Color shift of head lamps for automotive lighting over lifetime

M. Kettlitz, O. Krylova
INP Greifswald
D-17489 Greifswald, Germany
kettlitz@inp-greifswald.de

D. Ehrlichmann, K. Günther, L. Vollmer
OSRAM
D-13625 Berlin, Germany

Abstract—**The color shift of head lamps for automotive lighting over lifetime was investigated. For that purpose a combination of emission spectroscopy and thermography was used to determine spectra, color data and the cold-spot temperature. There are changes in the lamp behavior over lifetime with a visible blue shift until 500 h and a reversal afterwards. The cold-spot temperature is nearly constant until 1000 h and then increases slowly. The different behavior of Sc und Na partial pressure with increasing lifetime leads to a change of the spectral output of the lamp and therefore of the color appearance over lifetime.**

light sources, plasma diagnostics

I. Introduction

In recent years, plasma lamps have increasingly been used as head lamps for automotive lighting. They have a good performance, high luminous flux and efficacy [1]. Unfortunately they undergo a decrease in lumen output as well as a change in their color appearance over lifetime. Because of color recognition of traffic signs and road safety that deficiency should be minimized. The intention of the work was to investigate and explain the color shift of head lamps (D2 lamps). Therefore color data, spectra and the cold-spot temperature were measured for a set of D2 lamps during several phases of age.

II. Experiment

The investigations were performed with a set of 30 lamps. The lamps are made of quartz and have an outer bulb (sleeve) as UV protector and thermal shield (see fig. 1). They are cylindrically shaped and have tungsten electrodes. The lamps contain a mixture of some tenth of mg of NaI, ScI_3, Hg and 8 bar Xe at room temperature. During operation the salts are partly evaporated and most of the radiation output comes from Sc and Na spectral lines. The lamps were operated with adjustable electronic ballast (Schieder) with 400 Hz square wave voltage and the input power was 35 W ± 0.2 W.

Then measurements were done after several phases of age. A combination of emission spectroscopy and thermography was used to determine spectra, luminous flux, geometrical data, color data and the wall temperature. The color measurements were performed in an Ulbricht-sphere (Ø = 45 cm). The spectra were recorded in the spectral range between 360 nm and

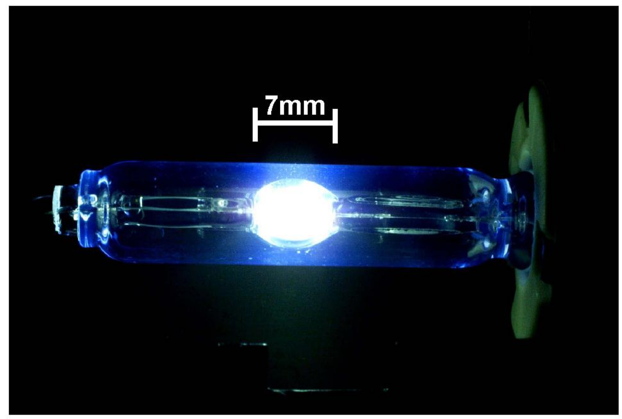

Figure 1. Picture of a D2 lamp with sleeve and socket on the right-hand side.

830 nm (resolution 0.25 nm) with a 0.5 m-spectrograph (SpectraPro 500i, Acton) with an ICCD-camera (Proscan). Additionally, spectra with a better resolution (0.03 nm) were measured at the positions of important Sc, Na and Hg lines to get information on the plasma behavior.

For plasma diagnostics spectroscopic measurements were carried out with a 1 m-spectrograph (AM510, Acton) with an ICCD-camera necessary for a high spectral resolution. The plasma temperature was determined according to Bartels [2] from the radiance of the self-reversal maxima of the optically thick Hg spectral line at 546 nm [3-6].

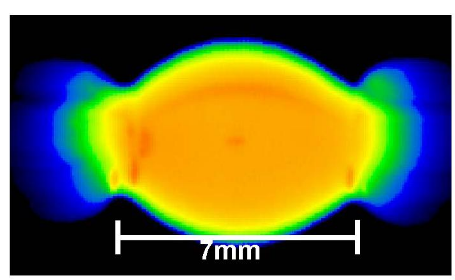

Figure 2. Thermographic shot of the bottom of the lamp without sleeve for the determination of the temperature distribution of the wall and therefore the cold-spot temperature.

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A thermographic system was used to measure temperature profiles of the discharge tube (see fig. 2) and by that the cold-spot temperature (T_{CS}) which leads to an estimation of the vapor pressure. The problem for a determination of the wall temperature is the outer bulb which is not transparent in the infrared region where the temperature can be measured pyrometrically. Therefore a combination of thermography and spectroscopy was used.

The idea was to keep the lamp without sleeve (where the wall temperature and therefore T_{CS} can be measured) at the same wall temperature as the original one with sleeve. That was realized by additional internal heating by an increase of the electrical input power (and therefore the plasma temperature). The achievement of the original situation was checked with the line profiles of the Na D lines. Here the fact is utilized that the distance of the self-reversal maxima $\Delta\lambda$ of the Na D lines strongly depends on the Na partial pressure and therefore on T_{CS} [7].

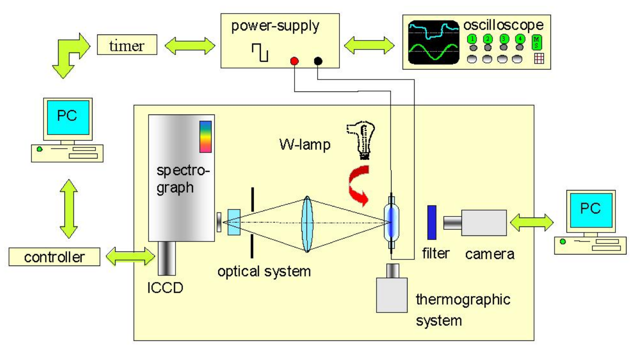

Figure 3. Experimental set-up for the measurement of the plasma temperature and the cold-spot temperature.

That means the lamps were first operated in the U-sphere at 35 W. Then the sleeves of two lamps were extracted, the input power increased until the spectra of the Na D lines of each lamp without sleeve were identical with the original one. Then the wall temperature of the lamp with the newly installed power was determined at the bottom of the lamp (where the molten salts were) with a thermographic system (Varioscan 3011 STPC, Jenoptic), see figure 3. In this manner it was guaranteed for every lamp individually that the same Na partial pressure and therefore the same T_{CS} were established.

III. Results

The measurements were performed after 1, 12, 100, 500 1000, 1500 and 2600 hours. There are rapid changes in the lamp behavior in the first ten hours, followed by slower changes in the same direction until 500 h and a reversal after that. There is a change in the color temperature from about 4000 K at the beginning to 4800 K at 500 h, and then it returns slowly to its original value after 2600 h. That change of the color temperature is accompanied by a change of the

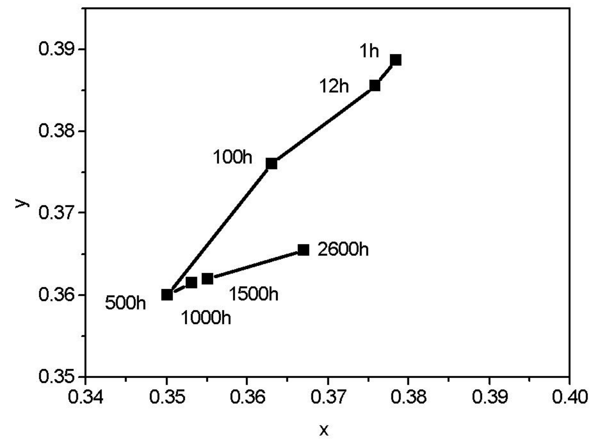

Figure 4. Color maintenance as function of lifetime.

chromaticity coordinate (x, y). There is a permanent blue shift until 500 h, thereafter it reverses. Figure 4 shows the change of the color maintenance over lifetime.

Plasma temperatures can only be measured up to a lifetime of 1000 h. Afterwards scattering of the rough inner walls caused by frosting avoids a plasma temperature determination. The temperatures in the arc core are around 5000 - 5400 K at the beginning, go through a maximum at 500 h and decrease later.

The plots of cold-spot temperature and distance of Na D self-reversal maxima as functions of lamp life are shown in figure 5. T_{CS} is nearly constant around 700 °C up to 1000 h and increases slowly to 730 °C for 2600 h. That increase of the wall temperature has unfavorable consequences on the lamp according to a higher load of the walls and leads to intensified frosting and a deformation of the arc tubes with increasing age.

Additionally there is a loss of sodium due to diffusion through the lamp walls. The distance of the Na D self reversal maxima $\Delta\lambda_{Na\ D}$ (as quantity for the Na partial pressure) decreases until 500 h and slowly increases after that age.

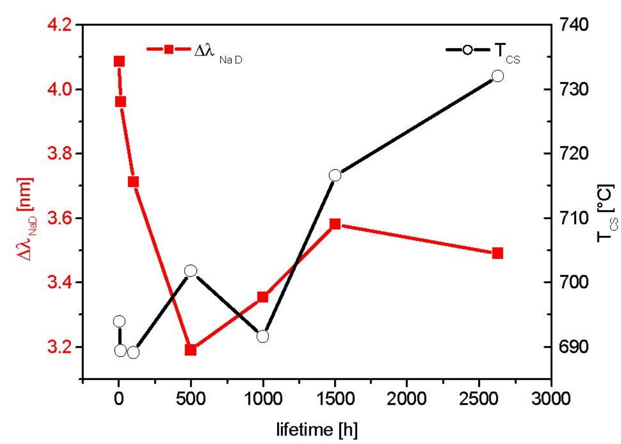

Figure 5. Cold-spot temperature and distance of Na D self reversal maxima as functions of lifetime.

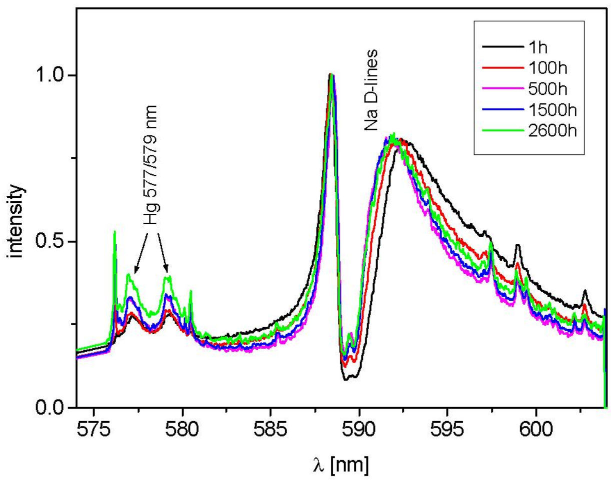

Figure 6. Normalized Ulbricht-sphere spectra of the self reversed Na D lines and the Hg 577/579 nm lines as functions of lifetime.

The distance of the self reversal maxima of Sc resonance lines $\Delta\lambda_{Sc}$ (as quantity for the Sc partial pressure) decreases constantly, in the first 10 h rapidly and afterwards slowly.

The different behavior of Sc und Na partial pressure with increasing lamp life leads to a change of the spectral output of the lamp and therefore of the chromaticity coordinate. An increase of the Na partial pressure goes along with an increase of yellow and red parts of the spectrum; the increase of Sc partial pressure affects all parts of the spectrum due to the homogeneous distribution of the Sc lines in the visible spectral range. The reversal of the color shift seems to be a combination of the change of plasma temperature and partial pressure ratio.

References

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