MicOS for semiconductor research

Combined Photoluminescence and Photoreflectance for Semiconductor Characterization

Introduction

Photoluminescence (PL) and photoreflectance (PR) are two popular techniques for semiconductor characterization. They are both appealing, for they are non-contact methods and require virtually no sample preparation. Both PL and PR directly characterize materials' band structure (bandgaps) and, by inference, other derived properties (material composition, carrier/dopant concentration, strain and electric field determination in epitaxy, etc.). All of these have correlations with properties and performance of semiconductor devices. PL is often simpler to implement but constrained by the need for radiative transitions. PR does not have this requirement and can sometimes show details of interband transitions with no PL signature. Thus PL and PR are complementary techniques: the latter providing confirmation and additional information unavailable from the former.[1]

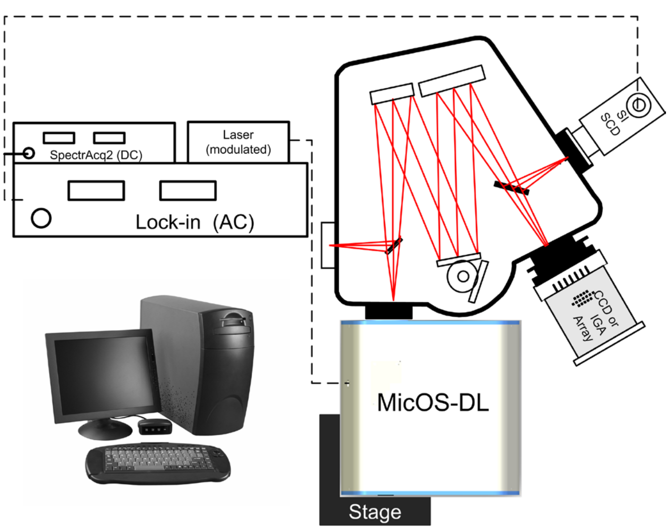

Fig. 1. Schematic of combined PL-PR system.

Historically PL and PR measurement systems are built as two separate and potentially costly instruments. Furthermore, common PR systems have not been integrated, so that most PR systems are table-top assemblies of components with beam propagation through free space. This configuration does not lend itself to environments such as an industrial shop floor or a wafer-fabrication facility.

The HORIBA MicOS-PR is a compact and integrated micro PL and PR measurement system. A schematic of the complete system is shown in Figure 1. The main components of the system are the MicOS head, which houses laser excitation and PL and PR collection optics, plus optics to direct the PR probe beam to the

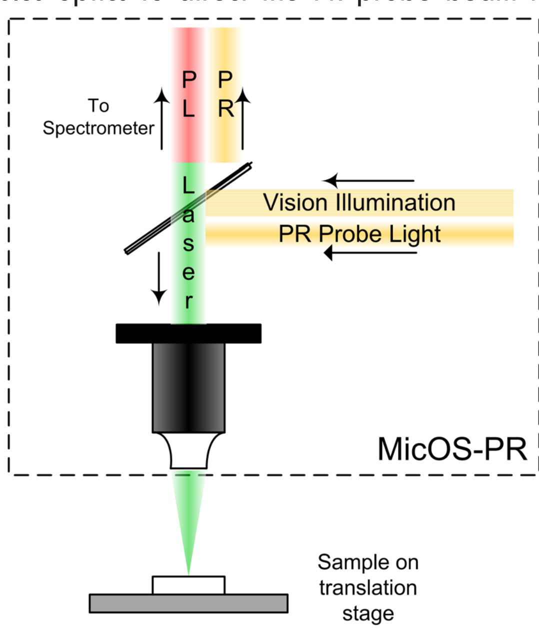

Fig. 2. Diagram of the MicOS-DL head.

[1] J. Misiewicz, *Materials Science*, **21**(3), 2003.

sample, and a vision camera to see the sample (Figure 2).

The MicOS head is directly coupled, conveying the PL and PR emissions to a triple-grating imaging spectrometer with a single-channel detector (SCD) on one exit port (PR, PL) and an array detector (PL) on the other port. For PR measurements, the signal from the SCD detector is split between DC (SpectrAcq2, R) and a lock-in amplifier (SR810, ΔR). The PR signal is $\Delta R/R$. The modulated excitation laser can be fiber- or free-space-coupled to the MicOS head. A TTL signal from the laser modulation provides a reference to the lock-in amplifier. Instrumentation is automated, and hardware control and data collection are controlled by HORIBA Scientific's LabSpec software.

Sample data

Figure 3 shows PL and PR spectra for GaAs. PL was measured using the CCD array detector (the SCD detector is also possible), following laser excitation at 532 nm without laser modulation. Fig. 3 shows how the measured bandgaps of GaAs (~872 nm) using the PL and PR signals coincide.

For PR, the laser was modulated and coincident on the sample with a white-light source whose modulated reflectance constitutes PR, the ratio of AC to DC de-

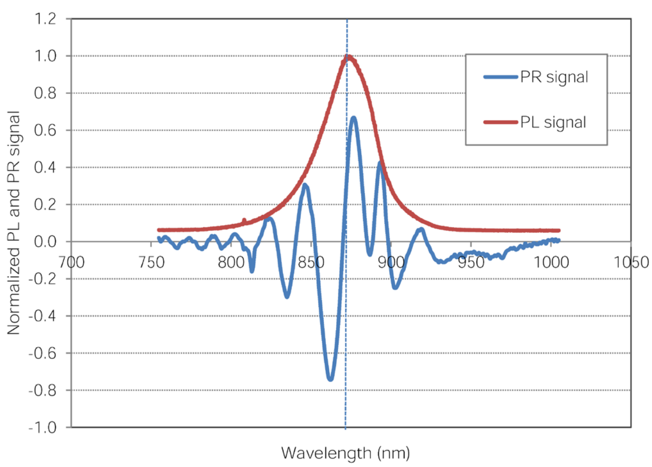

Fig. 3. PL and PR signals of GaAs at room temperature.

(a)
(b)
(c)

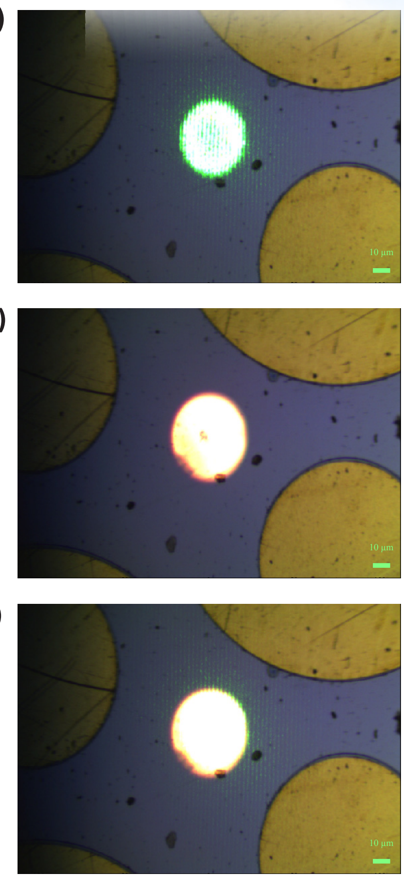

Fig. 4 (a) Laser excitation beam incident on sample for PL. (b) Probe white-light beam incident on sample. (c) Modulated laser and white-light probe beam coincident on sample for PR measurement.

scribed above. Because PR is a derivative, the PR signal is virtually background-free, with often higher sensitivity and S/N as compared to PL.

Figure 4a shows the laser on the sample (as with PL). Figure 4b shows the white-light probe beam used for PR measurement on the sample. Figure 4c shows both laser and white-light probe beams coincident on the sample (as with PR measurement).