

ON THE UV EMISSION FLUX CONTROL FOR SOME METAL-HALIDE LAMPS

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The last generation of metal-halide (MH) lamps are very attractive from the lighting point of view and also from other specific applications. In this paper is analyzed the ultraviolet emission of two MH lamps, UVAprint 250 LE and UV Blue-Point, with respect to the power supply. Both of the two lamps can be used in the chemical applications like water depollutions or desalinization. From this point of view are analyzed the possibility to control the surface polymerization of acrylic acid (AA) on the poly-sulfone (PS) hollow fiber through UV illumination. Was found the UV band where the integral flux variation with the power supply is more sensitive, allowing the control of photo-polymerization layer size trough power illumination and speed of PS hollow fiber in the AA solution. Also, the spectral bands, which can favor the photo-polymerization process for other substances, were found.

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1. Introduction

The use of mercury as buffer and work gas in most of the lamps is due to their easy vaporisation, low ionisation and excitation potential and to a small reactivity with silica. This made very attractive both the high and low-pressure mercury lamps, but after the lamp destruction this gas will arrive in the atmosphere. The mercury toxicity problem has determined a considerable effort of physicists and engineers in order to find new lamps free of mercury or using small mercury quantities. So, lately a new plasma lamp generation has appeared. This represents the metal-halide (MH) lamps, which are more efficient from the lighting point of view, than one of the high-pressure mercury or sodium lamps. The advantage of these kind of lamps is due to the fact that there can be used not only for the illuminating skill, but also in specific applications like surface deposition [1], photochemical generations of the radicals used in polymerisations [2], UV photo-grafting [3, 4], etc. This is possible by a using a convenient choice of the metallic halide salts and their concentrations. As a consequence of high temperature plasma discharge the metal-halide salts decay releasing metallic atoms. The big difference between the halogen and metal atoms excitation and ionisation potentials determines that in the electric discharge exist only excited metal atoms. So, there are obtained only some metal atomic lines.

The metallic bromide or iodine salts are chosen by taking into account the specific applications. For example, from the lighting point of view the sodium (Na), indium (In) or thallium (Tl) halides are used preponderantly. The gallium (Ga) atoms are used for the surface treatment due to the violet and ultra-violet emission. The iron (Fe) iodine is used for photochemistry.

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2. Motivation of the study

The High Technology Group from Chemical Laboratory of Paul Sabatier University proposes the study presented in this paper. This group is interested to find the possibility to stimulate the photo-polymerization of the acrylic acid (AA) on the hollow fiber of poly-sulfone (PS). For this study we choose two MH-lamps with high emission in UV [5]: UVAprint 250 LE and Blue-Point made by "Dr. Hoenle" UV Company – Lyon, France. Both of the two lamps are functioning in the a. c. at 50 Hz frequency. These have applications in the chemical ignition and control of photo-polymerization processes and also in the surface treatment.

The photo-polymerization schema is presented in Fig. 1. The UV lamps are placed on one of the focal axis of an elliptical cylinder reflector. Through the second focal axis is moving the hollow poly-sulfone fiber, which before was immersed in acrylic acid solution. The lamp emitted radiations are focalized by the cylinder reflector on the poly-sulfone fiber increasing the efficiency of the photo-polymerization process.

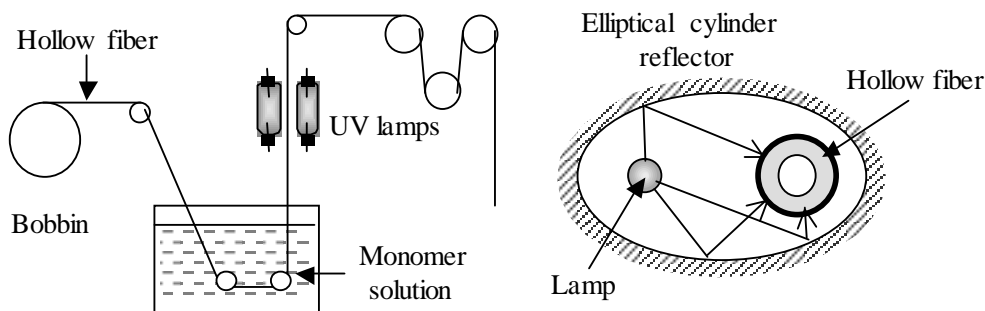


Fig. 1. Principle of photo-polymerization process.

The principle of this treatment is as follows. The hollow poly-sulfone fiber looks like a narrow tube. The water to be treated is out of the tube. Inside the fiber is water, which has penetrated the hollow fiber. As a function of the size of porous fiber, the bacterias, the viruses, the salts or the other impurities are prevented to penetrate so, the fiber tube is filled by pure water. This process is made out of pressure or under pressure diffusion.

The porous size can be modified by a surface photo-polymerization. Before this reaction the porous diameter is 10 – 20 nm and the salt retention rate is near to zero. Salt treatment is not possible. After the pore size modification by surface photo-polymerization the pores diameter become 1 – 2 nm and, at this size, it is possible to separate the salt. In this context, for the Ca^{2+} ion the retention rate is 90%.

3. Experimental set-up

All the measurements are made at the SIP Group (Sources Intenses des Photons) at the Plasma Physics Center and their Applications, Paul Sabatier University of Toulouse. The experimental set up is made from an Ulbricht integrative sphere, a spectrometer CP 200 with photodiodes barrettes, a computer equipped with Spectramax Jobin-Yvon software package and MH-lamps.

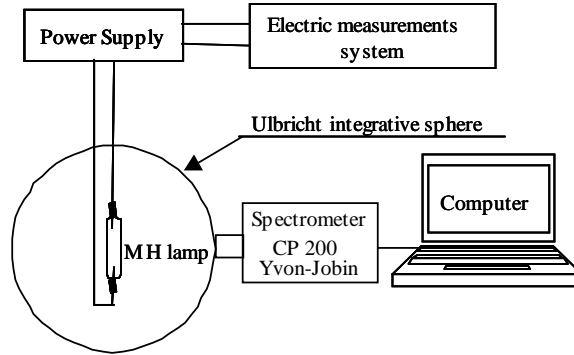


Fig. 2. Experimental set-up.

The Ulbricht sphere has a 1.7 m diameter and a special treatment of the internal surface made by multilevel painting with a special dye (three levels "Master Peintures" white polyurethan and four levels "Osram Centra" white paint). So, all the inside sphere surface is like a perfect diffusant surface with 0.8 deflection coefficient constantly on all spectral interval. Due to the large radius range it is possible to burn any lamp without supplementary heating of the internal surface of the sphere.

The CP 200 Jobin-Yvon spectrograph has a concave optical grating (with 190 mm focal distance and 200 lines / mm) calibrated from 190 nm to 820 nm with linear dispersion of 24 nm/mm.

In Fig. 2 the experimental set-up arrangement for electric, optical and spectroscopic measurements is presented. Detail of calibration set-up can be found in [6].

4. Theory

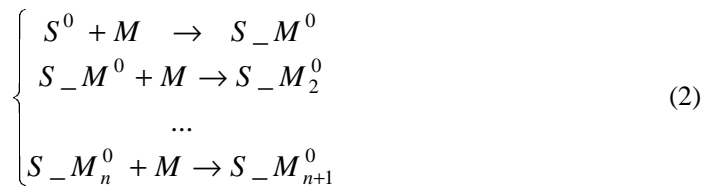
Generally, the photo-polymerization process is described as follows [2]:

With S - the support, S^0 - the radical, M - the monomer, $S_M_{n+1}^0$ - polymer ($n + 1$ index of polymerization), S_M_{n+1} - deposited and fixed polymer, the reactions schema is:

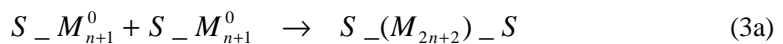
- the ignition reaction:



- the propagation reaction characterized by the reaction rate k_p [mol/l/s] :



- the end reaction characterized by the reaction rate k_t [mol/l/s] :



or



The following relation gives the speed of the polymerization reaction

$$V \approx \frac{k_t}{k_p} I_0 [M] \tag{4}$$

where I_0 is the UV intensity, k_t is the finish reaction rate, k_p is the rate of propagation equation and $[M]$ represents the monomer concentration.

The speed and size control of the photopolymer deposited layer can be made through the speed of the hollow fiber in acrylic acid solution, the monomer concentration, the UV lamp time exposure, the wavelength and the lamp input power.

The experiments carried out by Becquet [3] at 300 nm wavelength, $\varepsilon = 2.06 \text{ l} \cdot \text{g}^{-1} \cdot \text{cm}^{-1}$ extinction coefficient and $c_p = 1240 \text{ kg} \cdot \text{m}^{-3}$ poly-sulfone density shows that the photo-polymerization reaction profile is the same with Lambert-Beer UV intensity profile in poly-sulfone ($I = I_0 \exp(-\varepsilon x c_p)$). These measurements show a rapid reaction decrease, this being efficient only for few micrometers depth.

The polymerization reaction depends on the adsorbed radiation by the involved substances. The AA and the PS adsorption spectra are presented in Fig. 3. This will allow choosing of the spectral band, which will favor the photo-polymerization process.

If $\lambda < 300 \text{ nm}$ the acrylic acid gives the reaction $AA \xrightarrow{h\nu} AA^0$ and the acrylic acid photo-polymerization is not possible. If $\lambda > 320 \text{ nm}$ the poly-sulfone is not sensitive. So, Fig. 3 shows clearly that the photo-polymerization process is favored by the UV radiation having the wavelength between 300–325 nm. Our study regards with preference this range in order to make the AA photo-polymerization on the PS support, but we extend the analysis in the 200–450 nm spectrum band. This analysis can be useful in order to find other chemical substance combination for photo-polymerization process.

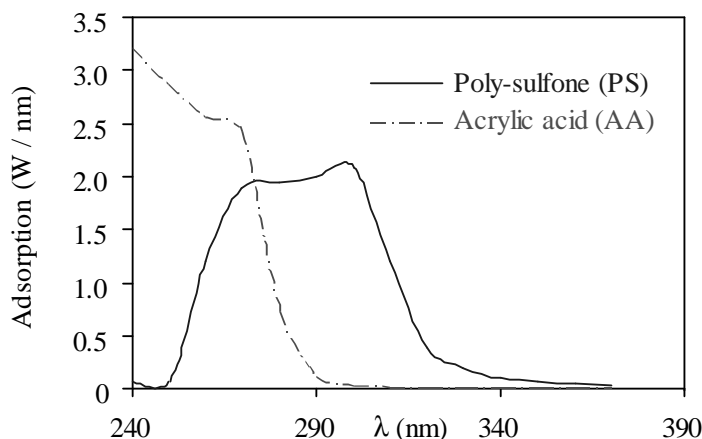


Fig. 3. Adsorption spectrum for poly-sulfone (PS) and acrylic acid (AA).

5. Experimental results

The lamps are supplied at the desired power and the emission spectrum is registered. The power input is modified step by step and the emission spectrum is obtained at each input current discharge. Starting from these spectra, are carried out some specific analysis. The radiant emission modification with respect to the power supplies are presented in Fig. 4 for UVA print lamp and in Fig. 5 for UV Blue-Point. The integral flux calculation in various narrow bands (not only in 300–325 nm band) for both of the lamps are presented in Fig. 6 and respectively in Fig. 7.

From Fig. 4 is obvious that by increasing the power supply the UV A print lamp emission in the UV zone is considerably increased, especially in 325–375 nm range, where the emission radiation has a continuum spectrum.

From the AA on the PS photo-polymerization point of view, in UV A print lamp we check the Hg line of 296.72 nm (transition from 6^3D_3 to 6^3P_0), the iron line of 301.80 nm and the indium line of 303.9 nm. The iron line is formed by the superposition of FeI-300.814, FeI-302.064, FeII-302.11 nm lines.

The integral flux for UVAprint lamps is presented in Fig. 6. From this figure (Fig. 6) it is clear that the conversion efficiency of the electric power in radiation power is of 48.6 W (UV light power) / kW (electric input power) for the band where the photo-polymerization of the acrylic acid on the poly-sulfone is favored (300-325 nm).

A good efficiency exist also in the 395 – 420 nm band (centered around the Hg line of 404.66 nm given by the transition from 7^3S_1 to 6^3P_0) and 425 – 450 nm (around the Hg line of 435.83 nm: 7^3S_1 to 6^3P_1). It must be noted that the mercury blue line absolute intensity is not significantly modified.

The mercury resonance line of 253.7 nm given by the transition $6^3P_1 \rightarrow 6^1S_0$ is strongly self-absorbed in the discharge plasma and the transition energy is converted in a continuum spectra. The integral flux in 240 – 260 nm band is almost constant with the power input. This is an expected result because all mercury mass participates at the electric discharge while the metal-halide quantity is changing in various conditions of discharge (current, pressure, temperature).

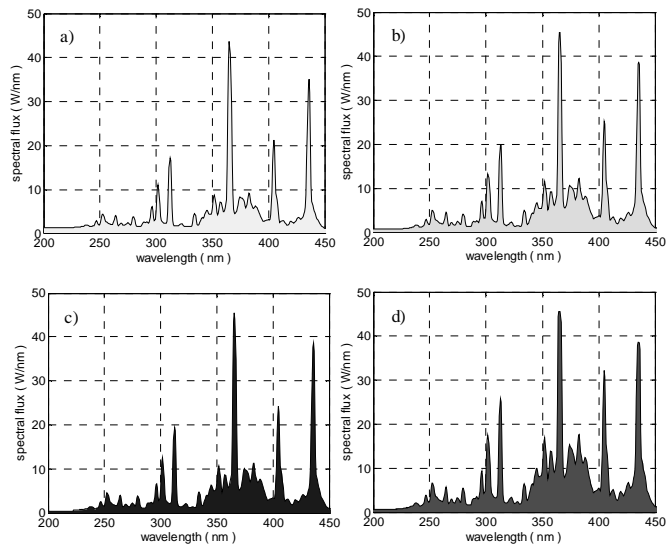


Fig. 4. Emission spectrum of UVAprint-lamp for various power supplies: a) 2.3 kW; b) 2.42 kW; c) 2.76 kW and d) 3.56 kW.

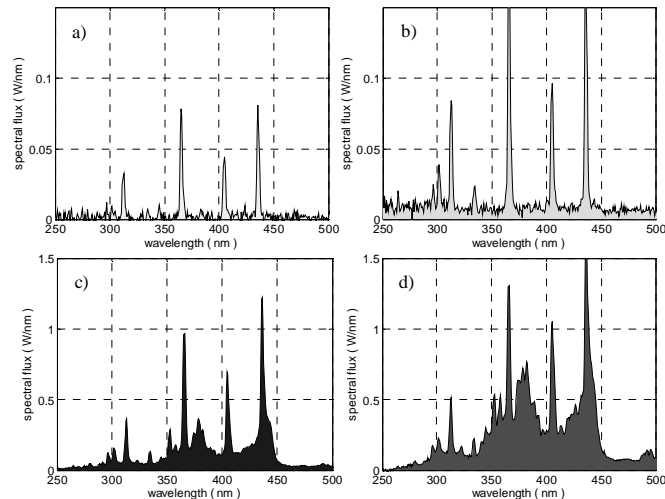


Fig. 5. Emission spectrum for UV Blue-Point lamp for various power supplies: a) P=76 W, b) P=97.5 W, c) P=155 W, d) P=250 W.

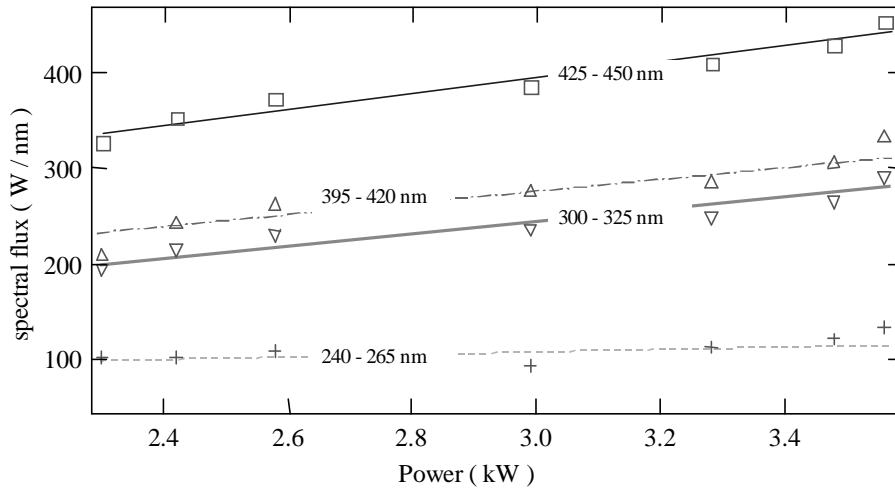


Fig. 6. UV Aprint-lamp band-flux dependence with respect to the input power. In the band where the photo-polymerization of the acrylic acid on the poly-sulfone is favoured (300-325 nm) the efficiency is: 48.6 W (UV light power) / kW (electric input power).

For the UV Blue-Point lamp, a significant increase of the radiant emission with respect to the power supply input was found in the ultraviolet and blue spectrum regions (see Fig. 5). The integral flux dependencies with respect to the power supply calculated in some narrow bands are presented in Fig. 7.

The convenient spectral band from photo-polymerization point of view contain the Hg line of 313.02 nm (superposition of HgI-312.56, HgI-313.13, HgI-313.15 nm lines). The calculus shows that the power supply determine a linear influence on the emitted flux in the 300-325 nm band (see Fig. 7). So, for the UV Blue-Point lamp, the light flux rate increases with the power supply and the energy conversion efficiency is of 15 W for each kW of the lamp power.

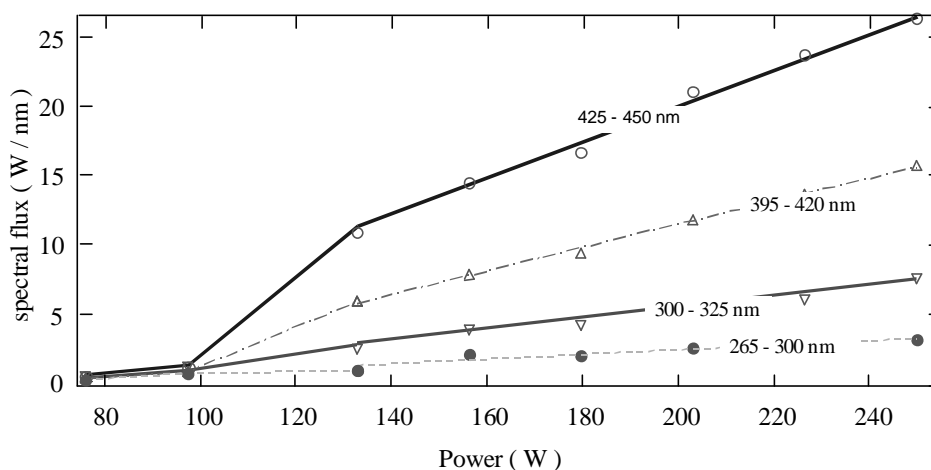


Fig. 7. UV Blue-Point-lamp band-flux dependence with respect to the power input. In the band where the photo-polymerization of the acrylic acid on the poly-sulfone is favoured (300-325 nm) the efficiency is: 15 W (UV light power) / kW (electric power input).

Many UV lines are found in the 350 – 385 nm region. In this band are localized the lines of Hg (365.01 nm), Fe (Fe line of 375.06 nm (superposition of FeI-374.55, 374.82, 374.94, 375.82 nm lines), Fe line of 382.32 nm (superposition of FeI-381.58, 382.04, ... , 383.42 nm lines)) and Tl (line

of 352.62 nm (superposition of TII-351.92, 352.94 nm lines)). So, from this point of view, is interesting to find other substances for the photo-polymerization process.

Also the 265 – 300 nm band has a low efficiency.

Very good energy conversion efficiency is in the blue band (425-450 nm), but is more less probable to find the substance that allows a photo-polymerization process.

For both of the lamps, the input electric power transformation efficiency in UV light is not large, but is sufficient to control the photo-polymerization size layer. In the particular case of the acrylic acid photo-polymerization on the poly-sulfone hollow fibber, the UVaprint lamp seams more attractive.

6. Conclusions

In this paper we have presented a study of the spectral emission of two MH-lamps with high emission in UV: the UVaprint 250 LE and the Blue-Point made by “Dr. Hoenle” UV Company – Lyon, France. This study was made from the chemical applications point of view. We found that to favor the acrylic acid photo-polymerization process on the poly-sulfone hollow fibber, a lamp wich mainly emits in the 300 – 325 nm range should be used. In this range, the flux-increasing rate with the power supply for UVaprint lamp is 48.6 W for each kW of the electric power lamp, while for the Blue-Point is of 15 W in the same conditions. So, from the AA on the PS photo-polymerization point of view, it is preferable to use the UVaprint lamp. For both lamps, increasing of the iron-iodine composition of the filling mixture can augment the conversion efficiency.

A good continuous and controllable emission through the power supply in 350 – 450 nm range was also found. In order to use this spectral band in chemical applications it is necessary to find other substances for surface photo-polymerization.

The violet and blue lines (HgI-404.66 nm, HgI-435.83 nm) are favoured by the electric power increase in the UVaprint lamp, while in the Blue-Point lamp the blue and green lines (HgI-435.78 nm, HgI-435.83 nm, TII-535.05 nm) are amplified by the electric power increase.

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