

Flat Panel Ultraviolet Lamps by vehicle of Porous Alumina and ITO glass

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Abstract. Lamps with about 20W/m² UV emission were made in our work. The lamp was fabricated by ITO glass and bonded aluminum with porous alumina on the surface. The working gas is the mixture of argon and Nitrogen. Lamps properties were investigated.

Introduction

Dielectric barrier discharge (DBD), also referred to as barrier discharges or silent discharges have found a number of interesting industrial applications in addition to the historical ozone generation. Dielectric barrier discharge is important in that it can easily produce non-thermal plasma in an easy way. Most of all, it has been used widely in the PDP production. Argon and Nitrogen mixture is good for ultraviolet emission. Ultraviolet (UV) and Vacuum Ultraviolet (VUV) radiation are important applications [1-5]. Usually the UV lamps are tube sources. The flat panel UV source are seldom designed and referred[6, 7].

In our work, a flat panel UV lamp was fabricated by using ITO glass as the transparent electrode and dielectric, bonded aluminum with porous alumina acts as the other electrode. The properties of the discharge are investigated. With nitrogen concentration increasing at 0.5-20 percent, the UV emission decreases at the same voltage. However, the UV emission properties in the total emission dropped meanwhile. The spectra of the lamp were also taken and analyzed.

Experiment

Figure 1 shows the flat panel UV lamp. The 0.56-mm-thick ITO glass acts as the front electrode and the dielectric of the UV lamp. The rear electrode is made of bonded aluminum with porous alumina on the surface. The distance between the front and rear electrode is 0.44 mm. The aluminum thickness is 50 μm, and the alumina, which is produced by anodizing in the oxalic acid, is 5 μm. After anodizing, the porous AA is eroded by voltage drop till the voltage is 3 V. Pore widening in 0.1M H₃PO₄ solution is carried out afterwards. Nickel pigmented the porous alumina in the end to increase the alumina thickness.

The UV lamp was filled up with Ar-N₂ mixture after the lamp was vacuumed till 10⁻⁷torr. In discharge, the gas mixtures were excited in a pulsed transverse power supply. The power supply repetition is 20–40 kHz and the peak voltage is about 15 kv. The spectra were taken in the course of the discharge.

The power density was tested by a power meter with and without the SRG-610 filter. The Power Meter is 2832-C Dual-Channel Power Meter (produced by Newport Company). SRG-610 filter can separate the emission into two parts: 200-610 nm and above 610 nm. So we can test the total emission power density without SRG-610 filter and the near IR emission (above 610 nm) power density with the filter. Therefore, the UV emission power density can be attained by subtracting the near IR emission power density from total one.

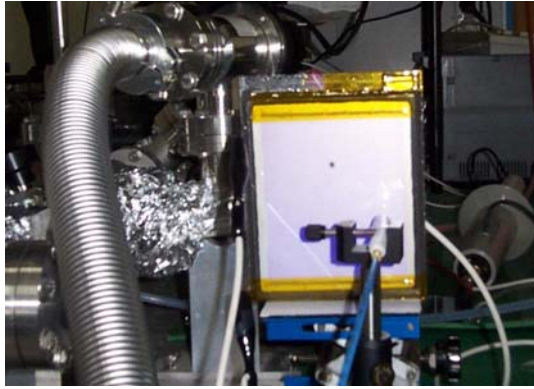


Figure 1. Flat panel UV lamps

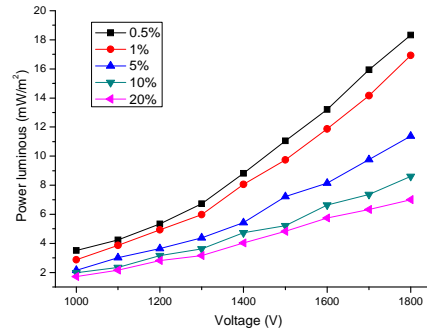
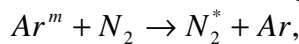


Fig.2. Power density versus voltage at different N₂ concentrations

Result and discussion

In Ar-N₂ mixture discharge, when N₂ is of small quantity, the excited species are mainly atomic argon ions (Ar⁺), electrons (e⁻), and the excited argon species in radiative or metastable states. It was believed that the Ar metastables (Ar^m) is the common energy source for all the species emitting ultraviolet (UV) and vacuum ultraviolet (VUV). Nitrogen can get energy, and turn it into active species and give out UV emission [8].

Ar alone can only give out near IR emission in the lamps. Because of the lower concentration, Nitrogen cannot have an appreciable influence on the argon metastable states processes populating. However, it can efficiently depopulate these states in the reaction:



where N₂^{*} represent all possible molecular excited states, which can give out UV emission.

The UV Power and Nitrogen concentration. Figure 2 shows the curve of the UV power density vs. voltage at different Nitrogen concentration. The testing condition is: 0.5 to 20 per cent Nitrogen in the mixture, total pressure 200 torr, the power supply repetition 40 kHz. With the Nitrogen concentration increasing, at the same voltage, the UV emission will decrease and the UV emission proportion in the total emission will increase.

In the working gas, the Ar^m concentration drops with Nitrogen concentration increasing[9-12]. As the Nitrogen is lower, the quantity of argon metastable states is enough to excite the Nitrogen molecules to give out UV. So Ar^m can excite the Nitrogen molecules more effectively. More UV emission will be given out.

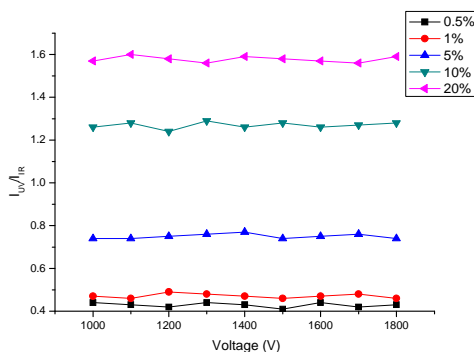


Figure 3. UV concentration in radiation versus voltage at different N₂ concentrations

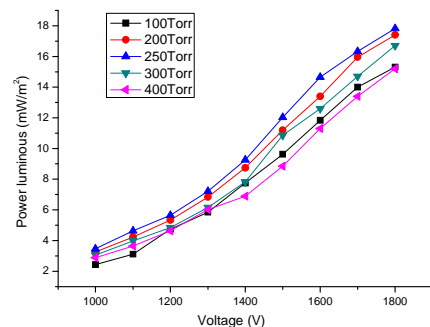


Figure 5. Power density versus voltage at different N₂ concentrations

Meanwhile, lower Nitrogen concentration will result in more argon relative species present, which give out higher near IR emission. The UV emission power in the total emission dropped with Nitrogen concentration increasing. This can be proven in the lamp spectra, which is shown in Figure 3.

Figure 4 shows the spectra of the UV lamp. There are mainly two parts of spectra lines which locates at UV region and near IR region. They are Nitrogen related species and Argon related species

respectively. The near IR emission power density at 1 percent Nitrogen is more intense than that at 5 percent. When a pulsed discharge of a short duration excites the mixture of Argon and a small amount of Nitrogen, the excited species in the plasma are mainly Argon related species. Argon metastables (Arm), which has longer lifetime, act as the energy source of the UV and VUV emission [13-15]. In our experiment, the UV emission acceptors are mainly Nitrogen molecules. Arm also provides energy to the other Argon related species and gives out near IR emission. So a competition occurs between Ar and N₂ species. When N₂ concentration increases, more N₂ molecules existing in the mixture will cause higher UV emission power proportion. However, as Ar concentration dropping, Arm concentration drops. The total UV power density decreases too.

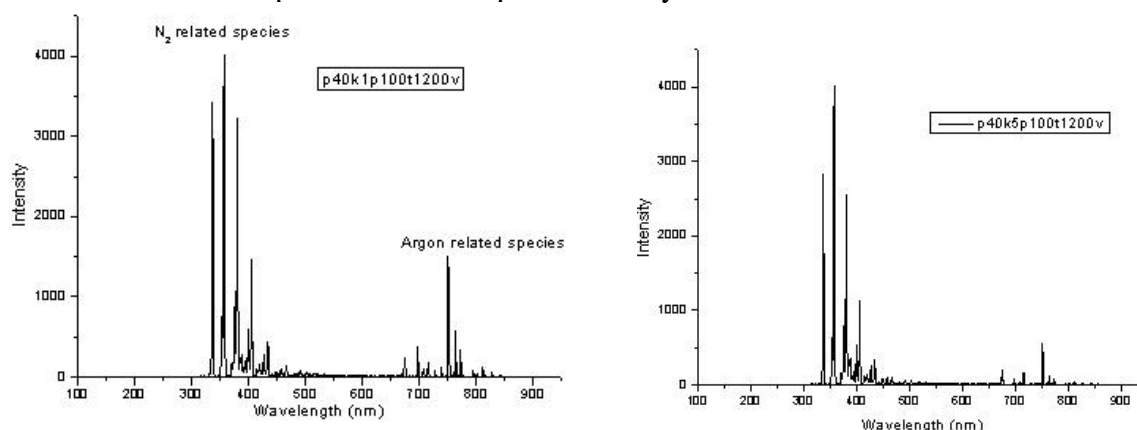


Figure 4. The UV lamp spectra: 1 and 5 percent nitrogen in the Ar-N₂: 100torr; 1200v, 40kHz.

The UV power and pressure. Figure 5 shows the experimental curves of UV power density and voltage at different pressures. The pulsed power supply repetition is 40 kHz. The UV lamp performs better when the pressure is at 200 and 300 torr. From 200 to 400 torr, the UV power density emission performance becomes worse, which is similar to that of 100torr.

In Ar-N₂ discharge, the UV emission performance rests on the quantities excited N₂. Excited Nitrogen molecules get energy from Arm by collisions. Therefore, Nitrogen molecules and Arm concentration is the key to UV emission performance [16]. At 100 torr or lower pressure, there are not enough Nitrogen molecules colliding with Arm, so that more argon related species are excited and give out more near IR emission. At 200-300 torr, the Nitrogen molecules are just suitable, and the lamp will give out more UV emission and less near IR emission than at 100 torr[17].

From the spectra 100 and 300 torr, more IR emission produces produced at 100torr than that of 300torr. Therefore, we can conclude the N₂ molecules absolute concentration at 300 torr is more suitable for the collisions between N₂ molecules and Arm than that at 100 torr. More UV emission is produced at 300 torr.

If the pressure goes on increasing, the plasma properties will change: the electron free path will shorten and the number of the excited species will reduce. So the lamp will perform worse when the pressure gets to 400torr or above.

Conclusion

Flat panel UV lamps which can give out above 20 mW/m² UV emission are made in our laboratory by using ITO glass and bonded aluminum with porous alumina as the former and rear electrode structures. The lamps can emit intense UV emission by vehicle of Ar-N₂ discharge. At 200-300 torr and less than 1 percent N₂ in Ar-N₂ mixture, the lamps UV emission performance is much better than those at the other conditions.

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