Performance optimisation of a high-pressure argon dielectric barrier discharge excimer lamp: transient behaviour of the VUV output

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We report an experimental study of the operating characteristics of an air-cooled, high-pressure argon excimer VUV lamp (λ~126nm), driven by a dielectric barrier discharge (DBD), in the regime of high electrical power loadings close to the thermal loading limit. Remarkably, under such conditions, the VUV output is seen to reach a maximum a few seconds after turn-on, and thereafter decrease by ~50% within a few minutes. Although the rate of decrease in the VUV output is shown to be matched in part to the thermally induced rate of gas expansion from the plasma region, we propose this VUV ″spiking″ behaviour is similar to that reported by Gerasimov (Opt. & Spectros. **83**, 534, 1997) for an interrupted discharge in a liquid N_2 cooled excimer lamp.

1. Introduction

We have investigated the electrical and optical characteristics of a high-pressure argon excimer lamp excited by a dielectric barrier discharge (DBD) when operated with relatively high electrical power loadings. The excimer lamp produces λ=115-140nm (~10eV) photons in the vacuum-ultraviolet (VUV) spectral region which are effective at ionizing many chemical analytes. The availability of intense, narrow-band VUV light sources could potentially make a big impact in the field of mass spectrometry ion sources. The specific aim of this work is to optimise the overall VUV output power and efficiency of an excimer lamp by undertaking a detailed experimental characterisation of its performance over a range of operating parameters for the DBD plasma (namely argon pressure up to ~1bar, short-pulse bipolar and sinusoidal high-voltage waveform excitation, waveform peak voltage, duty-cycle, and repetition frequencies up to 100kHz). A wide range of operating conditions has been tested up to the thermal loading limit of the air-cooled VUV lamp. The optical and electrical diagnostics and techniques employed are broadly similar to those described in [1].

2. Results

The experimental results clearly show an improvement of the overall lamp performance when utilizing short-pulsed high-voltage excitation waveforms compared to conventional sinusoidal ones at comparable electrical input power loadings. Lamp performance, in terms of maximum VUV output optimised at the highest gas pressures and input power loadings investigated (p=800-900mb, ~2W/cm^3). In this regime, however, it was generally observed that the lamp attained maximum VUV output a few seconds after turn-on, after which the output dropped by ~50% over the first few minutes of running, whilst the input power remained unchanged. To investigate the potential to run the lamp with sustained high VUV output, we studied this phenomenon by monitoring the long-term VUV output of the lamp when subjected to several periods of interruption of the electrical power. We observed that the VUV output “spike” decayed exponentially in time in three distinct stages, with two of the deduced time constants matching those for thermally induced expansion of the fill gas from the lamp’s plasma region. However, the large ~50% drop in VUV output cannot be attributed solely to a reduction of gas density and/or to the increased average gas temperature in the lamp’s plasma region. Similar spiking of the VUV output has been reported previously by Gerasimov et-al [2], in an experimental study of an interrupted discharge in a liquid nitrogen cooled capillary Krypton excimer lamp. They observed a ~50% drop of VUV intensity over several seconds after lamp turn-on, and attributed the initial enhanced VUV output from Xe, Kr and Ar gas fills to enhanced production of the principal VUV emitting species (e.g. $Kr_2^*(1_u,O_u^+)$) via electronic excitation of weakly-bound molecular ground states e.g. $Kr_2(O_g^+)$ formed during the “off” period of a cooled (77K) discharge. We propose that we may be observing the same intrinsic VUV spiking phenomena in an excimer-based VUV lamp, only in our case with gas fills at, or slightly above, room temperature (without liquid nitrogen cooling).

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