Journal of Optoelectronics and Advanced Materials Vol. 6, No. 1, March 2004, p. 87 - 94

ON THE EMITTED SPECTRUM CHANGING IN METAL-HALIDE LAMPS

M. Cristea*, B. Lafitte[a]

« Politehnica » University of Bucharest, Physics Department, Splaiul Independentei 313, 77206 Bucharest, Romania
[a]Paul Sabatier University of Toulouse, Plasma Physics Centre and their Applications of Toulouse, Route de Narbonne 118, Toulouse, France E-mail: lafitte@cpat.ups-tlse.fr

In the case of classical high-intensity discharge lamps (high-pressure mercury or high-pressure sodium lamps) the current intensity do not change the colour emission of the lamps. Only the integral flux is modified proportionally to the power input. But, for the metal-halide lamps some of the metal spectral lines are amplified by increasing the power input. In this paper, the spectral emission change of Uvaprint 250 LE, UV Bluepoint and GL 150 lamps are studied with respect to the power supply.

(Received August 22, 2003; accepted after revision February 2, 2004)

Keywords: Metal-halide lamps, Index colour rendering, Spectral flux changing

1. Introduction

In the last time the high-intensity discharge (HID) lamps have been intensively studied from both experimentally and theoretically point of view. Mathematical models have been created for the positive plasma column [1-3], for the electrode temperature distribution [4-6], or for the cathode fall zone [7,8]. Experimental and theoretical investigation of plasma contraction high-pressure arc electrode regions was carried out [9]. Two [10,11] or three-dimensional [12] models have also been considered.

But, all these studies make data bases for a better understanding of the metal-halide (MH) lamps functioning. It is possible to optimise the lamps radiation by using different combinations and concentrations of some metal-halide. Research on the lamp design [13] and on the plasma lamp correlation with metal-halide segregation or electrode temperature [14] was carried out. The iodines and bromides of the rare earth metals, especially those of thulium, holmium and dysprosium, are particularly important for the light generation since these metals display many lines in the visible spectrum when there are excited in the high temperature arc column of the lamp. The advantage of the rare earth metals concerning the light emission contrasts with the disadvantage of their corrosive reactions with the arc tube material (quartz glass, polycrystalline alumina) was studied [15]. Various characteristics required for the optical device, the structure of such a lamp built into the optical device, the characteristics of the spectrum of emitting light and the electronic glow switch starter (safety device) represented the object of intensively studies [16]. Recent applications of metal-halide lamps with strong ultraviolet rays for colouring, paint hardening [17] or chemical polymerisation reaction ignition [18] were studied. In order to meet the Hi-Vision request, a high importance was given to the increase of the index colour rendering [19].

The aim of this paper is the study of spectral emission for some special metal-halide lamps. This study is focused on “the lamps light colour” change with respect to the input power. Are studied the Uvaprint 250 LE, UV Bluepoint and GL 150 lamps. All lamps are functioning in the a. c. at 50 Hz frequency. The first two lamps have good applications in the chemical ignition and control of photo-

* Corresponding author: mcristea@physics1.physics.pub.ro

polymerisation processes and in the surface treatment. The third lamp is very attractive from lighting point of view.

2. Experimental set up

The experimental set up is made of an Ulbricht integrative sphere, a spectrometer CP 200 with photodiodes barrettes, a computer equipped with Spectramax Jobin-Yvon software package and of Uvaprint 250 LE, UV Bleuepoint and GL 150 lamps (Fig. 1).

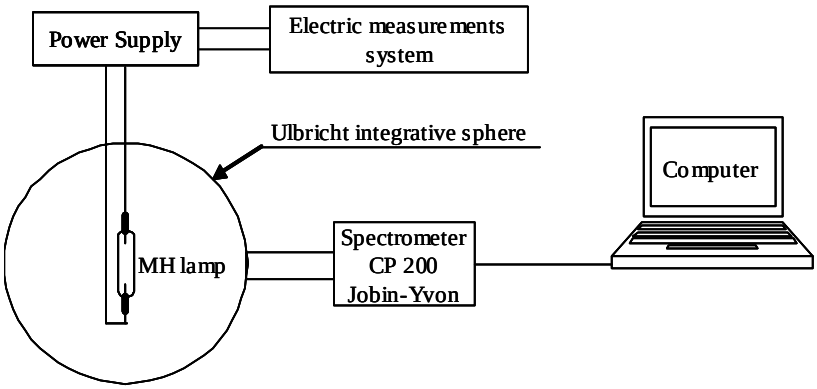

Fig. 1. Experimental set-up; arrangement for electric, optical and spectroscopic measurement.

The measurement of spectral flux is performed with Ulbricht sphere having 1.7 m diameter. At this radius range it is posible to burn any lamp without supplementary heating of the sphere internal surface. In adition, a special treatment of the internal surface is 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.

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

3. Set up calibration

The experimental set up was calibrated by using a reference lamp with dominant emission in UV and VIS spectrum zone. This is a Guy Daric SA (UV 1300W) lamp, having 80 mg mercury mass and 2 mg mercury iodine (HgI_2). This lamp has 8 torr argon buffer gas, 5.7 A nominal current intensity, 245 V voltage and 1300 W power. The ignition voltage varies between 600 V and 900 V (function of the voltage signal form). During the functioning 1.7 atmosphere pressure is reached.

In Fig. 2 the Guy Daric lamp reference spectrum is presented. This one allows the calibration of our experimental set up in 250 – 380 nm wavelength. For the VIS domain an incandescent reference lamp is used.

Because our data acquisition system is based on a photodiodes barrette different than the reference device set up, the full-width at half-maximum intensity line of our results is greater than the one of the reference spectrum. Our diodes are covering 0.66 nm while the reference spectrum cover 0.5 nm. It is not possible to compare the pick intensity, but is possible to compare the spectral flux of the identical bands.

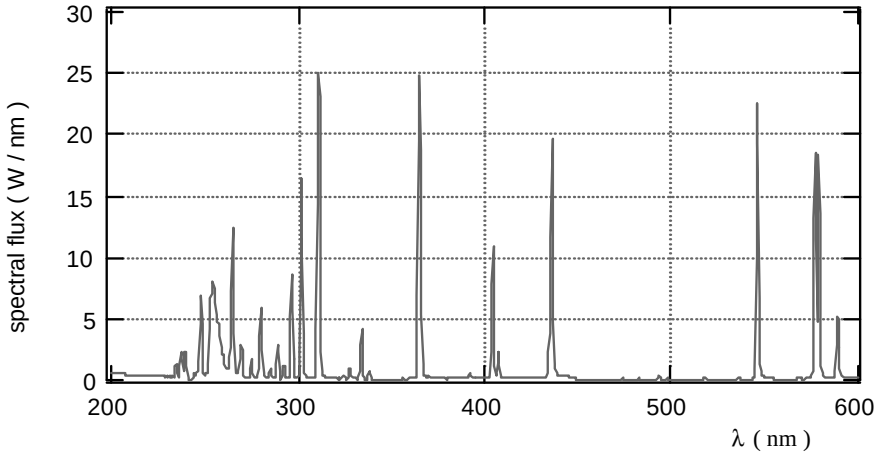

Fig. 2. Guy Daric UV 1300W lamp reference spectrum.

4. Results and discussions

All the above lamps are working at high-pressure discharge with mercury gas as buffer gas. In such type of lamp different metals are introduced via iodine or bromide compounds. The atom metal type, concentration and combination of metal-halide makes the lamp characteristics. But any lamp use the mercury atoms. For this reason our analysis is made around the principal Hg spectral lines.

The most important and intense mercury lines are the ultraviolet line of 253.7 nm given by the transition $6^3P_1 \rightarrow 6^1S_0$, the violet line of 404.7 nm ($7^3S_1 \rightarrow 6^3P_0$), the blue line of 435.8 nm ($7^3S_1 \rightarrow 6^3P_1$), the green line of 546.1 nm ($7^3S_1 \rightarrow 6^3P_2$) and the yellow doublet 577 nm ($6^3D_2 \rightarrow 6^1P_1$) respectively 579 nm ($6^3D_1 \rightarrow 6^1P_1$).

During the lamp functioning some mercury lines intensity can be reduced and other metal lines can be amplified. Due to high-pressure discharge the spectrum enlarging became important. So, the spectral lines are modified in the continuum bands spectrum. After spectrum recording for each lamp at various power supplies, a flux band analysis is made as follows.

4.1. Uvaprint 250 LE lamp

This high-pressure metal-halide lamp has an output of 150W/cm and a 250 mm arc dimensions. The dominant emission is in UV and Violet spectrum zone. For this reason this lamp is generally used for chemical treatment, like the acrylic acid polymerisation on sulfonide surfaces [18]. When the power input increase, the emission spectrum change in the UV zone by amplification of the metal lines (Fe and Ga). In Fig. 3 the emissive spectrum of Uvaprint lamp is presented for 2300 and 3560 watt power input. In Fig. 4 is presented the band spectral flux increase with respect to the power supply.

For this lamp the spectral flux in the band containing the resonance Hg line of 253.7 nm remain almost constant until 3200W. After that, a small increase appear. For the bands centred on other mercury lines, the increase is relatively slow. However, we can conclude that the band spectral flux in 300-325 nm range (which is very interesting from the chemical point of view) increase significantly. This means that for the chemical polymerisation processes this type of lamp is attractive.

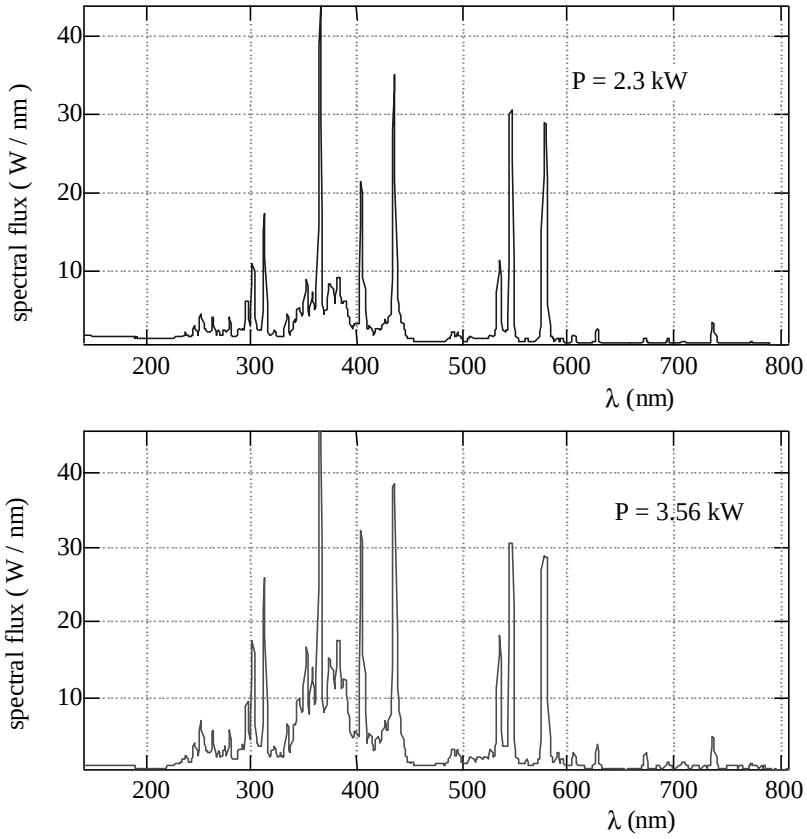

Fig. 3. Uvaprint-lamp emission spectrum for various input power.

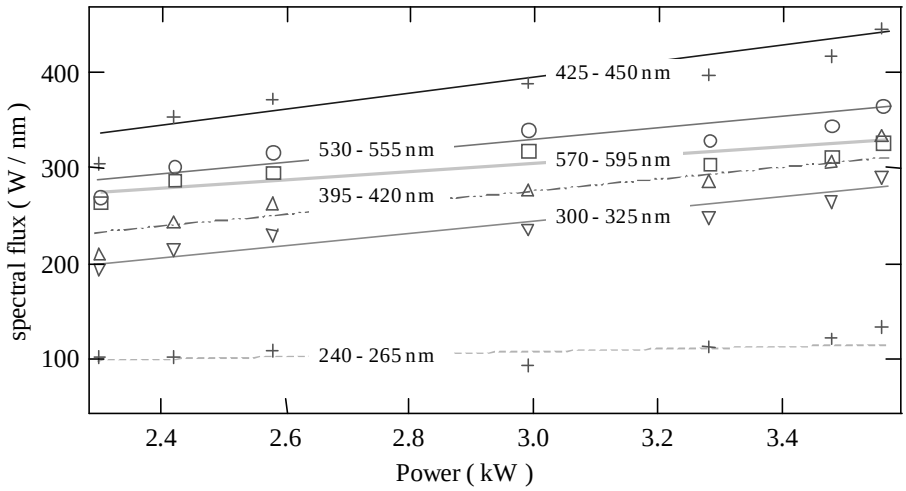

Fig. 4. Uvaprint-lamp spectral flux dependence with respect to the input power.

4.2. UV Bluepoint lamp

It is a high-pressure UV Lamp with 250 W power. This allows an irradiation higher of 2000 mW/cm^2. For this reason this lamp is used for the surface treatment and chemical applications. The

spectrum for two input power values is presented in Fig. 5 and the band spectral flux analysis is presented in Fig. 6.

By increasing the power input the emission is modified. This lamp has continuous spectrum in the UV-Violet zone. The most important emission is produced in the blue-green region. By increasing the power supply, the light emission of the lamp is passing from UV to the blue zone. The spectral flux increase in 300-325 nm band is uniform. This makes interesting the lamp usage in membrane treatment for water desalinisation. In [20] references a UVB Hoenle UV France with $I_0 = 338\ \mathrm{mW/cm^2}$ and $\lambda > 295\ \mathrm{nm}$ was used.

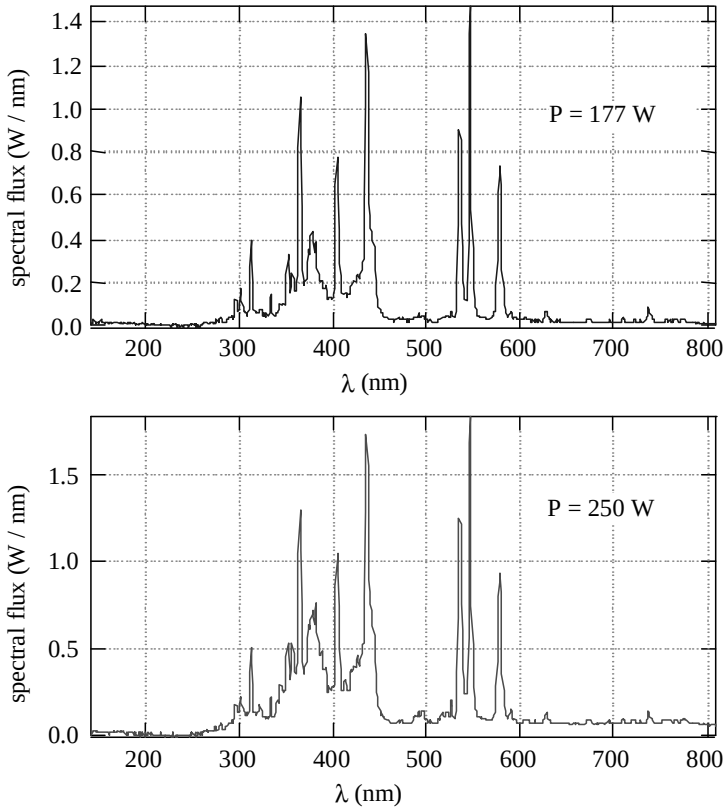

Fig. 5. Bluepoint lamp emission spectrum for various input power.

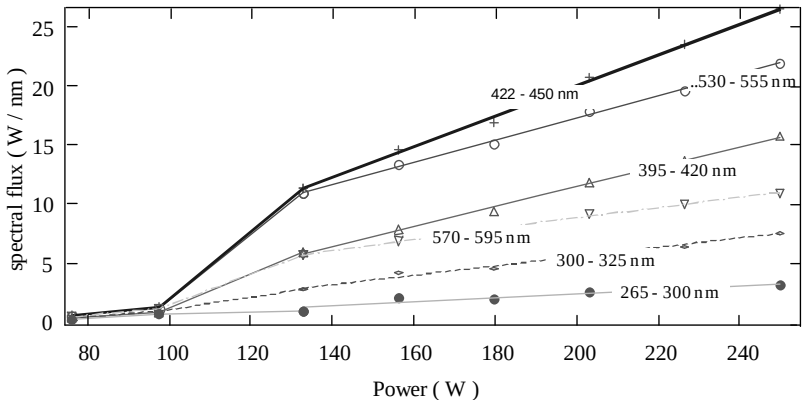

Fig. 6. Bluepoint lamp spectral flux dependence with respect to the input power.

4.3. GL 150 lamp

This lamp is generally used for the outdoor lighting. In this lamp the iodines introduce the sodium and dysprosium atoms. The sodium line (doublet) of 589 nm is visible. The dysprosium atom has the red line and makes a good compensation. The index colour rendering increase. The emissive spectrum and the different bands spectrum flux repartition are shown in Fig. 7, respectively, Fig. 8.

Fig. 8 shows that the UV emission in 300-325 nm band is not significant. This lamp is used in lighting process, and not in the chemical ignition and control.

Fig. 9 shows that the spectral flux in the band 560-700 nm is more sensitive at power input changing. This fact is due to the quick vaporisation of the sodium iodine with respect to another iodine. So, the iodine vapour comes into the channel discharge and it is dissociated. The yellow component of the light increases by the sodium doublet activation (589, 589.6 nm). By increasing of the power input, the sodium red lines 615.4, 616.1 and 619.5 nm starts to be favoured.

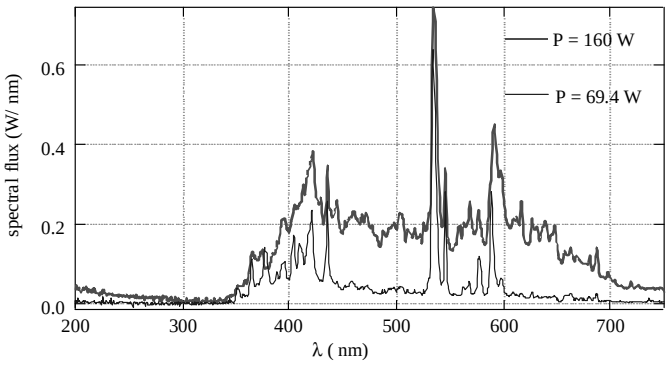

Fig. 7. GE 150 lamp emission spectrum for various input power.

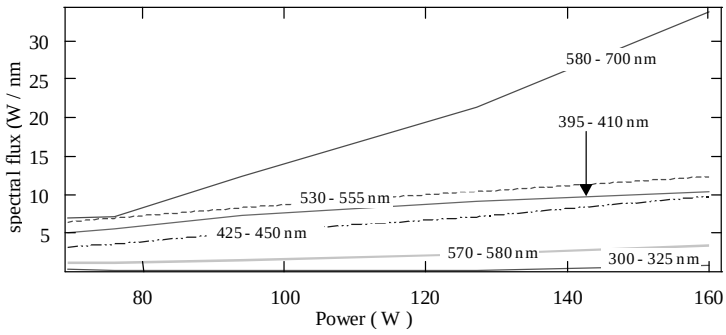

Fig. 8. GE 150 lamp spectral flux dependence with respects to the input power (around principal mercury lines).

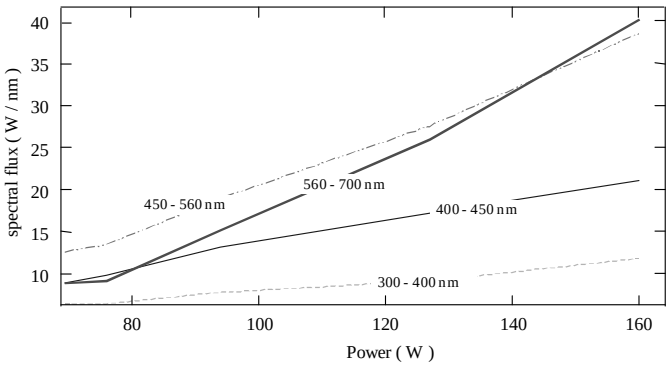

Fig. 8. GE 150 lamp spectral flux dependence with respects to the input power (large bands of the emitted spectrum).

By the indium lines of 410.2 and 451.1 nm, thallium line of 535 nm and sodium line of 568.3 nm the GE 150 lamp spectrum became cuasi-continuous and the index colour rendering increase significantly with the power input. In addition, this lamp gives the possibility to reduce the electric energy consumption in the slipping period. The power input can be reduced but the green, blue and orange lines remain so that their combination give an agreeable effect for the eyes with acceptable index colour rendering.

In conclusion for the bands where the mercury lines exist, the power input flux increasing is produced with the same rate. But, for the bands containing the metal-halide lines, the flux increasing is faster and non-linear. This fact allows the usage of the lamp for specific chemical applications or index colour rendering control for a better lighting.

6. Conclusions

The usage of some metal atoms in high-pressure discharge lamps allows us to obtain the spectral lines combination, which can have a good index colour rendering in lighting activity. It is the case of GE 150 lamp with sodium, thallium and indium iodines or bromides. In addition, this type of lamp allows over the night the power supply modification obtaining an important electrical energy economy. Reducing the power input the green, blue and orange lines remain so that their combination gives an agreeable effect for the eyes with acceptable index colour rendering. For the classical HID lamps, if the power input is modified (diminished) the arc is stopped. This makes very important the MH lamp for lighting activity.

Introduction of gallium or iron atoms inside the discharge allows the obtainance of the lamps which spectral emission is changing - especially in UV spectral region - with respect to the power input. During the discharge the metal-halide salts decay as consequence of high temperature releasing the metal atoms. The big difference between the halogen and metal atoms ionization potential makes that only the metals atom to be excited by the discharge and there are obtained only some the metal atomic lines. Such types of lamps are used in chemical industry, in surface treatment and water de-pollution or desalination (Uvaprint and UV Bluepoint) by using the spectral band where are localised the iron (302.06 nm, 302.11 nm) or indium (303.9nm) lines.

Acknowledgements

This work is partial supported by European Project NumeLiTe (NNE 5 – 2001 – 0282) and by Franco-Romanian Brancusi Project (06161XF – I54-03-01).

References

[1] J. J. Lowke, R. J. Zollweg, R. W. Liebermann, J. Appl. Phys. **46**, 650 (1975).
[2] K. Charrada, G. Zissis, M. Stambouli, J. Phys. D: Appl. Phys. **29**, 753 (1996).
[3] P. Flesch, M. Neiger, J. Phys. D: Appl. Phys. **36**, 849 (2003).
[4] M. Cristea, I. Iova, I. M. Popescu, Romanian Reports in Physics **50** (10), 765 (1998).
[5] R. Botticher, W. Botticher, J. Phys. D: Appl. Phys. **34**, 1110 (2001).
[6] M. S. Benilov, M. D. Cunha, J. Phys. D: Appl. Phys. **35**, 1736 (2002), J. Phys. D: Appl. Phys. **36**, 603 (2003).
[7] B. Rethfeld, J. Wendelstorf, T. Klein, G. Simon, J. Phys. D: Appl. Phys. **29**, 121 (1996).
[8] R. Hemmi, Y. Yokomizu, T. Matsumura, J. Phys. D: Appl. Phys. **36**, 1097 (2003).
[9] M. Kettlitz, R. Grossjohann, J. Phys. D: Appl. Phys. **35**, 1702 (2002).
[10] S. Hashiguchi, S. Mori, K. Tachibana, Jpn. J. Appl. Phys. **36**, 6533 (1997).
[11] K. Charrada, G. Zissis, M. Aubes, J. Phys. D: Appl. Phys. **29**, 2432 (1996).
[12] M. Cristea, I. Iova, C. P. Cristescu, I. M. Popescu, J. J. Damelincourt, Contr. Plasma Phys. **40** (5-6), 545 (2000).

[13] J. Gao, T. R. Brumleve, Proc.9th Int. Symp. Science and Technology of Light Sources (Ithaca, NY, USA, 2001), 205.
[14] D. C. Fromm, G. H. Lieder, K. H. Gleixner, J. Phys. D: Appl. Phys. **35**, 1668 (2002).
[15] K. Hilpert, U. Niemann, Proc. 8th Int. Symp. Science and Technology of Light Source (Greifswald, Germany, 1998), 326.
[16] K. Maseki, J. Illum. Eng. Inst. Japan, **77**(12), 746 (1993).
[17] S. Ezaki, J. Honda, J. Illum. Eng. Inst. Japan **77(**12), 741 (1993).
[18] M. Cristea, B. Lafitte, Rev. Roum. Chim. (2003), subbmited to publication.
[19] A. Mii, T. Iizuka, J. Illum. Eng. Inst. Japan **77**(12), 735 (1993).
[20] S. Bequet, J-C. Remigy, J-C. Rouch, J-M. Espenan, M. Clifton, P. Aptel, Desalination **144**, 9 (2002).