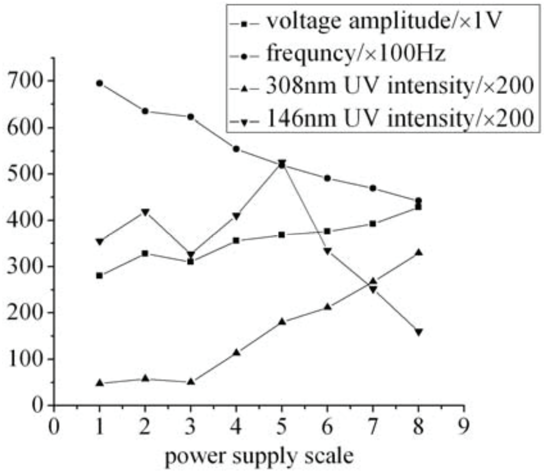

Fig.7 Radiation characteristic of the VUV lamp

According to the detecting results, we find, with the change of voltage and frequency, the lamp radiates 146nm narrow-bandwidth VUV light, accompanied by 308nm narrow-bandwidth near UV ray. When the voltage and frequency are 368V and 51.9kHz respectively, 146nm VUV intensity reaches a maximum of 105185. Simultaneously, 308nm near UV intensity also came up to 35902. When the voltage and frequency are 328V and 63.5kHz respectively, 146nm VUV intensity is also quite high, reaching 83767. Nevertheless, 308nm near UV intensity is weak, only 11489.

4 Summary

(1) 146nm VUV light source which is developed in this article radiates fairly wide VUV light with dominant wavelength of 146nm and a full width at half maxima of 12nm.

(2) In order to get 146nm UV light with higher intensity, the preferred gas pressure of the light source is set as about 30kPa.

(3) When sinusoidal power supply is used in the light source, 146nm UV intensity would be affected by the voltage amplitude and frequency and reach maximum at certain voltage amplitude and frequency.

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