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APPLICATION OF METAL HALIDES IN COMPACT SOURCE LAMPS WITH LOW COLOUR TEMPERATURES

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ABSTRACT

The application of metal halide additives in compact source mercury lamps causes a strong continuous radiation. Measurements and thermodynamic calculations assert that the continuum mainly is generated by HgJ molecules. This radiation in combination with strong resonance lines enables to develop lamps of high luminance and low colour temperature.

1. INTRODUCTION

Compact source lamps are light sources with high luminance. Owing to the good focusing properties of their radiation these lamps are mainly used in optical devices. Mercury and xenon compact source lamps are well-known for a long time. By application of metal halides as lighting additives in compact source mercury lamps it is possible to realize special photometric qualities. Among them the colour rendering properties are important for many visual observations direct by the human eye or in connection with colour films and television. The particular plasma conditions in compact source discharges in comparison with conventional metal halide discharges - higher partial pressures of both the additives and the buffer gas mercury - effect extreme widths of several resonance lines and a very strong continuum. Additionally, various absorption processes become significantly in the spectrum of these lamps.

2. CONTINUOUS RADIATION

A strong continuum can be observed in all compact source mercury discharges containing iodides with high partial pressures, for instance ZnJ_2, GaJ_3, InJ, TlJ or SnJ_2. In pure mercury discharges and in iodide discharges with the buffer gases xenon or argon this strong continuum does not appear. Therefore, it can be concluded that the molecule HgJ gives rise to the appearance of this continuum. Zollweg [1] carried out similar investigations for high pressure mercury discharges containing iodine and 0.24...0.28 MPa Hg. He expounded the continuum by two main processes: 1. Transitions between low-lying states of the molecules HgJ and J_2, 2. Associative continua by formation of these molecules.

The spectrum of a compact source discharge with 3 MPa Hg and 0.4 MPa HgJ_2 is shown in Fig. 1. In addition to the mercury lines Hg 546 and 577/79 nm a nearly structureless continuum is evident. It extends from 450 to 840 nm, and its intensity increases to the red part.

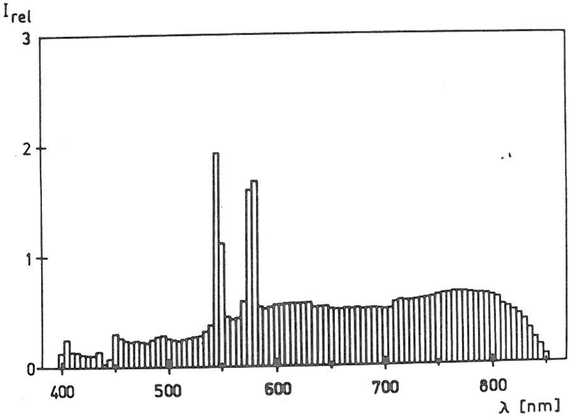

Fig. 1: Spectrum of a compact source discharge with 3 MPa Hg and 0.4 MPa HgJ_2

Weak features in the spectrum of compact source mercury discharges with metal halides, being characteristic of the added metal (maxima for Ga at 463 and 501 nm, for In at 498 and 521 nm and for Tl at 457 and 522 nm), may be caused by the quasimolecules Hg-Ga, Hg-In and Hg-Tl respectively. Analogous phenomena are known from high pressure sodium-mercury discharges [2].

The well-known HgJ molecular band $B\ ^2\Sigma^+ \rightarrow X\ ^2\Sigma^+$ appears in strong absorption in consequence of the high partial pressure. This leads to a marked dip in the spectral energy distribution between 440 and 446 nm which can be found for compact source mercury discharges with the other specified iodides too. Towards shorter wavelengths a region of weaker absorption appears clipping the mercury lines Hg 436 and 405 nm almost utterly.

Radiation emitted below 450 nm is very ineffective in regard to the luminous flux, but highly effective for attaining of high colour temperatures. Therefore, it is possible to use the HgJ absorption for lowering the colour temperature of compact source lamps without considerable losses in efficiency.

3. THERMODYNAMIC CALCULATIONS

The formation of the molecule HgJ in compact source mercury discharges with iodide additives could be confirmed by thermodynamic calculations of the plasma composition, using data from JANAF-tables [3] and other sources [4, 5]. As an example, in Fig. 2 the partial pressures of the plasma components are figured as functions of temperature for 5 MPa Hg and 0.03 MPa SnJ_2. At temperatures higher than the dissociation temperature of the additive nearly 1 % of the iodine available in this plasma is converted into HgJ.

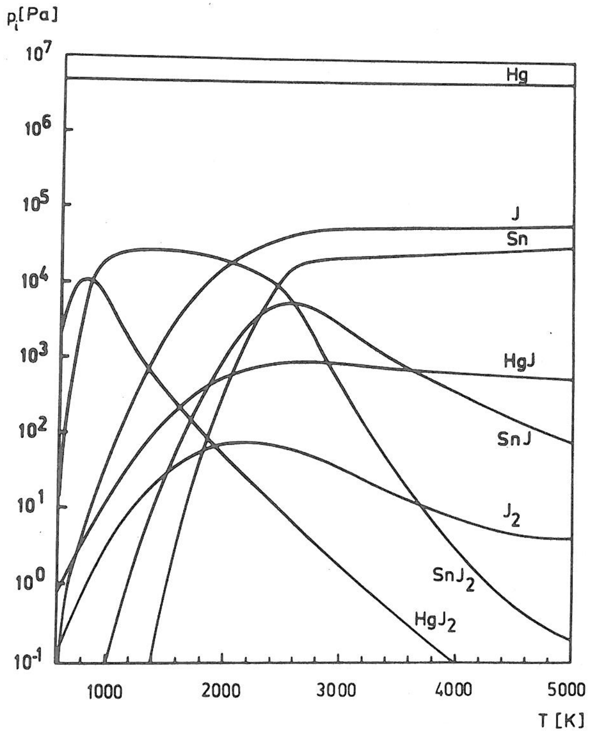

Fig. 2: Partial pressures p_i of the plasma components versus temperature T for 5 MPa Hg and 0.03 MPa SnJ_2

A remarkable result is the fact that the HgJ molecule is very stable at high temperatures in comparison with other iodides, for instance the SnJ molecule, well-known as continuous radiator too. This is caused by the small formation enthalpy of HgJ and leads to considerable consequences for the luminance which can be achieved with these radiators. Assuming that the radiation is emitted in the middle of the visible region by a molecular transition to the ground state, the volume radiance is given by $\varepsilon \sim n \cdot \exp(-E/kT)$ with the excitation energy $E = 2.3$ eV. Fig. 3 shows the resulting volume radiances of HgJ and SnJ in a relative comparison as functions of temperature T for partial densities n of the radiating species according to Fig. 2. The volume radiance of SnJ exhibits a maximum nearly 3000 K. Therefore the SnJ radiation is emitted predominantly by the cooler outer regions of the discharge, and in a lamp a rather extensive luminous field is shaped. On the contrary, we have the maximum volume radiance of HgJ in the hot core of the discharge connected with significant contributions to high values of luminance.

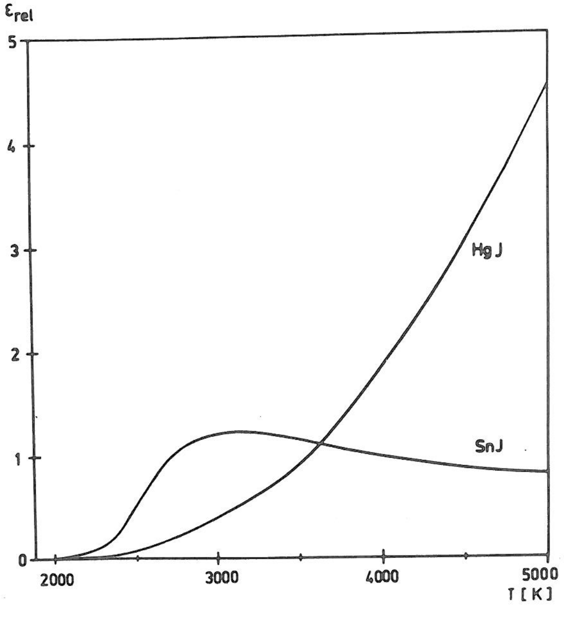

Fig. 3: Relative volume radiances ε of HgJ and SnJ as function of temperature T

4. LINE RADIATION

Beside the continuum, the resonance lines of the additives substantially contribute to the luminous flux of compact source discharges with metal halides. These lines are asymmetrically van-der-Waals-broadened by the buffer gas mercury. For high pressure discharges the line profile can be described by the superposition of a dispersion profile and a profile in conformity with the statistical theory of line broadening [6, 7]. The resulting line width Δ depends on the partial pressures of both the radiating gas p and the buffer gas p': $\Delta \sim (p \cdot p')^{0.6}$. Because of the great optical depth in compact source discharges the resonance lines show broad selfabsorption dips, and the line widths increase so that the red line wings cover large parts of the visible range.

5. APPLICATION

The combination of the resonance lines of In, Tl, Na and Li, the continuous radiation of HgJ and the absorptions in the blue-violet spectral region can be applied for the development of special compact source lamps. Particularly it is possible to connect high values of luminance and colour rendering with low colour temperatures. It is serviceable to control the line widths so that the line wings cover the visible range as far as possible without too large energy losses in the infrared region. In Fig. 4 the spectrum of such a lamp is reproduced. At a power input of 250 watts we

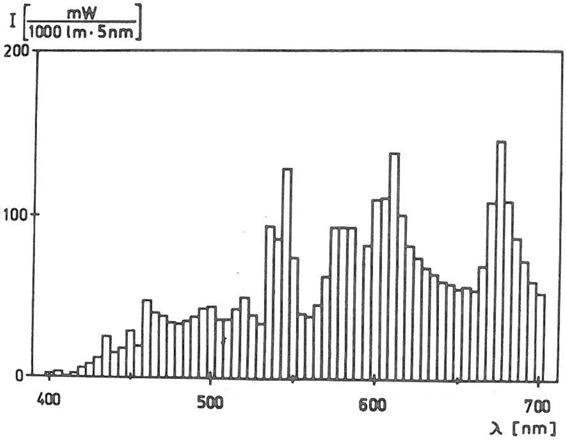

Fig. 4: Spectrum of a compact source lamp with metal halides realizing high luminance at low colour temperature

have realized a luminance (for a luminous field of $2.8 \times 0.8\ mm^2$) of $2.1 \cdot 10^8\ cd/m^2$ and a general colour rendering index of 90 at a colour temperature of 3200 K near to the black-body locus in the UCS diagram [8].

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