I_2 capacitive discharge lamp

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Received January 8, 2004

The energy and UV spectral parameters of the iodine capacitive discharge lamp were studied at different I_2 vapor pressure and input electric power. The low-pressure capacitive discharge lamp based on the atomic iodine transition can make up the deficiency of light sources in the spectral range from 180 to 210 nm.

1. Introduction

By now, different sources of spontaneous radiation with a wide range of spectral and energy characteristics have been created. Basically, the attention is given to the excilamps of high-pressure barrier discharge when developing and investigating the spontaneous radiation sources in the UV and VUV spectral ranges. In these excilamps the radiation of excimer (or exciplex) molecules is used.[1–6,etc.] There are also low-pressure intense radiation sources emitting atomic lines in the UV and VUV spectral ranges, in particular, the low-pressure mercury-vapor lamps on resonance lines at 185 and 253 nm with the specific radiation power of 10 mW/cm^2 (Ref. 7). Relatively low intensities in the short-wave spectral range can be obtained using a deuterium lamp on atomic line 121.5 nm and continuous radiation with maximum close to 161 nm. Lower radiation fluxes of 4–7 mW/cm^2 can be obtained on the resonance argon lines (107 nm), on the resonance krypton (124 nm) and xenon lines (147 nm) excited by a low-pressure discharge.[8] A search for new media, extending the spectral range and energy parameters of radiation sources in the UV and VUV spectral ranges, is now the problem of current interest. From this standpoint, one of the promising media is the iodine vapor or its mixture with inert gases. Some papers, though few in number,[9–13] are devoted to the study of spectral and power characteristics of I_2 discharge radiation. As a rule, a glow discharge was used for excitation of a working medium, under conditions of which there is a contact of iodine vapor with the electrode metal that reduces the resource and makes difficult the provision of stable mode of the lamp operation.

The goal of the present paper was to study the spectral and energy parameters of a capacitive low-pressure discharge in iodine vapor.

2. Experimental setup and methods

A capacitive discharge in I_2 was obtained in a 30-cm long cylindrical tube with the inner diameter of 4 cm, sealed end plates, and ring electrodes of 3-cm width superposed outside on the walls, to which the alternating voltage of 100-kHz frequency was applied. The mean generator power varied within 10 to 90 W. The discharge tube was made from high quality quartz with the transmission in the range of 200 nm of 80%. On one of the tube ends, a container with iodine in solid phase was placed.

The distance from the ring electrode to the container at a given input power determined the container temperature, and, hence, the saturation pressure of I_2 vapor in the bulb, which did not exceed 15 Torr. The general view of the discharge in this case was like a glow discharge in the shape. The radiation spectra were recorded with a VM-502 vacuum monochromator. Measurements of the radiation intensity were carried out with a FEK-22SPU calibrated photodiode using the technique described in Ref. 14. In this case the emission power calculated was integrated over the entire spectrum from 200 to 650 nm, i.e., in the entire range of the FEK-22 spectral sensitivity. The energy deposited to the medium was determined using the measurement technique described in Ref. 15. The emission efficiency of the lamp was calculated as the ratio of the emitted power to the power deposited to the medium. The temperature of the current channel was calculated by solving the equation of thermal conductivity.[16]

3. Results and discussion

Figures 1 and 2 show the output emission power and efficiency of the lamp as functions of the excitation power and I_2 vapor pressure. It has been found that the increase of the input power from 35 to 60 W (2–9 W/cm^3) makes the emission power to increase linearly from 2 to 3 W (6–10 mW/cm^2) so that the efficiency remains constant in this case. At the excitation power of 30 W and the I_2 vapor pressure of 0.5 Torr the discharge character is diffuse. As the excitation power increases up to 60 W and the I_2 vapor pressure increases up to 2.5 Torr, the narrowing of the current channel is observed and in the further development the discharge becomes constraining. In this case the radius of the current channel decreases from 8 to 2.7 mm and the temperature of I_2 vapor at the channel center varies from 180°C to 280°C (Fig. 3).

At the minimum radius of the current channel (2.7 mm), the mean excitation power of 60 W (2 W / cm^3), and 2.5 Torr of the I_2 vapor pressure the maximum of the emission power occurs. In the range from 200 to 650 nm the power is 3 W (10 mW / cm^2) at the efficiency of 5%. The radiation emitted in the atomic line at 206 nm is about 25% of the mean emitted power. The greatest part of the remaining emitted power is within the molecular band of I_2^* at 342 nm (Fig. 4).

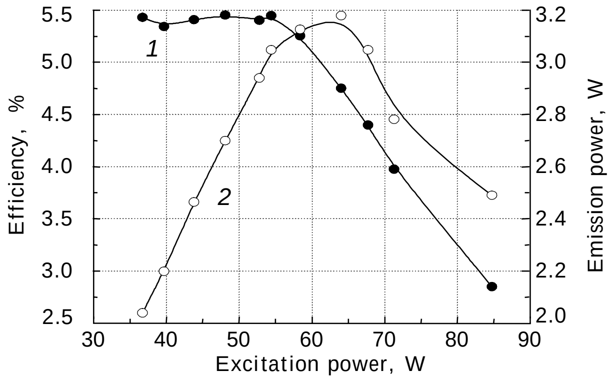

Fig. 1. Radiation efficiency (*1*) and the radiation power (*2*) of the lamp depending on the excitation power.

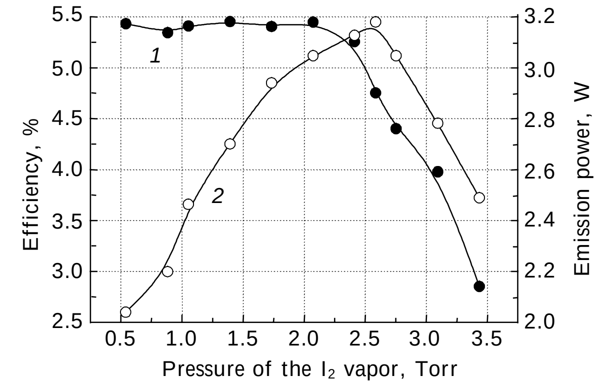

Fig. 2. The emission efficiency (*1*) and output power (*2*) of the lamp depending on the iodine vapor pressure.

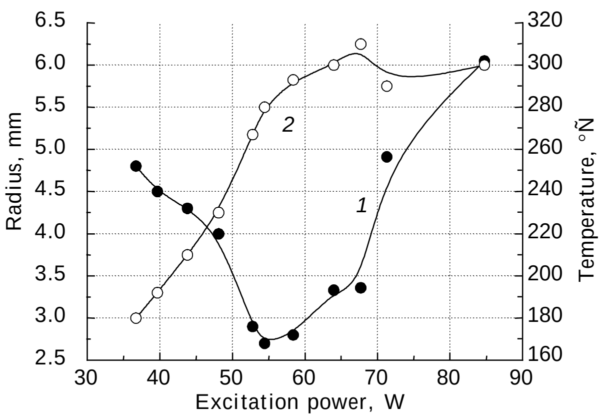

Fig. 3. The current channel radius (*1*) and the temperature on the axis of the current channel (*2*) depending on the excitation power.

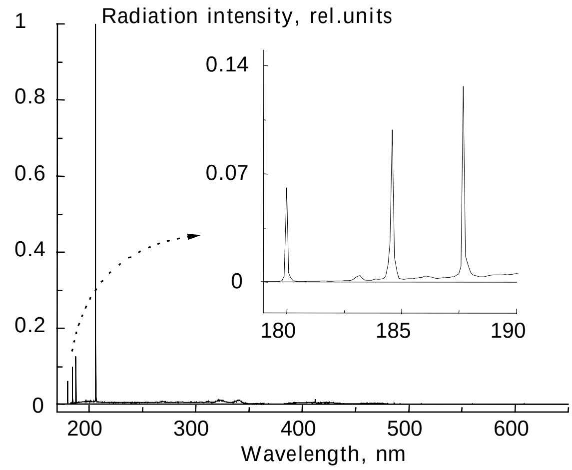

Fig. 4. The lamp emission spectrum at the iodine vapor pressure of 2.5 Torr and the mean excitation power of 60 W.

The components made up by the atomic lines at 179.9, 184.4, and 187.6 nm in the vacuum UV spectral range were not taken into account in calculating the emitted power. The temperature of the external bulb surface under optimal operating conditions was equal to about 100°C. At the further increase of the input power from 60 to 90 W and the iodine vapor pressure up to 4 Torr the current channel broadening up to 6 mm is observed (in this case the specific excitation power decreased from 9 to 3 W / cm^3) as well as a decrease of the emission power. The temperature at the center of the current channel under these conditions is about 300°C. When the iodine vapor pressure varied from 5 to 15 Torr at the excitation power varying from 70 to 90 W, the channel radius changed from 4 to 1.5 mm. The temperature of the current channel varied in the range from 300 to 500°C. In this case the emitted power was by one order of magnitude smaller than in the case of optimal operating conditions of the bulb. At the resource testing under optimal conditions from the viewpoint of the radiation power during the first 1000 hours, the bulb has been emitting without any decrease in the emission power.

4. Conclusion

We have presented the results of investigation of the power and spectral characteristics of the iodine lamp emitting in the UV spectral range being excited with a capacitive discharge. The iodine vapor pressure and the input power have been varied. For I_2 lamp operated in the optimal mode at the excitation power of 60 W (2 W / cm^3) and the iodine vapor pressure of 2.5 Torr the maximum of the emitted power was observed. In the range from 200 to 650 nm the peak power was 3 W (10 mW / cm^2) at the efficiency 5%. Specific powers of the I_2 lamp radiation and the mercury lamp of low pressure are comparable. In this case one of the problems, connected with the operation of mercury lamps and reducing the lifetime of lamps, is the darkening of a quartz envelope due to frequent cycles of ignition – extinction of the lamp and electrode sputtering.[7] Lamps of a capacitive discharge excitation are free of this defect, and even after several hundred thousand cycles of the ignition and quenching of the discharge in the bulb the quartz material does not lose its optical transparency at operating wavelengths. The service life of the lamp is no less than 1000 hours.

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