Examination

Electrical and Optical Characterisation of Materials

M.Sc. Chemical Engineering / Material Science and Engineering

February 02nd, 2024

(Part: Prof. Dr. Thomas Jüstel)

Name, Given name: ______________________________

Enrolment number: ______________________________

Birthday: ______________________________

Duration: 180 minutes (for both parts)

Achievable score: 50 Points (for this part)

Please use these sheets only (you might also use the reverse)! Please employ IUPAC units solely. Assign axes of graphs and parts of sketches properly!

Success!

Task 1) **(10 Points)**

Terms and Quantities

a) Describe the difference between external and internal quantum efficiency by the aid of simple equations! (2 Points)

b) Explain the terms diffuse and specular reflection of radiation at an arbitrary sample by a simple sketch! (2 Points)

c) What is meant by the term actinometry? Please also sketch a simple experimental set-up that is used for actinometry! (3 Points)

d) Which quantities can be determined by emission spectroscopy of a luminescent material required for the development of fluorescent lamps and displays! (3 Points)

Task 2) **(10 Points)**

Luminescence spectroscopy

a) Sketch the build-up of a typical fluorescence spectrometer and give examples for all required optical components! (4 Points)

b) Describe the way to record an emission spectrum of a luminescent material, e.g. of $LaPO_4:Ce^{3+}$ powder that shows the most intense excitation band at 270 nm! Which type of correction has to be applied and why? (2 Points)

c) Describe the way to record an excitation spectrum of a luminescent material, e.g. of $LaPO_4:Ce^{3+}$ powder that shows a broad emission band at 320 nm! Which type of correction has to be applied and why? (2 Points)

d) What kind of radiation sources should be used for the following measurement purposes? Explain your choice! (1 Point each)

Transmission spectrum between 320 and 2000 nm

Excitation spectrum between 100 and 350 nm

Task 3) (10 Points)

Temperature resolved spectroscopy - Thermoluminescence

a) Describe the procedure to record a glow curve of an arbitrary luminescent material! (3 Points)

b) Which information can be derived from a glow curve? (3 Points)

c) Sketch the shape of a typical glow peak and also show the effect on the glow peak and also discuss by the peak position the meaning of shallow or deep traps! (2 Points)

d) Explain an application area of thermoluminescence measurements! (2 Points)

Task 4) **(10 Points)**

Absorption and reflection spectroscopy

a) Is it possible to measure a reliable transmission spectrum of powder samples? Explain your answer! (2 Points)

b) Explain the role of the integration sphere for reflection measurements of powder samples by a simple sketch! (3 Points)

c) You have recorded a reflection spectrum of $CaAlSiN_3:Eu^{2+}$ powder (spherical particles with d = 10 µm). At 450 nm 10% of the light is reflected, at 650 nm 97% of the light is reflected. Please calculate the absorption coefficient in cm^{-1} at both 450 nm and 650 nm by using the Kubelka-Munk-Function! Remark: The scattering coefficient is approximately equal to 1/d. (3 Points)

Kubelka-Munk-Function: $\frac{A}{S} = \frac{(1-R_\infty)^2}{2R_\infty}$

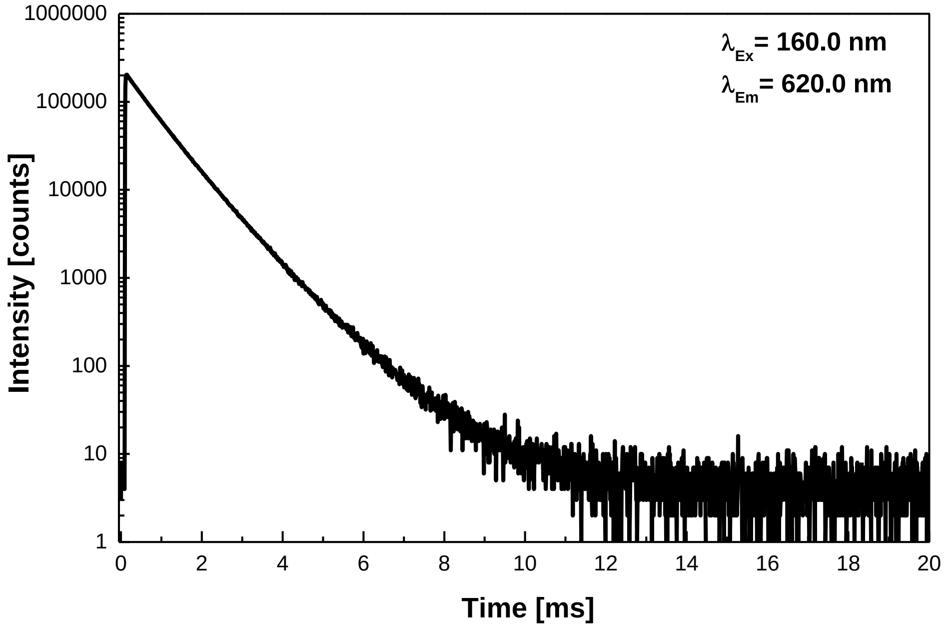
d) Name a window material for VUV excitation spectroscopy and a material for NIR transmission spectroscopy and explain your choices! (2 Points)

Task 5) **(10 Points)**

Time and temperature resolved spectroscopy

a) Describe the procedure to record a decay curve of a luminescent material! (2 Points)

b) The figure below displays the decay curve of $YVO_4:Eu^{3+}$, which is applied in high-pressure Hg discharge lamps and plasma displays. Please determine the decay constants $\tau_{1/e}$ and $\tau_{1/10}$ from the following graph! (2 Points)



c) Select a function for the fitting of the decay curve shown above and explain your choice! Which is the origin of the deviation from linearity in the above plot? (2 Points)

$I(t) = A_0 - B_1 * t/\tau_1$

$I(t) = A_0 + B_1 * \exp(-t/\tau_1)$

$I(t) = A_0 + B_1 * \exp(-t/\tau_1) + B_2 * \exp(-t/\tau_2)$

d) Describe the way to record a thermal quenching curve, e.g. of $YVO_4:Eu^{3+}$, and to fit the experimental data by the so-called Struck-Fonger equation! (2 Points)

$I(T) = A_0 + I_0/[1 + B\exp(-\Delta E/k_B T)]$ „Struck-Fonger-Equation“

e) Draw the shape of a typical thermal quenching curve in a respective intensity-temperature diagram and assign the $T_{1/2}$ value! (2 Points)