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

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

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_2* 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 luminescent screen. A schematic device sketch including a schematic circuit diagram is given in Figure 1.[1,2]

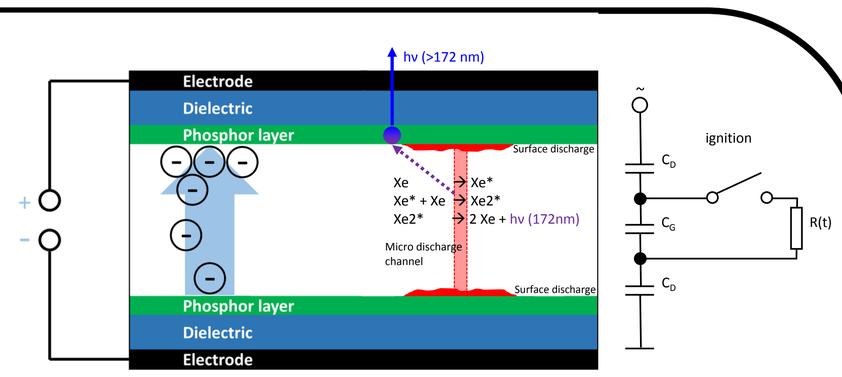

Fig. 1 Schematic illustration of the principle of operation of a Xe-excimer DBD lamp including a simple circuit sketch.

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

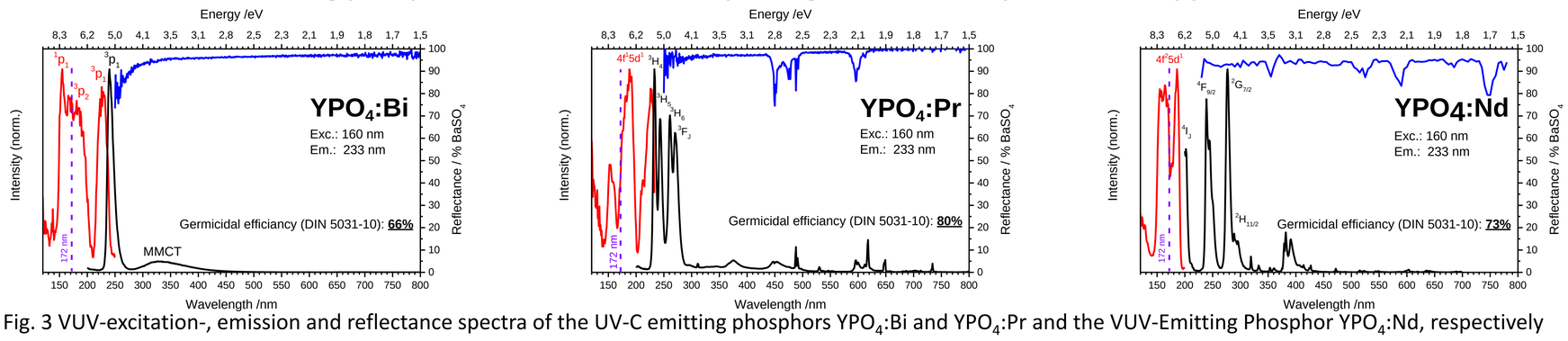

Fig. 3 VUV-excitation-, emission and reflectance spectra of the UV-C emitting phosphors YPO_4:Bi and YPO_4:Pr and the VUV-Emitting Phosphor YPO_4:Nd, respectively

YPO_4 is a radiation-stable wide-bandgap material (Δ_{BG} = 9.2 eV) which turns into a very efficient UVC / VUV emitter when doped with e.g. Pr^{3+}, Bi^{3+} or Nd^{3+} [3]

3. Lifetime Investigations for YPO_4 phosphor charged Xe lamps

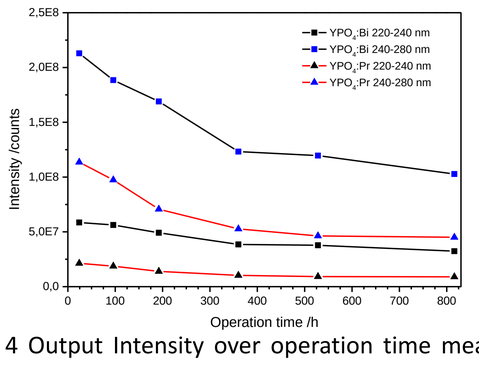

Fig. 4 Output Intensity over operation time measured from a YPO_4:Bi and YPO_4:Pr charged lamp, respectively.

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, YPO_4: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 YPO_4:Bi and a YPO_4:Pr coated Xe-DBD lamp at the respective emission intensity peak over operation time.

Observable over lamp operation:

- Loss of output intensity which sets in after a short starting period and which in correlation with operation time.
- Intense greying of phosphor material in the discharge region proportional to operation time.
- Spectral emission lines caused by XeO which intensify in correlation with operation time

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

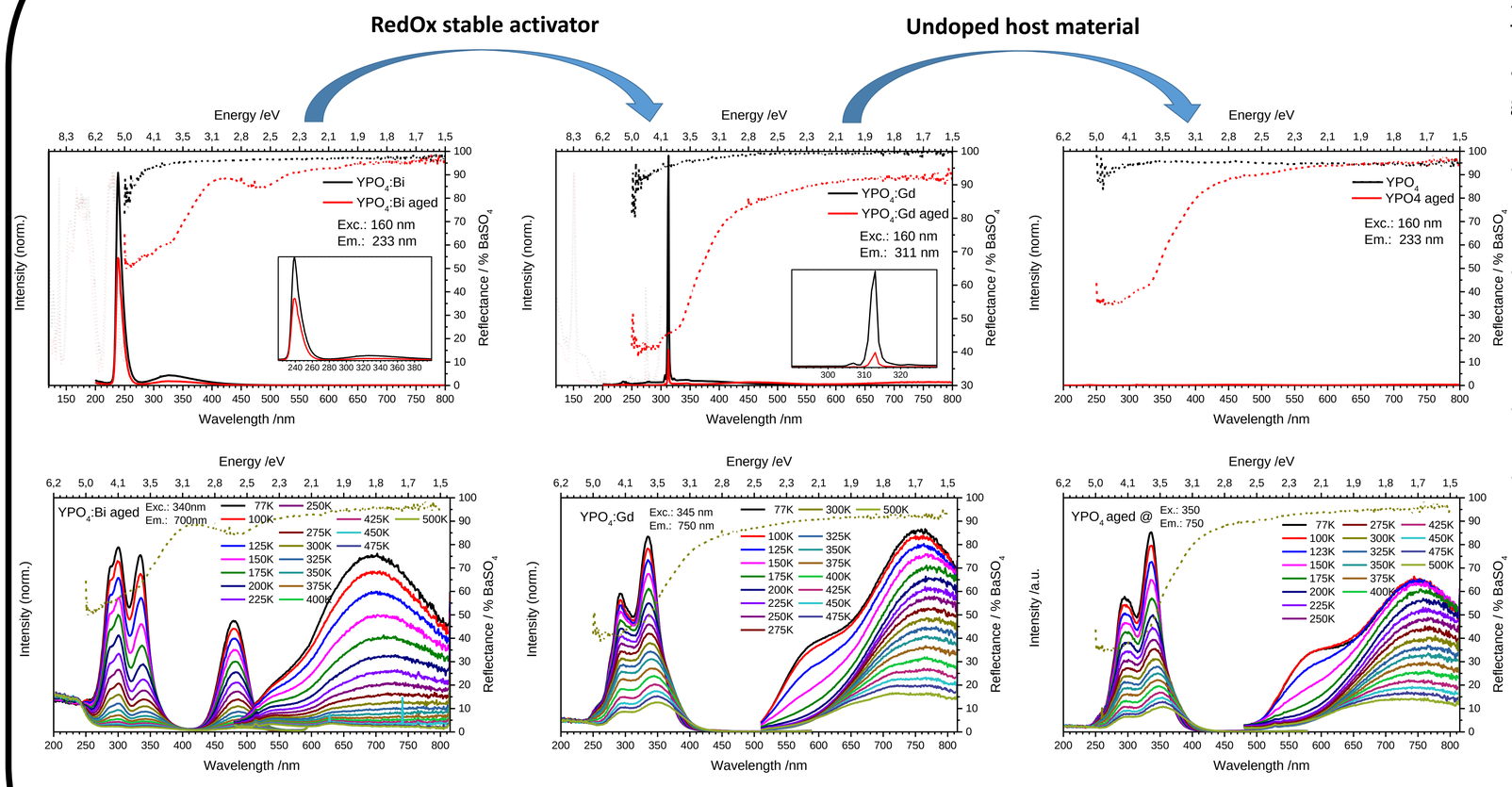

Fig. 5 Top line: excitation-, emission and reflectance spectra measured from fresh and aged samples of YPO_4:Bi (left), YPO_4:Gd (middle) and YPO_4 (right); bottom line: RT-reflectance spectra and temperature dependent (77-500K) excitation- and emission spectra of YPO_4:Bi (left), YPO_4:Gd (middle) and YPO_4 (right)

Doped YPO_4 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 YPO_4 as can be seen for aged pure YPO_4.
- **Activator reduction:**
  Aged YPO_4:Bi exhibits another absorption band peaking around 485 nm which was identified to be sourced by reduced activator species (Bi^+/Bi^{2+}).
- **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]$2s^2$).

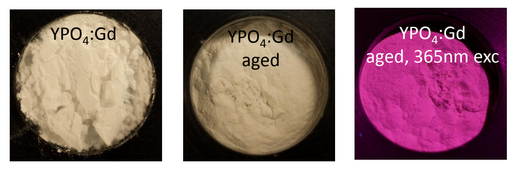

Fig. 6 Photographs of YPO_4:Gd samples

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

By our investigations regarding the aging characteristics of YPO_4 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 YPO_4 it worth to implement dense and homogeneously distributed phosphor particle coatings by resistive materials like Al_2O_3 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.[4]

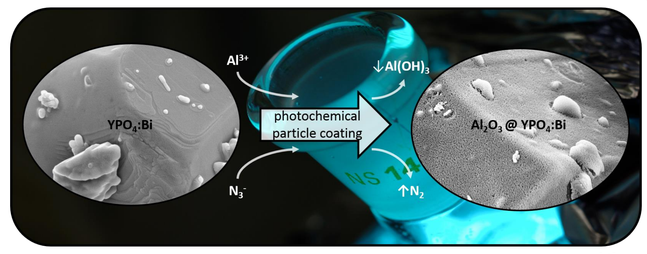

Fig. 7 Illustration of UV driven particle coating process [4]

Acknowledgement:

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Literature:

[1] N. Sewraj et al., J. Phys. D: Appl. Phys. 42 (2009) 13.
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