The Effect of X-ray Exposure on $Ba_2SiO_4:Eu^{3+}$

Max-Fabian Volhard and Thomas Jüstel

Department of Chemical Engineering, Münster University of Applied Sciences,
Stegerwaldstr. 39, D-48565 Steinfurt, Germany
E-mail: m.volhard@fh-muenster.de, tj@fh-muenster.de

PGS 2018, March 13-15, 2018, San Diego, CA, USA

Background

- Luminescent materials for the detection of high energy radiation are widely applied as storage materials. Widely applied phosphors for this application area are e.g. BaFBr:Eu^{2+} or CsBr:Eu^{2+} [1,2].
- To determine the radiation dose that has been perceived by a storage phosphor, optical or thermal stimulation of formed traps is applied, which implies a rather large uncertainty level.
- Due to the phosphor material described here, this uncertainty can be rather reduced by detecting the displacement of the CIE 1931 color points.
- By applying the phosphor to a surface, a 2D detector can be built and the high energy radiation is detectable in a spatial resolution.
- Ortho-silicates activated with Eu^{3+} can be photochemically reduced to Eu^{2+} upon excitation by high energy radiation.

Synthesis and Structure

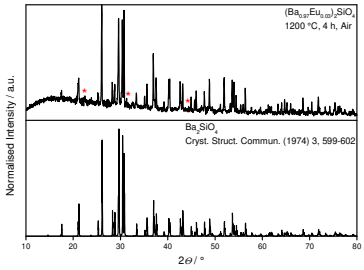

Figure 1: XRD patterns of $(Ba_{0.5}Sr_{0.5})_2SiO_4:Eu^{3+}$ and the reference of Ba_2SiO_4 [3].

Synthesis

- $BaCO_3 + Eu_2O_3 + SiO_2$ were weighed in stoichiometric amounts
- Flux: 2.6 wt-% NH_4Cl
- Calcination: 1200 °C for 4 hours in air

Space group: *Pnma* (#62)

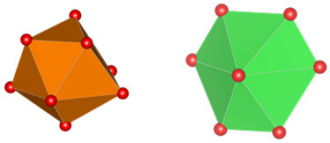

Figure 2 : Coordination polyhedral of both Ba^{2+} sites in Ba_2SiO_4 [3].

$$2\text{-}2x\ BaCO_3 + x\ Eu_2O_3 + SiO_2 \longrightarrow (Ba_{1-x}Eu_x)_2SiO_4 + 2\text{-}2x\ CO_2 + x/2\ O_2$$

Results and Discussion

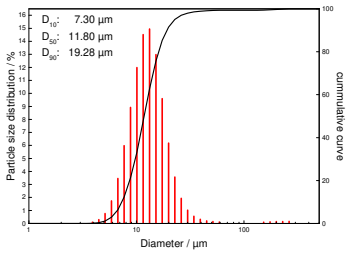

Figure 3: Particle size distribution of $(Ba_{0.97}Eu_{0.03})_2SiO_4$ after ultrasonic treatment (2x)

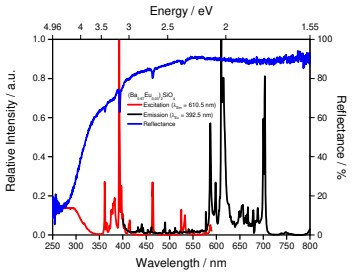

Figure 4: Room temperature PLE, PL and reflectance spectra of $Ba_2SiO_4:Eu^{3+}$.

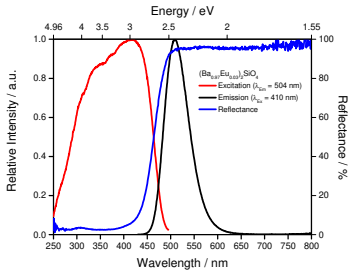

Figure 5: Room temperature PLE, PL and reflectance spectra of $Ba_2SiO_4:Eu^{2+}$.

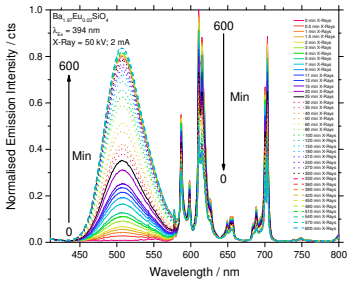

Figure 6: Integral normalised emission spectra of $Ba_2SiO_4:Eu^{3+}$ excited at 394 nm with increasing X-ray irradiation time (50 kV; 2 mA; tungsten target)

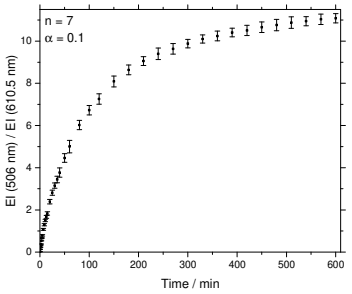

Figure 7: Ratio of the integral of emission from the band at 506 nm and the intensity of the line at 610.5 nm as a function of irradiation time

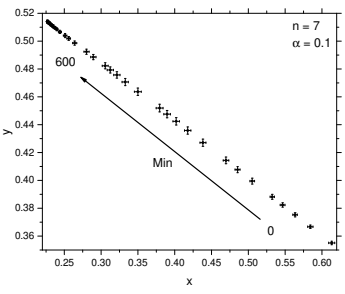

Figure 8: CIE 1931 colour diagram showing the colour change as a function of irradiation time

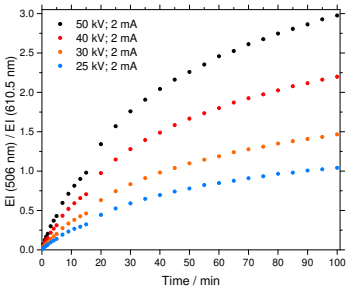

Figure 9: Integrated emission intensity ratio (Eu^{2+} / Eu^{3+}) as a function of time for different acceleration voltages

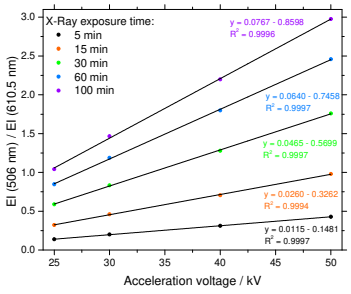

Figure 10: Plot of the integrated emission intensity ratio as a function of the acceleration voltages for different irradiation times

- Eu^{3+} is a line emitter and emits in the range between 590 and 710 nm, which are caused by intraconfigurational [Xe]$4f^6$-[Xe]$4f^6$ transitions of Eu^{3+} (see Figure 4).
- The green band emission between 450 and 650 nm is arisen by the [Xe]$4f^65d^1$-[Xe]$4f^7$ transition of Eu^{2+} (see Figure 5).
- High-energy radiation reduces Eu^{3+} cations to Eu^{2+}. The ratio between the green and the red emission is formed. The strong raise between 0 and approx. 100 min (see Figure 7) is suitable for quantitative measurements.
- The good visibility of the reduction phenomenon is ensured by converting the emission integrals to CIE 1931 color points and depicts them against time (see Figure 8).
- The reduction of the activator raises with increasing acceleration current and the resulting radiation dose (see Figure 9).
- Figure 10 shows that the relationship between green band and red line emission increases linearly with the acceleration voltage.

Acknowledgement

The authors are grateful to Merck KGaA Darmstadt, Germany for generous financial support.

References

[1] H. Li, P. Hackenschmied, E. Epelbaum, M. Batentschuk, Mater. Sci. Eng. 94 (2002) 32–39.
[2] P. Leblans, D. Vandenbroucke, P. Willems, Materials 2011, 4, 1034-1086
[3] H.-P. Große, E. Tillmanns, Cryst. Struct. Commun. (1974) 599–602.

M.Sc. Max-Fabian Volhard
Department of Chemical Engineering
Research Group Prof. Dr. T. Jüstel
Phone: +49-(0)2551-9-62392
E-Mail: m.volhard@fh-muenster.de

FH MÜNSTER
University of Applied Sciences

TOM
Tailored Optical Materials

The effect of X-ray exposure on $Ba_2SiO_4:Eu^{3+}$,
Max-Fabian Volhard and Thomas Jüstel,
Opt. Communications 410 (2018) 617,
DOI: 10.1016/j.optcom.2017.10.050

RG Tailored Optical Materials – http://www.fh-muenster.de/juestel