Development and Evaluation of Microwave Discharge Lamp for VUV Point Light Source

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Abstract-- We have been developing a vacuum ultraviolet (VUV) point light source. A small short arc lamp filled with xenon gas was prepared for microwave discharge. An intense peak at 172 nm from xenon excimer was confirmed by emission spectroscopy. The VUV emission was localized only on the electrode surface in the observation of luminance distribution image while the UV-visible emission widely distributed between the electrodes. It was expected that the characteristic of point light source could be improved by decreasing the electrode gap.

I. Introduction

VUV light below 200 nm in wavelength has high photon energy sufficient to induce the interaction of various organic bonds. VUV light has been used for semiconductor manufacturing processes, UV cleaning, sterilization, ozone generation, and so on. As commercially available VUV source, the excimer lamps have been widely used. The conventional excimer lamps are long length tubes or wide area type designed for uniform and high-speed processing to large area targets. There are few examples of high intensity VUV point light source necessary for application to imaging optical systems such as photolithography.

While a short arc lamp is promising for a point light source, the DC arc discharge thermally damages the electrodes with resulting in short lamp life. It is expected that, by using microwave discharge, the thermal load can be reduced and lamp life can be extended. In the microwave discharge, the electrode temperature is actually lower than that of DC arc discharge.

In this study, a novel short arc lamp using microwave discharge is developed for VUV point light source. For characterization of the lamp, VUV spectroscopy and observation of luminance distribution are carried out.

II. Material And Methods

A prototype short-arc lamp made of synthetic quartz (SUPRASIL-310, Shin-Etsu Quartz) with a light-emitting tube diameter of 11 mm and an effective antenna length of 31 mm was fabricated (Fig.1). The tungsten electrodes were sealed with a gap length of 1 mm; the filled gas was xenon at 1–5 atm in pressure. A 2.45 GHz microwave power source (Collabora Technica) was used to excite discharge. A vacuum ultraviolet spectrometer (JASCO Corporation) and an ultraviolet-visible spectrometer (Otsuka Electronics Co., Ltd.) were used for emission spectroscopy. An ICCD camera (Teledyne Technologies) was used to capture the luminance distribution in the lamp with separation of wavelength between the VUV and the UV-visible regions using a bandpass filter (Fujitoku) with a wavelength of 172 nm.

III. Results And Discussion

The emission spectrum of the lamp is shown in Fig. 2. An intense VUV emission from the xenon excimer was confirmed at the wavelength of 172 nm and xenon atomic emission peaks were found in the visible region. The luminance distribution images of the lamp are shown in Fig.3 for the VUV region and the UV-visible region. It was found that the VUV emission was localized only on the electrode surfaces while the UV-visible emission was widely distributed in the space between the electrodes.

The rapid potential gradient near the electrode surface caused electron amplification, which shrank the ion sheath region and rapidly increased the electron and ion densities with resulting in promoting production of xenon excimer (Xe_2*). From the results of localized VUV emission on the surfaces of electrodes, it was expected that, by bringing the electrodes closer to each other, the light spot could become smaller and the lamp could perform better as the point light source.

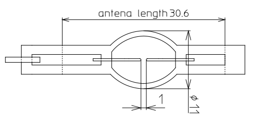

Fig.1 Appearance of the lamp

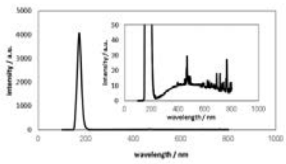

Fig.2 Emission spectrum

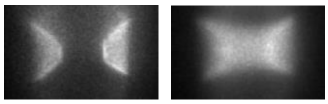

Fig.3 Brightness image
(Left: VUV region, Right: ultraviolet to visible light region)

IV. Conclusions

We developed a microwave discharge VUV point light source. The emission of xenon excimer at 172 nm in wavelength was localized on the electrode surfaces. By reducing the electrodes gap, the characteristic of point light source could be improved.

References

[1] A. Oda, Y. Sakai, H. Akashi and H. Sugawara, *J. Phys. D: Appl. Phys.*, **32** (1999) 2726–2736.