Ultraviolet Emission from Argon Water-vapor Mixtures excited with Low-energy Electron Beams ◇

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It is known that under certain conditions mixtures of light rare gases (He, Ne or Ar) with water vapor emit intense ultraviolet radiation on the OH (A $^2\Sigma^+ \rightarrow X^2\Pi$) molecular band around 310 nm. Low pressure mixtures of argon with small amounts of water vapor excited with glow discharges were already proposed as ultraviolet light sources [1,2]. However, data presented on the emission from such mixtures are still mainly qualitative. Moreover, discharge-based light sources have the intrinsic problem that there is a considerable rate of impurity production in the gas cell due to erosion of the electrodes. In the year 2004 we have applied an alternative way to excite argon water-vapor mixtures using low energy (10 to 15 keV) electron beams in order to measure the efficiency of the conversion of electron beam power to OH ultraviolet light emission [3]. Details of the experimental setup were presented e.g. in the previous Annual Report 2003 [4]. The gas cell is first filled with water vapor from a chamber containing bi-distilled and degassed water. Then high purity argon is added from a rare gas purifier (Monotorr, SAES getters). To monitor water vapor partial pressure an impedance hygrometer (Easidew Transmitter, Michell Instruments) has been installed in a small chamber attached to the side of the gas cell. The hygrometer measures water vapor partial pressures from 20 down to 2×10^{-5} hPa and shows reproducibility of about 10%. Calibration of the hygrometer was performed using a high precision capacitive manometer (MKS Baratron, model 128AA). Light emission was recorded through a MgF_2 output window either with a photo-multiplier tube attached to a vacuum monochromator (McPherson 218), or with a calibrated photodiode (Hamamatsu G1126-02) with a filter (Schott UG11). The filter limited the photodiode sensitivity to the wavelength range of 250 to 400 nm. The OH band at 310 nm (A $^2\Sigma^+ \rightarrow X^2\Pi$ transition, v' and v" = 0) is the dominating emission in the entire range from 120 to 450 nm. Ar_2^* excimer emission appears at low partial water pressures only during the first minutes of electron beam operation. Light output from argon water-vapor mixtures was optimized in the argon pressure range from 250 hPa to 1000 hPa. The lowest pressure was limited to 250 hPa because data analysis of emission from lower pressure mixtures would require an accurate treatment of the geometrical factor of the light emitting volume. This is not straightforward since the stopping range of electrons is significantly increased at low pressures, causing a considerable expansion of the light emitting volume [5]. This expansion also leads to difficulties with light focusing which limits the practical application of the whole device. The dependence of the wavelength-integrated OH band intensity (using spectroscopic data) on Ar pressure is shown in Fig. 1 for four different water vapor partial pressures.

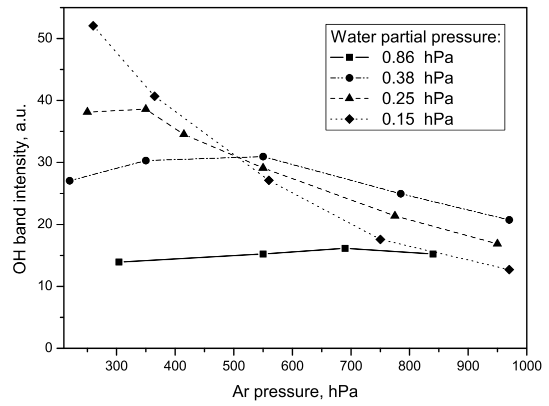

Fig. 1: Dependence of the wavelength-integrated OH emission intensity on Ar pressure for four different partial pressures of water vapor.

The systematic error due to water vapor pressure measurements is on the order of $\simeq$ 10%. The dependence of the OH band intensity on water vapor partial pressure for two Ar pressures (250 and 550 hPa) is shown in Fig. 2. In this study the maximum OH band intensity was observed at 250 hPa of Ar with a water vapor pressure of 0.048 hPa (concentration $\approx$ 0.02%).

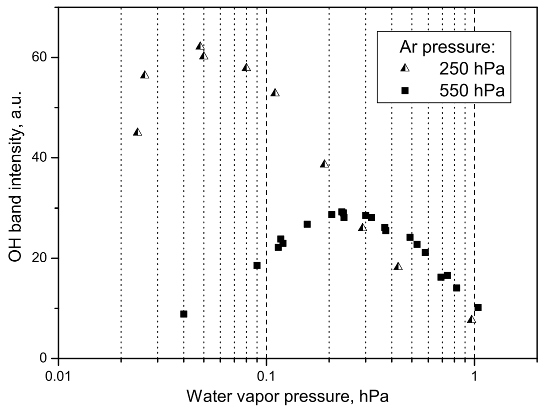

Fig. 2: Dependence of the wavelength-integrated OH emission intensity on the partial pressures of water vapor for mixtures with 250 and 550 hPa of Ar, respectively.

The efficiency of the light source can be defined as the ratio between the wavelength integrated output power of the OH band emitted into 4π solid angle and the power of the electron beam entering the gas volume. Using the calibrated photodiode with the filter to measure the light output and then placing a Faraday cup in the evacuated cell to measure the electron beam current, the following efficiencies were obtained: 3% for the intensity optimized

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conditions (250 hPa Ar + 0.05 hPa water vapor), 2.5% for 350 hPa Ar + 0.06hPa water vapor and 1.5% for 550 hPa Ar + 0.25 hPa water vapor. For 10 μA electron beam current and 15 keV electron energy the value of 3% corresponds to about 4 mW light output. The silicon nitride membrane used in the current experiments (0.7 by 0.7 mm^2) can withstand total electron beam currents on the order of 20 μA. Electron guns with rectangular beam shape (currently being manufactured) combined with rectangular membranes (0.7 by 40 mm^2) will allow to increase beam currents about 50 times, tentatively increasing the maximum light output to 200 - 400 mW.

References

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