

MiCOS Hybrid PL System

OSD-AN-117

ELEMENTAL ANALYSIS
FLUORESCENCE
GRATINGS & OEM SPECTROMETERS
OPTICAL COMPONENTS
FORENSICS
PARTICLE CHARACTERIZATION
RAMAN
SPECTROSCOPIC ELLIPSOMETRY
SPR IMAGING



All-in-one solution for steady state and time-resolved photoluminescence on a single, compact microscope platform

Introduction

Photoluminescence spectroscopy can be used to characterize a wide variety of materials. Examples include semiconductor wafers, photovoltaics, light sources, and biological systems.

In semiconductor research, steady state photoluminescence can be used to both determine the bandgap of the material, and identify defects or impurities in the sample. By monitoring peak intensity, wavelength, and peak width across a wafer, the manufacturing process can be optimized.

Time-resolved photoluminescence can provide a wealth of complementary information that is not readily accessible through steady state photoluminescence. For example, while defects may be identified with steady state photoluminescence, time-resolved PL can provide more information on the nature of the defect. It can also provide a probe into the dynamics happening within the material such as minority carrier lifetimes and recombination processes in the bulk or at the interface.

In photovoltaic systems, the quality of the material being manufactured is typically assessed by electrical measurements carried out after the device has already been fabricated. This means that a bad wafer is only caught after the expensive and time consuming step of device fabrication. By using time-resolved photoluminescence, the carrier dynamics that affect wafer quality can be assessed in a quick, low cost and non-contact method requiring no sample preparation.

System Configuration

The MiCOS optical spectrometer combines steady state

and time-resolved photoluminescence on a single, compact instrument. Figure 1 shows a schematic of the system layout. Dual fiber-coupled light sources, CW and pulsed, provide the necessary excitation for steady state and time-resolved PL. The use of a bifurcated fiber eliminates the need to swap sources during a measurement.

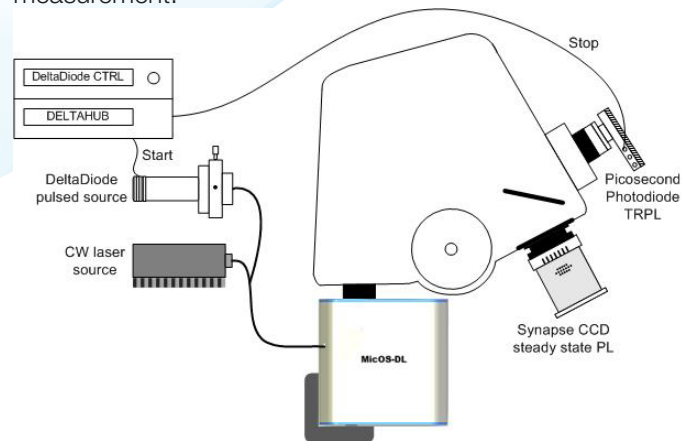


Figure 1. Schematic of MiCOS hybrid PL system.

The microscope head is directly coupled to the spectrometer, allowing for the best possible throughput—much higher than a traditional fiber-coupled microscope! In addition, the MiCOS microscope head includes a white light illumination source and vision camera for viewing and alignment of the sample under test. Because the microscope head is fully customizable, a wide array of sample handling options can be accommodated, including upright or down-looking cryostats for low temperature measurements and xyz mapping stages.



With the option of coupling to either the iHR320 or iHR550 imaging spectrometer, different spectral resolutions can be attained. The triple grating design and comprehensive HORIBA Jobin Yvon grating catalogue allows for wide spectral coverage. In addition, the ability to mount multiple detectors simultaneously means there is no need to swap detectors between different types of measurements.



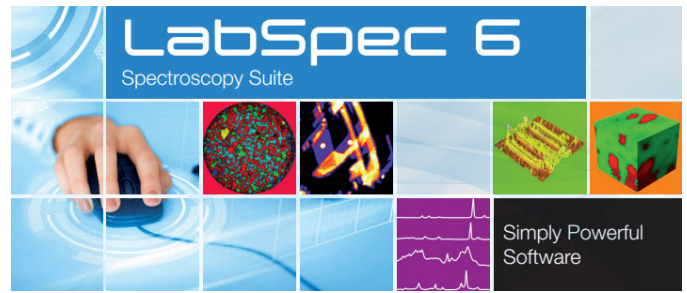
For detection, a wide variety of options are available, covering wavelengths from the UV to near-IR. For steady state measurements, either a CCD or linear InGaAs array may be used, covering 200 nm to 2000 nm. For time-resolved measurements, picosecond photon detection (PPD) modules allow for spectral coverage from 230 nm to 920 nm. Also available are additional PMT options that can extend spectral sensitivity for time-resolved measurements up to 1700 nm.



There are two options for TCSPC timing electronics: the DeltaHub and the FluoroHub A+. The DeltaHub has an ultrashort 10 ns dead time and minimum lifetime measurement of 25 ps. The FluoroHub A+ has the best possible timing resolution at 400 fs/point and a minimum lifetime measurement of 5 ps.

Finally, LabSpec and DataStation software packages seamlessly integrate all of the instrumentation together. LabSpec carries out steady state PL measurements with the option to map the PL signal over a sample's surface,

while DataStation carries out lifetime measurements at single points. The optional DAS6 software package includes many data analysis tools for lifetimes including multi, batch, and global exponential fitting.



Example Samples and Data

While there are a large variety of samples that the MicOS hybrid PL system can be used to analyze, a few examples are shown here. Figures 2 and 3 show steady state and time-resolved results obtained on a 2" semiconductor wafer. Figure 2 depicts steady state results of the fully mapped wafer, with analysis of the peak PL intensity (top), peak wavelength (middle), and peak width (bottom). The histograms on the right hand side of the figure show the distribution of values of interest. As can be seen from the three different results, different information can be gleaned from different PL parameters. In addition, changes in bandgap and identification of impurities or defects can also be carried out.

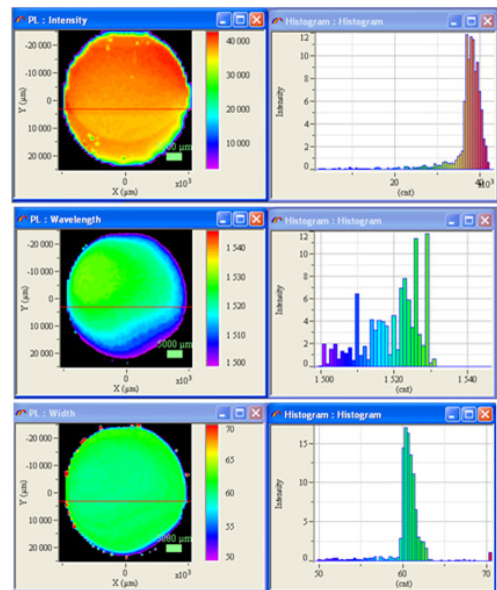


Figure 2. Steady state PL mapped results of a 2" semiconductor wafer. Peak intensity, wavelength, and width are plotted.

Figure 3 shows the results from time resolved PL measurements on two different points on the sample. As can be seen, different lifetimes are observed, reflecting a change in either the composition or structure of the wafer. Because both steady state and TRPL measurements are carried out on the same instrument, co-location of the sample is easily attained. The sample does not need to be removed from one instrument, moved to another, and realigned.

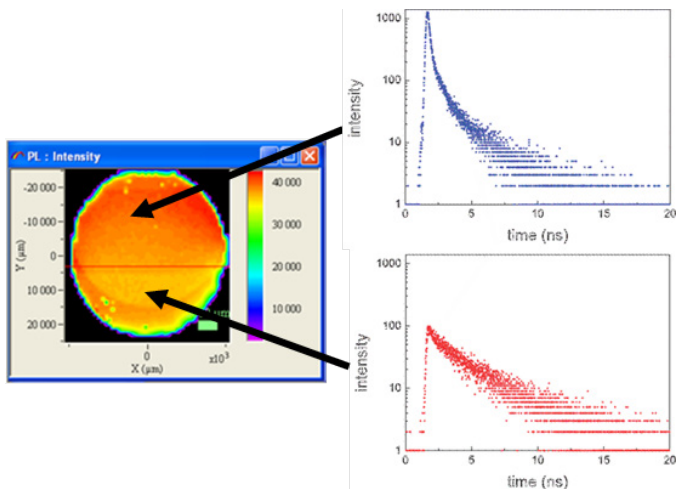


Figure 3: TRPL results from two points on a 2" semiconductor wafer showing different lifetimes.

The second example (Figure 4) shows measurements made on a rare earth doped glass, Pr³⁺ in borosilicate glass. In this example, the steady state spectrum is shown at the top, and the lifetime measurement is shown on the bottom. The steady state spectrum shows multiple peaks, indicative of different electronic transitions in the system. For the TRPL measurement, the PL wavelength was fixed at 650 nm, and TCSPC was used to build up a histogram of the PL signal over time. By measuring the lifetimes at different points in the PL spectrum, the dynamic processes within the molecular system can be probed for different electronic transitions. The results provide a probe into the environment in which the rare earth ion is held and can be used to identify probable transitions for lasing.

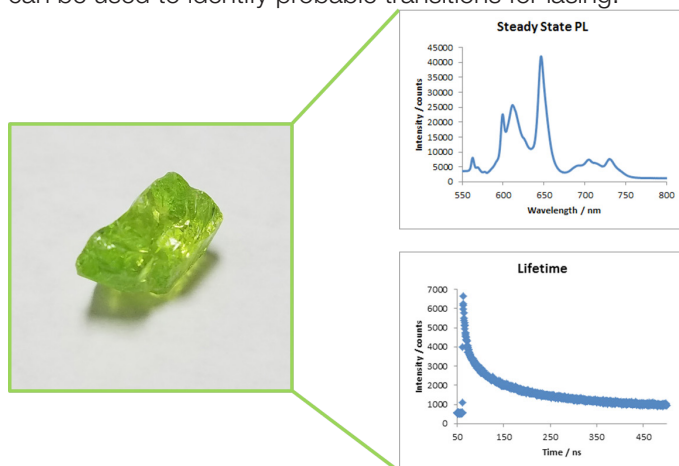


Figure 4. Steady state (top) and time-resolved (bottom) PL on Pr³⁺ doped borosilicate glass.

The use of a spectrometer in the MicOS system allows for lifetime measurements to be carried out at different wavelengths in the PL spectrum. In a filter-based system, the user would be restricted to a set of wavelengths and bandpass dictated by available filters. The new MicOS hybrid system provides much greater flexibility with virtually limitless choices for detection. In this example, the spectrometer position could be adjusted to measure the lifetimes at each peak in the steady state PL spectrum, providing much more information on different electronic states of the sample.

Features

- Simultaneous coupling of multiple laser sources (for steady state and TRPL)
- Direct microscope head coupling
- White light illumination and vision camera
- iHR series imaging spectrometer
- Multiple detector options (for steady state and TRPL)
- TCSPC electronics
- Powerful software packages for steady state and TRPL

Benefits

- Seamless integration of steady state and time-resolved PL on a complete system
- Wide spectral coverage (UV to near-IR)
- High system throughput
- Flexible, customizable platform for varied samples
- Co-location of sample between steady state and TRPL measurements

References

- ¹N. Bel Haj Mohamed et al, J. Nanoparti. Res. 16, 2242 (2014).
- ²D. Kuciauskas et al, PVSC, 2012 38th IEEE.
- ³G.E. Bunea et al, Appl. Phys. Lett. 75, 838 (1999).
- ⁴Y. K. Sharma et al, Am. J. Cond. Matter Phys. 5, 10 (2015).

Specifications

Part Number	MicOS-DL (Down-looking)	MicOS-SL (Side-looking)
Excitation Source Coupling ¹	Direct or Fiber-Coupled	
Excitation Wavelength (CW, Steady State) ¹	266 nm – 1064 nm	
Detector (Steady State)	Syncerity, Synapse, Symphony II CCDs (UV-VIS) Synapse, Symphony II linear InGaAs arrays (NIR)	
Excitation Source (Pulsed, TRPL)	DeltaDiode series, 250 nm – 1310 nm, 100 MHz max rep rate	
Detector (TRPL)	PPD-650, 230 nm – 700 nm, ambient (<80 cps dark typical) PPD-850, 230 nm – 850 nm, TE cooled (<200 cps dark typical) PPD-900, 230 nm – 920 nm, TE cooled (<3000 cps dark typical)	
TCSPC Electronics (TRPL)	DeltaHub (25 ps min lifetime, 2.5 ps/pt, 100 MHz) FluoroHub A+ (5 ps min lifetime, 400 fs/pt, 20 MHz)	
Spectral Resolution (nm) ²	0.18 nm (iHR320) 0.11 nm (iHR550)	
Minimum Spatial Resolution (µm) ³	1 µm (100x objective, direct coupling)	
Spectral Range (nm) ⁴	200 nm – 2000 nm	
Objectives ⁵	10x, 40x, 50x, 100x	
Sample Stage	XYZ (manual or motorized), wafer handling	

¹For UV excitation (<400 nm), direct coupling is required.

²For 1200 gr/mm grating at 500 nm with 26 µm pixel CCD.

³Measured with 532 nm excitation, 100x objective, and direct coupling.

⁴Requires multiple detectors to cover entire range.

⁵UV, NIR, and achromatic objectives also available.



www.microspectroscopy.com



info.sci@horiba.com

www.horiba.com/scientific

HORIBA
Scientific

USA: +1 732 494 8660
UK: +44 (0)20 8204 8142
China: +86 (0)21 6289 6060

France: +33 (0)1 69 74 72 00
Italy: +39 2 5760 3050
Brazil: + 55 11 2923 5400

Germany: +49 (0) 6251 8475-0
Japan: +81 (75) 313-81231
Other: +1 732 494 8660

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