Peculiarities in the Aging of Phosphate Phosphors in Xe DBD-Lamps Faced by Protective Particle Coating

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1. Phosphor converted Xe DBD lamps

Xe excimer lamps rely on a so called “silent discharge” which takes place between two electrodes that are separated by at least one dielectric and a Xe gas filled gap area upon impingement with an electric field large enough to cause breakdown. A plasma filament rises across the gas filled space and an avalanche of electrons is rapidly forced through it. The plasma filament stimulates the generation of Xe*, excimers through the excitation of Xe atoms. These short-lived excimers emit energy in form of photons with an energy primarily peaking around 172 nm (7.2 eV) when they relax under decomposition. This major emission wavelength may afterwards be converted to lower energy by using an appropriate luminescence screen. A schematic device sketch including a schematic circuit diagram is given in Figure 1.1,2

Fig. 1 Schematic illustration of the principle of operation of a Xe-excimer DBD lamp including a simple circuit sketch.

VUV and UVC emitting phosphors enable Xe DBD lamps for germicidal and purification application

Fig. 2 Coaxial Xe-DBD Lamp operated in water.

3. Lifetime Investigations for YPO₄ phosphor charged Xe lamps

Lifetime studies revealed that uncoated Xe-DBD lamps may have lifetimes of several thousand hours when high quality synthetic quartz glass is used. If an output intensity of 75% (rel. to the initial output) is set as lifetime threshold, YPO₄:X (X = Bi, Pr, Gd, Nd) converted Xe-DBD lamps are outdated after 200 - 300 hours of lamp operation. Figure 4 displays the measured lamp output for a YPO₄:Bi and a YPO₄:Pr coated Xe DBD lamp at the respective emission intensity peak over operation time.

Fig. 4 Output intensity over operation time measured from a YPO₄:Bi and YPO₄:Pr charged lamp, respectively.

Doped YPO₄ phosphor samples that were used in lamp operation show a distinct loss in UV-emission intensity under VUV-excitation. This stands in good agreement to the development of a pronounced absorption band rising below 500 nm accompanied by an overall greying.

- Host material absorption below 500 nm: The broad absorption below 500 nm is caused by the aged host material YPO₄ as can be seen for aged pure YPO₄
- Activator reduction: Aged YPO₄:Bi exhibits another absorption band peaking around 485 nm which was identified to be sourced by reduced activator species (Bi(V)/Bi(III)).
- Phosphor greying: Defect formation and activator/host reduction lead to greying.
- Red-luminescence at UV-B excitation: All aged phosphor samples reveal an intense red photoluminescence upon excitation in the UV-B range, which shows an additional blue component at low temperatures. The emission bands stand in correlation with discrete excitation bands. This red luminescence is thought to be caused by phosphorous in oxidation state III+ (configuration: (Ne)2s²).

Fig. 5 Top line: excitation-, emission and reflectance spectra measured from fresh and aged samples of YPO₄:Bi (left), YPO₄:Gd (middle) and YPO₄:Pr (right); bottom line: RT-reflectance spectra and temperature dependent (77-300K) excitation- and emission spectra of YPO₄:Bi (left), YPO₄:Gd (middle) and YPO₄:Pr (right)

Fig. 6 Photographs of YPO₄:Gd samples

4. A Key-Issue to lifetime investigation on phosphor converted Xe DBD lamps: phosphor aging

Fig. 7 Illustration of UV driven particle coating process.10

5. Particle coatings as a possible countermeasure to improve phosphor long-term stability

By our investigations regarding the aging characteristics of YPO₄ based phosphors in Xe excimer DBD lamps we have clearly shown that untreated orthophosphates do not lead to appropriate phosphor materials due to their incisive impermanence against the Xe excimer discharge. Due to the superior spectroscopic features that are offered by doped YPO₄ it worth to implement dense and homogeneously distributed phosphor particle coatings by resistive materials like Al₂O₃ and to examine the aging behaviour of thus coated phosphors. Where we experienced a common particle coating procedure to fail in terms of its protective effect, we were encouraged to introduce a novel method, recently described in literature.16

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Literature:

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