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Temperature-dependent Reflectance Spectroscopy of $Y_3Al_5O_{12}$:Ce

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Introduction

Yttrium aluminum garnet (YAG) doped with Ce^{3+} is the most widely chosen phosphor for the conversion of blue into yellow light in the rapidly expanding market of white light emitting pcLEDs [1]. The luminescence quenching temperature is an important parameter, especially in high-power pcLEDs, since the chip temperature can reach 200 °C or even more. Therefore, for LED phosphors the determination of their external quantum yield as a function of the operation temperature is of tremendous interest.

In the literature, there are some procedures for the determination of quantum yield stated, such as a calorimetric, an absolute and a relative reference-based method [2]. All these techniques can also be used for temperature-dependent measurements but require quite sophisticated equipment. In order to apply the relative method not only emission spectra but also reflectance values needs to be recorded at different temperatures. To the best of our knowledge so far published T-dependent external quantum yields are limited to T-dependent emission (integrated) values only. Thus, we have designed an integrating sphere with a sample holder that can be heated up to 500 K. In this work we present the quantum yield of YAG:Ce as function of temperature calculated by using T-dependent reflectance spectra and compare the findings to results gained by room temperature reflectance spectra.

Determination of the External Quantum as Function of Temperature

Relative Method by using a Reference Material with known eQY (YAG:Ce Philips U728)

Idea

- Ratio of the number of emitted photons N_{em} to the number of absorbed photons N_{abs} multiplied with the conversion efficiency η is unity for all samples
- Absorption as f(T) can be derived from T-dependent reflectance measurements (sum of absorption and reflection is unity if transmission is considered to be zero)
- Emission integrals as f(T) are direct proportional to the number of emitted photons

Requirements

- Reference sample with known eQY
- Similar luminescent properties of sample and reference because all data has to be acquired under identical conditions

Procedure

- Determination of reflectance at excitation wavelength and measurement of emission spectra for reference and sample at different temperatures
- Eq. (1) gives

$$eQY_{Sample}(T) = eQY_{Reference}(300K)\,\frac{\int_{\lambda_1}^{\lambda_2} I_{Sample}(T)\,d\lambda}{\int_{\lambda_1}^{\lambda_2} I_{Reference}(300K)}\cdot\frac{1-R^{\lambda(Exc.)}_{Reference}(300K)}{1-R^{\lambda(Exc.)}_{Sample}(T)} \qquad (1)$$

Results

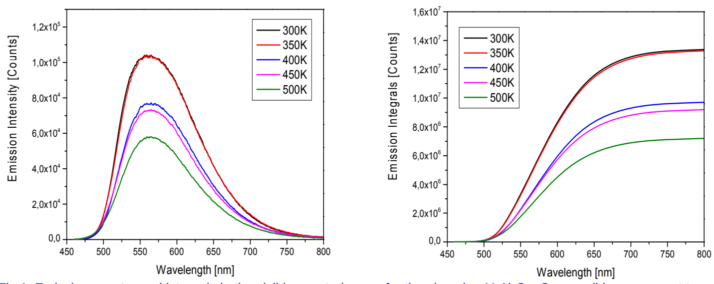

Fig.1. Emission spectra and integrals in the visible spectral range for the phosphor $Y_3Al_5O_{12}$:Ce, a well known garnet type luminescent material.

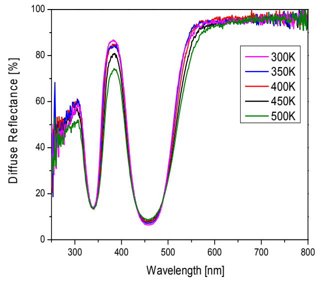

Fig.2. Reflectance spectra as f(T) in the UV/VIS spectral range of $Y_3Al_5O_{12}$:Ce.

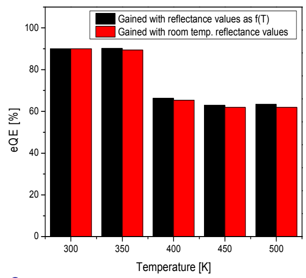

Fig.3. eQY derived from the reflectance values as f(T) (black bars) and with room temperature reflectance values (red bars).

- Emission spectra as function of temperature (Fig. 1) were recorded for λ_{exc} = 450 nm, which corresponds to the lowest crystal-field component of the [Xe]$5d^1$ configuration of Ce^{3+}.
- T-dependent reflectance spectra (Fig. 3) were also recorded, to extract reflectance values at λ_{exc} = 450 nm from these spectra.
- Reflectance values at 450 nm show a continuous increase with increasing temperature.
- According to Eq. 1 eQYs were calculated with room temperature and T-dependent reflectance values.
- Fig. 2 compares the eQYs gained with the two different measures.

References

[1] V. Bachmann, C. Ronda, A. Meijerink, Chem. Mater. 21 (2009) 2077–2084.
[2] U. Resch-Genger, Standardization and quality assurance in fluorescence measurements: 1: Techniques, Springer, Berlin, London, 2008.

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