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Scientific

High-Resolution Low-Temperature PL of Semiconductors

OSD-110

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

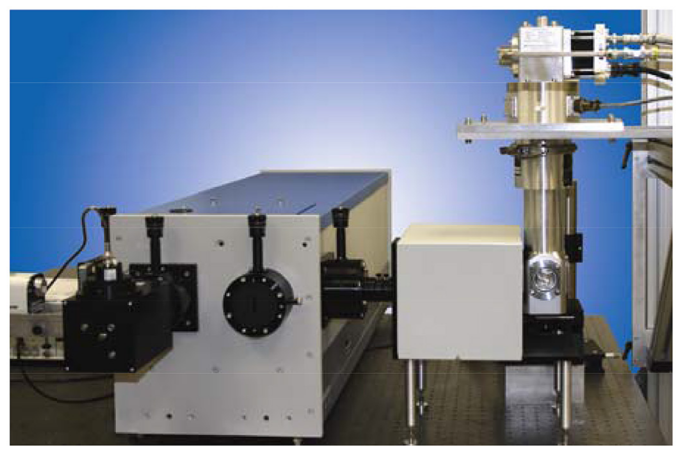
Characterize defects and impurities in semiconductors

Introduction

Temperature-dependent photoluminescence (PL) spectroscopy is a powerful optical method for characterizing materials. PL can be used to identify defects and impurities in Si and III-V semiconductors, as well as determine semiconductor bandgaps. At room temperature, PL emission is usually broad—up to 100 nm in width. When samples are cooled, structural details may be resolved; a small spectral shift between two samples may represent a difference in structure. For cooling, two types of cryostat typically are used: a cryostat using liquid N_2 or liquid He, or a closed-cycle cryostat in which cryogenic liquid is included as part of the cooling system. The cooled sample is excited by a laser, and the PL is coupled to a spectrometer via an optical interface. In this Technical Note, sample data are shown from a high-resolution PL system.

Experimental setup

A 1 m focal-length monochromator (1000M Series II, 600 gr/mm grating) scanned from 800–1650 nm. The detection system was a thermoelectrically cooled InGaAs detector with chopper and lock-in amplifier. Semiconductor samples were mounted in a closed-cycle cryostat mounted above the optical table, and cooled to 4.5 K. A HORIBA Scientific Low Temperature Cryostat Interface optimized the optical coupling into the monochromator. The excitation source was a 10 mW HeNe laser (λ= 632.8 nm). Fig. 1 shows the experimental apparatus.



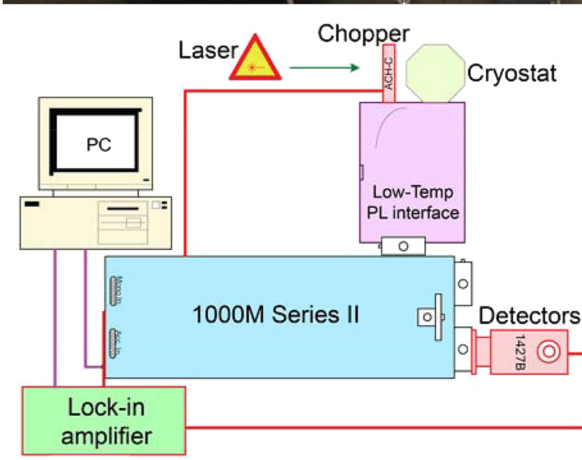


Figure 1. Experimental system.

Results

Fig. 2 shows spectra of the same sample measured at room temperature and at 4.5 K. In PL spectroscopy, a material absorbs light, creating an electron-hole pair. An electron from the valence band jumps to the conduction band, leaving a hole in the valence band. The photon emitted upon recombination corresponds to the energy-difference between the valence and conduction bands (bandgap), and is hence lower in energy than the excitation photon, so that the emission is red-shifted with respect to the excitation light. At low temperatures, a PL peak is quite sharp. As the temperature increases, the peak broadens and shifts to lower energy. This red-shift, typical for such materials, indicates bandgap

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shrinkage as a function of temperature. The decrease in peak intensity indicates that electrons escape via non-radiative processes.

Fig. 3 compares PL spectra from a sample of Nd:YAG laser-glass, using the 1000M Series II (1 m focal length) and the iHR320 (0.32 m focal length) spectrometers. Note the sharper peaks recorded with the 1000M system.

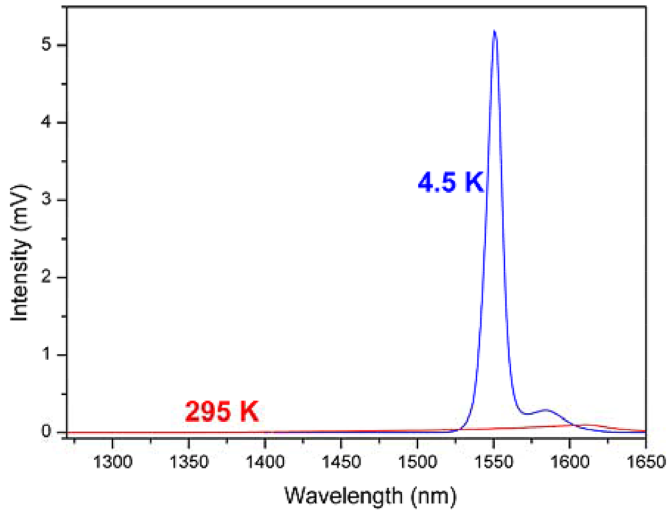

Figure 2. PL from typical semiconductor sample at room temperature, and also cooled to 4.5 K.

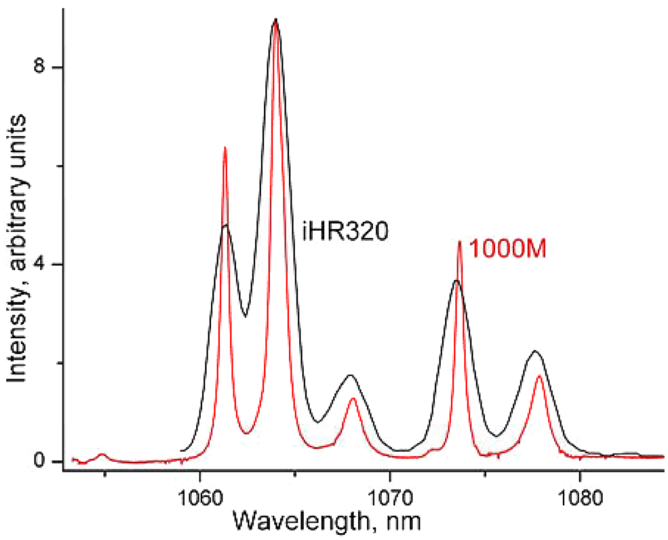

Figure 3. PL spectra of Nd:YAG laser-glass, taken with (black) iHR320 spectrometer and (red) 1000M spectrometer.

System components

In order to measure photoluminescence of semiconductors, the following are needed: a stable, powerful monochromatic light source, optics to focus light on the sample, a sample holder, collection optics, a spectrometer, and a detector for spectral analysis. The Low Temperature PL Optical Interface from HORIBA Scientific provides a stable collection-optics system, to collect the maximum amount of light from the sample inside either type of cryostat, and couple it efficiently into the spectrometer. Benefits include:

- Reflective optics for maximum light collection
- Compatible with M-Series, iHR320/550, and FHR640/1000 spectrometers
- Mounts directly on the spectrometer entrance slit
- Compatible with most cryostats with 90 mm dia. bodies
- Input *f*/1.5, output *f*/7.5
- Filter-holder included [standard 1″ (2.5 cm) filter]

HORIBA Scientific component	Part number
Low Temperature PL Optical Interface	ACC-CRYO-1000M
1000M Series II, 2 entrance and 1 exit slits	1000M II
Optical Chopper	ACH-C
Lock-in Amplifier	SR810
Solid-state detector interface	1427C
Thermoelectrically cooled InGaAs photodiode	DSS-IGA020T
SynerJY® spectroscopy software	CSW-SYNERJY
Closed-cycle He cryostat	Contact us
Cryostat-mounting hardware	Contact us

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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 (0)11 5545 1500
Germany: +49 (0)89 4623 17-0
Japan: +81 (0)3 6206 4721
Other: +33 (0)1 69 74 72 00