

# Photoluminescence mapping of defects in semiconductors

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## Abstract

Photoluminescence (PL) spectra with high spatial resolution provide insight into semiconductor defects, inhomogeneous composition, and surface imperfections. PL mapping with excitation wavelengths of from 266 to 975 nm reveals the spatial distribution of these features with micron resolution. Here, PL maps are shown for CdZnTe and  $\beta$ -Ga<sub>2</sub>O<sub>3</sub>.

## Method

- Klar Mini Pro PL microscope with XYZ scanning
- Ocean Optics spectrometers
- System can cover deep-UV to near-IR (266 to 2500 nm)

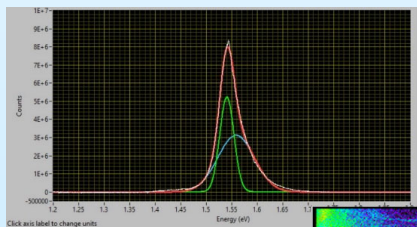


- T = 80 – 400 K
- This work: RT



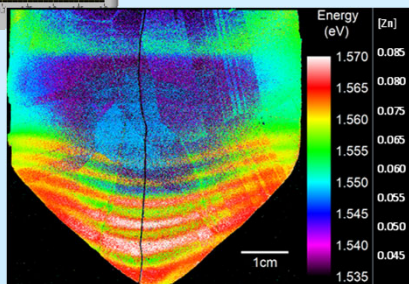
## CdZnTe

- Cd<sub>1-x</sub>Zn<sub>x</sub>Te crystal, Czochralski grown (WSU)
- [Zn] determined from PL peak position
- Inhomogeneities due to incomplete mixing during growth



PL shifts due to variations in [Zn]

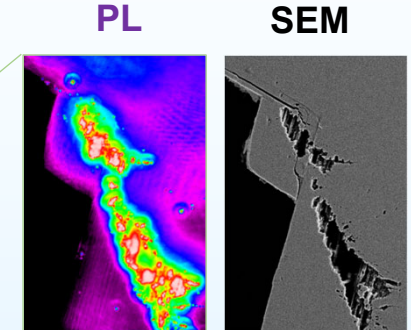
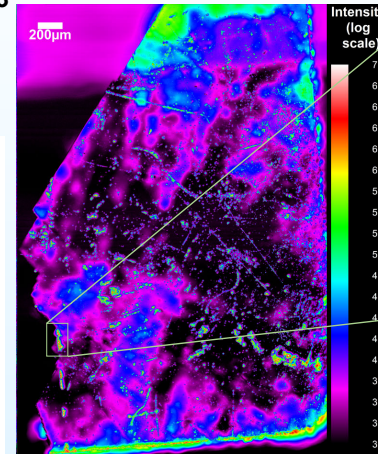
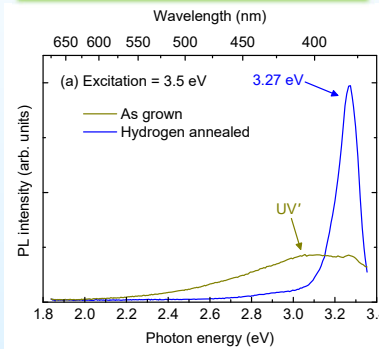
Autofocusing<sup>1</sup> keeps the laser spot diffraction-limited on the sample surface



Top left: Typical PL spectrum (excitation 532 nm) with a 2-peak fit.  
Bottom right: PL map of the peak center, along with [Zn] estimate.

## UV emitters in $\beta$ -Ga<sub>2</sub>O<sub>3</sub>

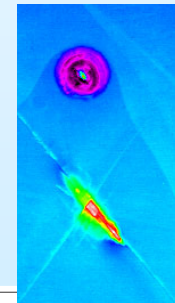
Bright emission at 3.27 eV localized at "pits" on the (010) surface.<sup>2,3</sup>



PL map of the 3.27-eV peak intensity (355 nm excitation). The sample was edge-defined film-fed grown (Tamura) and hydrogenated at 900°C. The emission occurs at surface pits.

## Laser damaged $\beta$ -Ga<sub>2</sub>O<sub>3</sub>

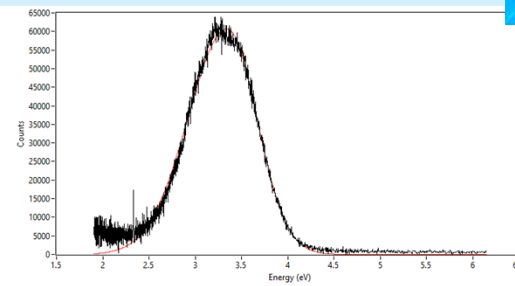
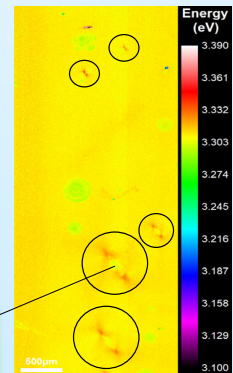
- MOCVD-grown (010)  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> (S. Krishnamoorthy, UCSB), homoepitaxy
- Irradiated with 1064 nm, 3 ns pulses
- Damage threshold = 10 J/cm<sup>2</sup>
- PL excitation 266 nm



Left: PL map of the UV-band intensity for a damaged  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> epilayer. Circular "conchoidal" fracture and a cracked structure are shown (image width ~ 0.8 mm).

Right: Map of PL energy, for a different sample.

Defects revealed by shifts in PL peak



UV band emission (excitation 266 nm) from  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> epilayer. Peak fit is shown in red.

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Laser damage: LLNL Contract DE-AC52-07NA27344, LDRD Project 22-SI-003

1. M.D. McCluskey US Patents 9,891,422 and 10,989,903
2. J. Huso, M.D. McCluskey, Y. Yu, Md. M. Islam, and F. Selim, "Localized UV emitters on the surface of Ga<sub>2</sub>O<sub>3</sub>," *Scientific Reports* **10**, 21022 (2020).
3. M.D. McCluskey, "Point defects in Ga<sub>2</sub>O<sub>3</sub>," *J. Appl. Phys.* **127**, 101101 (2020).