Enhancing the performance of persistent phosphors: focus on the trapping defects and detrapping processes

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1. Introduction

Persistent phosphors, also called glow-in-the-dark materials, are a specific type of luminescent materials. They can emit light long after the excitation ended, which is realized by temporarily storing energy in the crystal lattice [1,2]. Ambient heat can release the trapped charge carriers, after which recombination and light emission can occur. Several materials are known to emit light for tens of hours after the end of the excitation, not only in the visible part of the electromagnetic spectrum, but also in the infrared, opening novel applications in the field of bio imaging.

2. Optically stimulated detrapping

For many applications, such as in emergency signage, the storage capacity of persistent phosphors should further be increased, which would open new application areas, such as glowing road marks [3]. We show that the excitation of the europium center in the blue emitting $Sr_2MgSi_2O_7$:Eu,Dy by near-UV light not only leads to charge trapping – essential to the persistent luminescence - but also to optically stimulated release of previously trapped charges and subsequent luminescence (OSL) [4]. Furthermore, the optical detrapping is observed to be significantly more important when a larger fraction of the traps is already filled, suggesting OSL is the limiting factor in the storage capacity of persistent phosphors. The impact of this OSL process on the quantum efficiency of the persistent phosphor is demonstrated, which has implications for phosphors used in high brightness applications (e.g. laser based illumination).

3. Mechanical detrapping

Also mechanical pressure can in certain (mechanoluminescent (ML)) phosphors lead to light emission, allowing their use as pressure gauges or stress indicators [5]. Here we focus on the use of ML phosphors as a visualisation tool for ultrasound pressure fields [6]. In the case of $BaSi_2O_2N_2$:Eu, a bluish green ML signal is observed proportional to the ultrasound intensity which can be used to build a three dimensional representation of the ultrasound pressure field. The obtained results are validated by comparison to numerical simulations, showing an excellent match [6].

4. Nature of the trapping defects

Based on the insights from the temperature dependency of trapping and detrapping processes, in combination with the chemical nature of the defects, an empirical model is constructed to understand the trapping and detrapping mechanisms in persistent phosphors. A key element is the careful use of x-ray absorption spectroscopy to proof and evaluate the extent of valence state changes for the rare earth (co)dopants in persistent phosphors [7].

References

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