Conversion Efficiencies of Electron Beam Energy to Vacuum Ultraviolet Light for Ne, Ar, Kr and Xe Excited with Continuous Electron Beams

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Excitation of rare gases at pressures of 100mbar and above leads to emission of broad-band continua in the vacuum ultraviolet (VUV) spectral region (Fig. 1). They are dominated by the so called 2nd excimer continua. The word excimer describes an excited diatomic molecule with a repulsive ground state. Rare gas molecules exist only in excited states (except for a shallow Van der Waals minimum in the ground state). The transition to the ground state leads to the VUV emission and subsequent breakup of the molecule. Since the quantum efficiency is high and loss channels in the reaction chain leading to excimer formation are weak, highly efficient VUV lamps can be realized using this emission. Theory predicts efficiency values for rare gas excimer lamps on the order of 70%. Efficiency η is defined here as the ratio of power emitted in the 2nd excimer continuum and the power deposited in the gas.

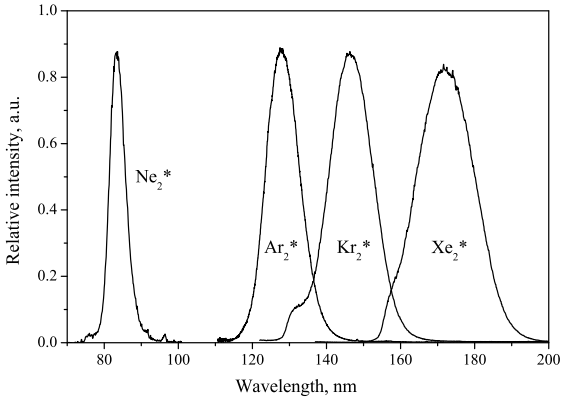

Fig. 1: Second continuum excimer emission from Ne, Ar, Kr and Xe at 1200 mbar

An experimental setup to study fluorescence of gases under electron beam excitation has been constructed. An electron beam ($5\mu A$, $12keV$) from an electron gun was sent through a thin ceramic membrane into a gas cell [1]. The stopping of the electron beam in the gas leads to excitation of rare gas atoms and subsequent VUV emission. The fluorescence emission was spectrally resolved by a monochromator (Fig. 1). The spectra show, that the gases are free from impurities. An absolutely calibrated Si photo-detector was used to measure the power of VUV-light emitted by the rare gases. A glass filter (not transmissive in the VUV) was used to separate the VUV excimer emission from visible and near infrared radiation which is produced by the excited rare gas atoms. Another filter was used to verify that the influence of x-rays on the detector was negligible. Therefore, the power of VUV emission could be determined separately. The excitation power was in a first step determined by measuring the electron beam current after transmission through the membrane using a Faraday cup.

The final value for the power deposition in the gas was simulated using the program package Geant4, taking the energy loss of the electrons in the foil and the backscattering of electrons from the gas volume into account. A problem concerning the VUV-power measurements was, that the membrane reflects VUV light. Therefore, the Si photo detector detected additional light which was reflected off the membrane, leading to an overestimation of VUV light emitted into 4π. This issue was solved by measuring the reflectance of the membrane in the VUV wavelength range and correcting the light signal accordingly. Another aspect is that the light emitting volume becomes large at reduced pressures. Therefore, the light source could no longer be treated as being point-like. However the spacial distribution of the light emitting volume could be simulated using the program Casino [2] and the detector signal was corrected using these simulation data. The final efficiency results are shown in Fig. 2.

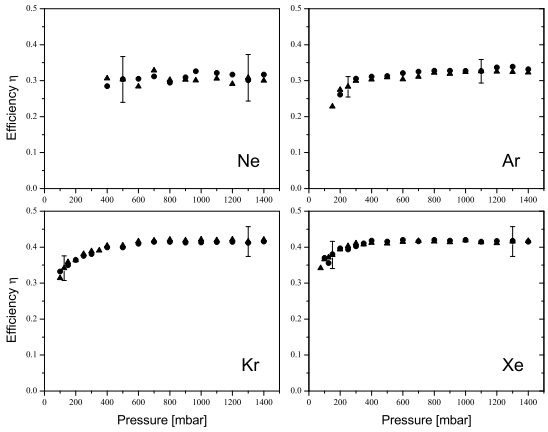

Fig. 2: Conversion efficiencies for the VUV emission from Ne, Ar, Kr and Xe.

The efficiencies η were found to be pressure independent for values above 600mbar (Fig. 2): $\eta_{Ne} = (0,31 \pm 0,06), \eta_{Ar} = (0,33 \pm 0,04), \eta_{Kr} = (0,42 \pm 0,05)$ and $\eta_{Xe} = (0,42 \pm 0,05)$ [6]. The efficency values obtained for Ar, Kr and Xe are close to the theoretical maxima given in literature [3,4,5]. To our best knowledge no value has been previously published for Ne.

References

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