Quattro™ Luminescence Spectrometer

—The Perfect Solution for Photoluminescence of Lanthanide-Doped Semiconducting Nanocrystals

Introduction

Photoluminescence (PL) studies of lanthanide-doped semiconducting nanocrystals have become very common in materials science. Both spectral and time-resolved luminescence properties are key parameters in quality control involving assessment of surface contamination, size distribution, upconversion efficiency and PL quantum yield. The increased research interest in lanthanide-doped nanocrystals is prompted by applications in solar energy conversion devices, lasing media, LED technologies and development of upconversion-based luminescent labels for biomedical analyses and bioimaging. The Quattro™ bench-top luminescence spectrometer is the ideal tool to fully characterize the PL properties of such materials in the UV-VIS range. The instrument introduces new and unique technology and offers the best sensitivity and fastest speed of any integrated bench-top instrument. For example, the Quattro™ can acquire real time 3-D scans of wavelength versus microsecond decay in mere seconds. The optical design of the Quattro™ minimizes stray light levels making it ideal for measurements of highly scattering solid and powder materials. The instrument is very easy to use, has full auto-calibration and provides real time excitation and emission corrections.

PL spectra and decay of Eu-doped semiconducting nanocrystals

Time-resolved emission and excitation PL spectra of 25% Eu3+ doped crystalline powder

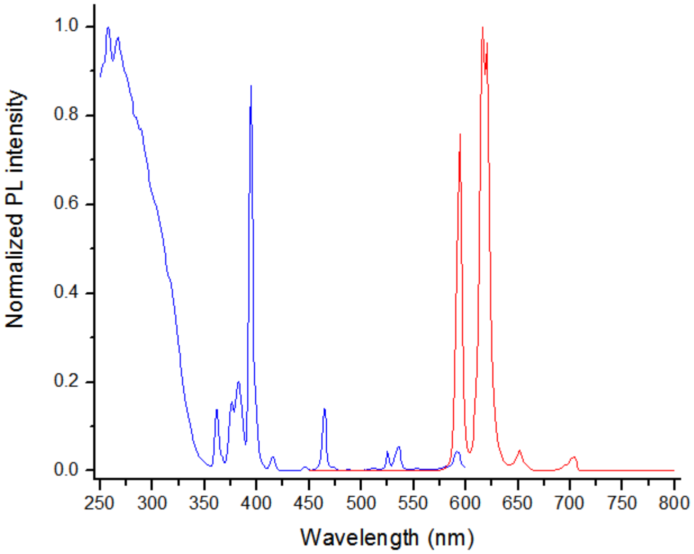

Fig. 1. Time-resolved PL excitation and emission spectra of Eu3+-doped Y1.5Eu0.5Mo4Sb2O18 crystalline powder

Fig. 1 shows the time-resolved emission and excitation PL spectra of 25% Eu3+ doped crystalline powder. The signal was measured with the pulsed Xe lamp set to flash at 100 Hz and the spectral intensities were calculated by integrating the emission signal along the output decay curve in the time window selected between 100 and 600 µs after the excitation pulse. Setting the signal integration boundary well after the excitation pulse guarantees that the collected spectra are free of any kind of stray (scattered) light or short-lived fluorescence contamination that may be present in the sample.

PL decay of 25 %Eu3+ doped nanocrystals

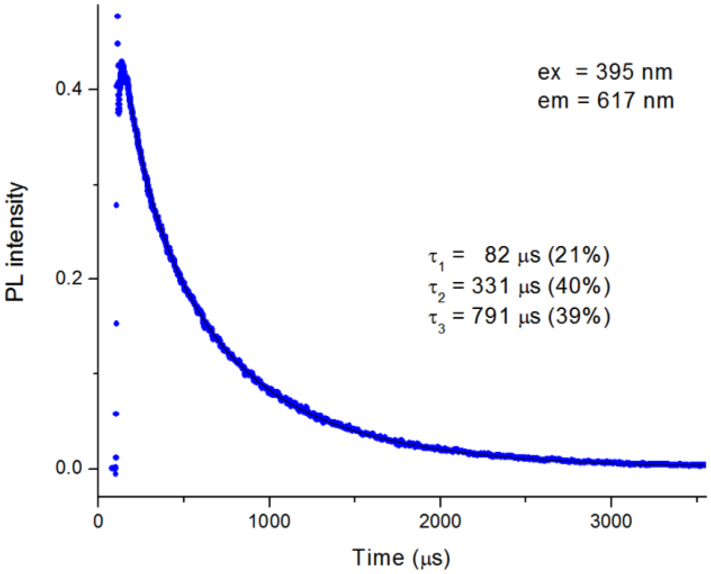

Fig. 2. PL decay of Eu3+-doped Y1.5Eu0.5Mo4Sb2O18 crystalline powder.

Fig 2 presents a PL decay of Eu3+ doped nanocrystals. Since the Quattro's unique transient digitizer detection enables very rapid accumulation and signal averaging, the decay in Fig. 2 was measured in less than 1 s. The Quattro™ can also report the measured lifetimes and amplitudes immediately after the decay is acquired without the need for an additional analysis step. This best-in-class speed provides Quattro™ users with much higher levels of lab throughput than has ever been possible before. The measured decay is triple-exponential with lifetimes varying from 82 to 791 µs, which points to the structural diversity of the nanocrystals.

Time-resolved emission and excitation PL spectra of 20% Ho3+ doped crystalline powder

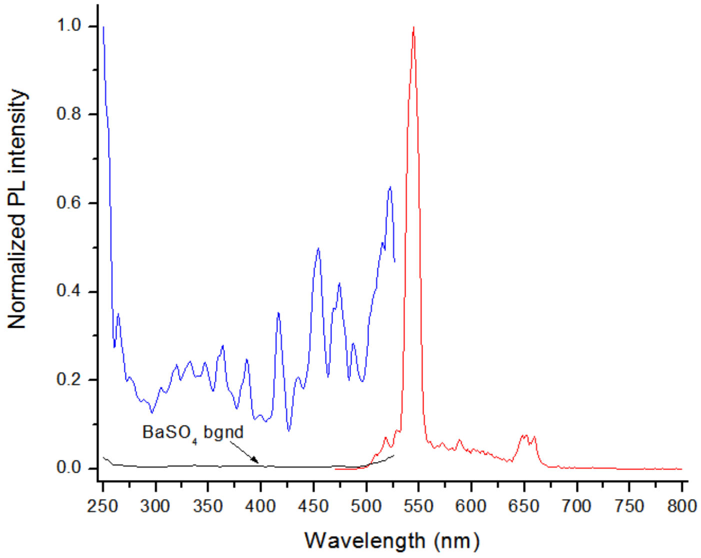

Fig. 3. Time-resolved PL excitation and emission spectra of Ho3+-doped Y1.6Ho0.4Mo4Sb2O18 crystalline powder

Fig. 3 shows the time-resolved emission and excitation PL spectra of 20% Ho3+ doped crystalline powder. The PL decay of this sample is around 1 µs, so the signal integration was carried out by selecting a 50 µs gate positioned 2 µs before the onset of the excitation pulse. To ensure that the measured spectra were free of stray light or short-lived ns fluorescent impurities, a test excitation scan was performed under the same experimental conditions using a light-scattering plate coated with BaSO4. This test experiment revealed excellent suppression of stray light despite the strongly scattering medium.

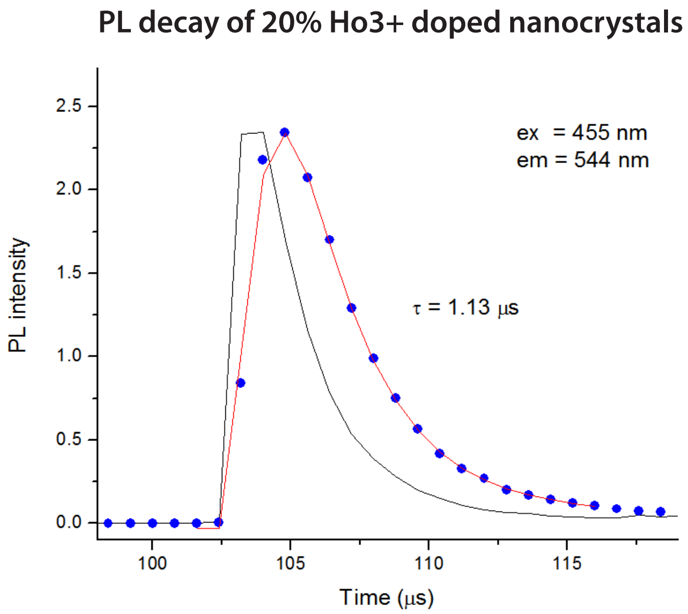

Fig. 4. PL decay of Ho3+-doped Y1.6Ho0.4Mo4Sb2O18crystalline powder. IRF trace was used for deconvolution analysis and is also shown.

Fig 4 presents a PL decay of Ho3+ doped nanocrystals. Since the PL decay of this sample is very short, an instrument response function (IRF) was also measured and the lifetime of 1.13 μs was determined by iterative reconvolution. This result demonstrates the Quattro's ability to measure lifetimes much shorter than the excitation pulse duration.

Conclusion

The results demonstrate that the new Quattro™ luminescence spectrometer is an excellent choice for photoluminescence studies of lanthanide-doped nanocrystals and other solid and powder inorganic materials. Due to its design the instrument features very efficient rejection of stray light and the ability to rapidly perform spectral and time-resolved characterization of these materials with a high degree of accuracy.