# COATING OF UV-C PHOSPHOR $YPO_4:Bi^{3+}$ WITH MgO, $Al_2O_3$, AND $MgAl_2O_4$

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## Introduction

**Covering a surface with a coating is a commonly applied method to modify and adjust the particular properties of a substrate. This strategy has also been extended to inorganic luminescent materials and has found to be especially valid in case of industrially implemented phosphors operating under extreme conditions.**

## Goal

**The general intention of this work was to apply a coating to $YPO_4:Bi^{3+}$ particles in order to improve its stability and performance in Xe excimer dielectric barrier discharge lamps, where a luminescent material is exposed to the high-energy discharge and destructive vacuum ultraviolet radiation. Successfully performed particle coating would provide devices with a sufficiently high lifetime, which are especially applicable for photochemical purposes.**

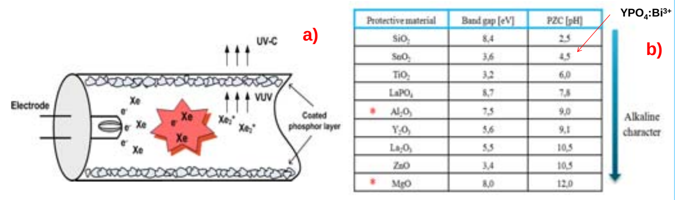
## Method

**Coating materials (MgO, $Al_2O_3$, and $MgAl_2O_4$ ) were deposited onto the phosphor surface by means of homogeneous precipitation from alcoholic or aqueous solution.**

## Experimental part

**The emission, excitation, and reflection spectra were recorded in order to characterize prepared coating samples. Additionally, the microstructural morphologies of uncoated and coated $YPO_4:Bi^{3+}$ were observed by Scanning and Transmission Electron Microscope. Finally, Electrokinetic Sonic Amplitude (ESA) measurements were performed to determine the point of zero charge values.**

**An emphasis was placed on the comparison of the particular coating influence on the emission and excitation intensity, and on the extent to which the preparation method conditions affect the resulting coating, i.e. its thickness and distribution, as well as the electrochemical behavior of the coated phosphor.**



| Protective material | Band gap [eV] | PZC [pH] |
|---|---|---|
| $SiO_2$ | 8,4 | 2,5 |
| $SnO_2$ | 3,6 | 4,5 |
| $TiO_2$ | 3,2 | 6,0 |
| $LaPO_4$ | 8,7 | 7,8 |
| * $Al_2O_3$ | 7,5 | 9,0 |
| $Y_2O_3$ | 5,6 | 9,1 |
| $La_2O_3$ | 5,5 | 10,5 |
| ZnO | 3,4 | 10,5 |
| * MgO | 8,0 | 12,0 |

**Fig. 1. a)** The principle of the light generation in xenon DBD lamps for disinfection purposes. **b)** Typical coating materials bang gap and point of zero charge values.

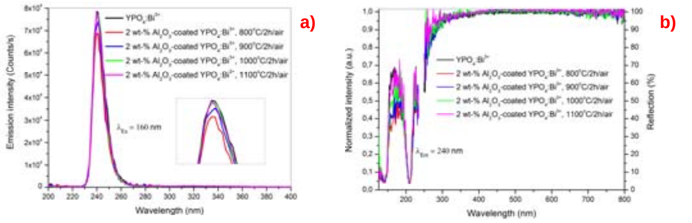


**Fig. 2. a)** Emission spectra of 2 wt-% $Al_2O_3$-coated $YPO_4:Bi^{3+}$ as a function of sintering temperature. **b)** Excitation and reflection spectra of 2 wt-% $Al_2O_3$-coated $YPO_4:Bi^{3+}$.

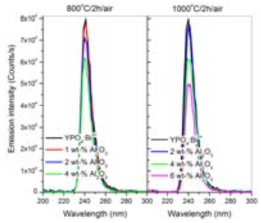


**Fig. 3.** Emission spectra of $Al_2O_3$-coated $YPO_4:Bi^{3+}$ ($\lambda_{Ex}$ = 160 nm).

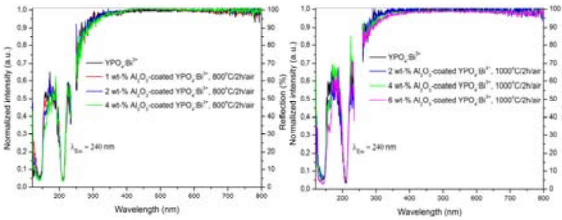


**Fig. 4.** Excitation and reflection spectra of $Al_2O_3$-coated $YPO_4:Bi^{3+}$ sintered at 800°C **(left)** and 1000°C **(right)**.

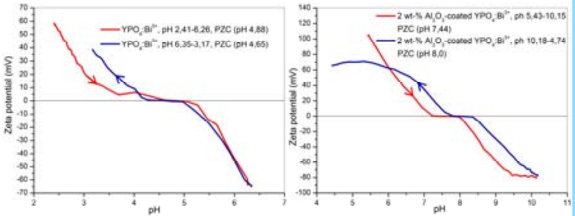


**Fig. 5.** ESA measurement of uncoated $YPO_4:Bi^{3+}$ **(left)** and $YPO_4:Bi^{3+}$ coated with 2 wt-% $Al_2O_3$ **(right)**.

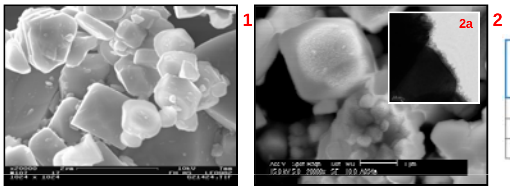
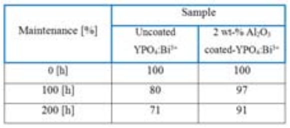


**Fig. 6.** Scanning electron micrographs of uncoated $YPO_4:Bi^{3+}$ **(1)** and 2 wt-% $Al_2O_3$-coated $YPO_4:Bi^{3+}$ **(2)**. TEM image of coated phosphor **(the inset 2a).**



| Maintenance [%] | Sample | |
|---|---|---|
| | Uncoated $YPO_4:Bi^{3+}$ | 2 wt-% $Al_2O_3$ coated-$YPO_4:Bi^{3+}$ |
| 0 [h] | 100 | 100 |
| 100 [h] | 80 | 97 |
| 200 [h] | 71 | 91 |

**Tab. 1.** Maintenance of the light output during initial hours of lamp performance.

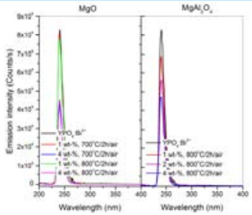


**Fig. 7.** Emission spectra of MgO- **(left)** and $MgAl_2O_4$-coated $YPO_4:Bi^{3+}$ **(right).**

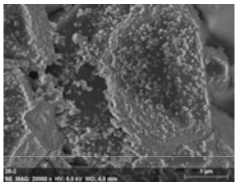


**Fig. 8.** SEM image of 2 wt-% MgO-coated $YPO_4:Bi^{3+}$.

## Discussion and Conclusions

**The quantity of MgO, $Al_2O_3$ or $MgAl_2O_4$ nanoparticles fixedly adhered to the $YPO_4:Bi^{3+}$ should be sufficiently high enough for a uniform surface coverage without significant loss of luminescence intensity and guaranteeing phosphor resistance to destructive Xe discharge atmosphere. The higher is the coating material mass fraction, the larger reduction in the phosphor efficiency can be observed (Fig. 3 and Fig. 8). Coating material particles provide new interface, which is responsible for observed intensity decrease due to the irregular reflection and/or partial absorption of radiation.**

**The extent to which the intensity decreases has been found dependent on the preparation method conditions, e.g., post annealing at elevated temperature yields superior results and provides conditions favoring desired α-$Al_2O_3$ formation (Fig. 2a).**

**A smooth and well-defined uncoated phosphor surface (Fig. 6.1), after deposition, shows a roughened morphology which is attributed to the presence of homogenously distributed coating material particles (Fig. 2 and Fig. 8).**

**The presence of the coating layer visibly shifts the PZC value from acidic toward the alkaline pH range due to the presence of $Al_2O_3$/AlOOH (Fig. 5). Materials tendency to donate electrons is used to neutralize xenon molecular ions (no $Xe_2^{+/*}$ adhesion to $YPO_4:Bi^{3+}$ surface), which are the products of the secondary reaction in the discharge gap and exhibit undesired absorption.**

**Lamp maintenance curve during the first 240 hours of performance indicates that application of 2 wt-% alumina coating on the phosphor surface results in 90% preservation of the light output during device initial hours of performance (Tab. 1).**