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DOPING-RELATED PHOTOLUMINESCENCE SPECTROSCOPY IN 4H-SiC

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Motivation

Relevance of doping-related photoluminescence for 4H-SiC device fabrication:

- In-process control measurements are essential to detect processing faults along the device production
- Such measurements need to be quick, precise, reproducible, and contactless and applicable without any preparation
- The in-process control of (local) ion implantation and subsequent activation by high temperature annealing is hardly implementable as no adequate tools or methods for local, non-contact electrical measurements are currently available.
- UVPL spectroscopy at room temperature is:
  - ✓ Quick, contactless, needs no preparation
  - But also precise (characteristic changes in spectra after ion implantation and annealing)?
  - → **Suitable for in-process control measurements?**

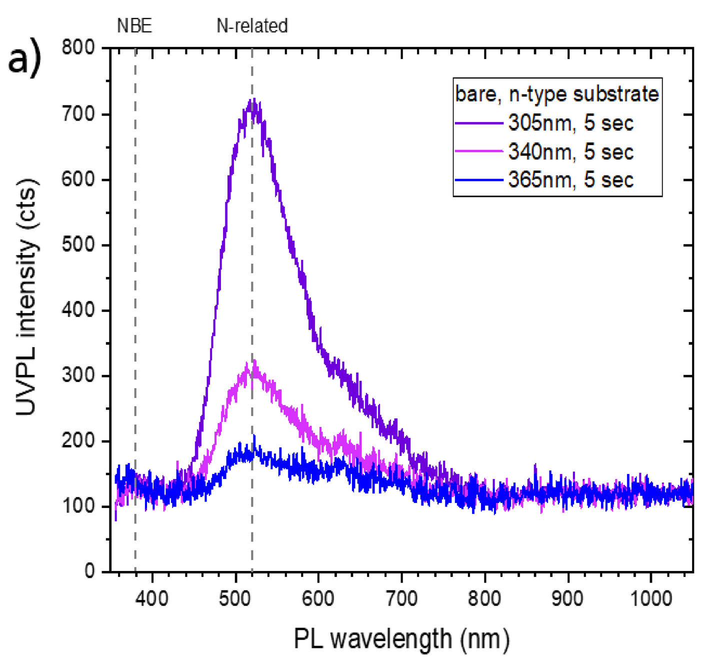
Intego's 2nd generation scanner

Multi-channel tool from Intego [1]

- Fully automated, multi-channel defect inspection with high throughput (25x150 mm in 8 h)
- Bright field/dark field (BF/DF) inspection for surface defects
- UV excited photoluminescence (UVPL) imaging of structural defects close to the surface
  - Different UV illuminations possible; default: 305 nm.
  - Spectral filtering of UV emission spectra possible; default: 380 nm to 1000 nm
  - Spectroscopic measurements
- Differential interference contrast (DIC) microscopy for surface defects such as particles, micropits, scratches, etc.

Proving the UVPL spectrometry

a)



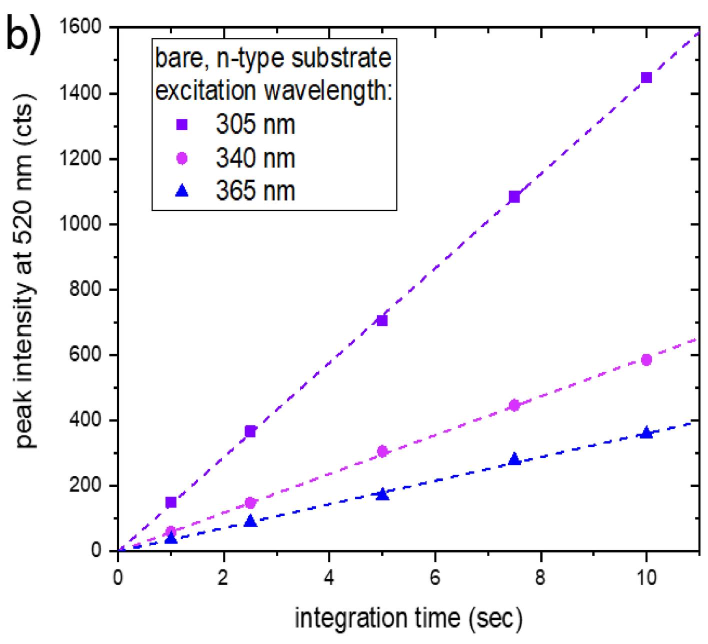
Basic measurements to check the PL spectroscopy system:

- n-type 4H-SiC substrate from commercial vendor (4° off-cut, 350 µm thick).
- Variation of UV excitation wavelength: 305 / 340 / 365 nm (with specific intensities)
- Integration time (spectrometer) fixed: 5 seconds

→ Near band edge emission (NBE) at 378 nm

→ Strong peak at 520 nm → attributed to presence of N and/or other dopants [2,3]

b)



Proving the linearity of PL response

- Variation of UV excitation wavelength:
- Variation of integration times: 1 sec. to 10 sec.
- Extraction of 520 nm peak intensity

✓ Peak intensity linearly increases with integration time

✓ Different slopes due to different intensities of UV LEDs

Basic measurements on substrates

- Different n-type 4H-SiC substrates from commercial vendors (4° off-cut, 350 µm thick) with:
  - Specific resistance from 18 mΩcm to 26 mΩcm
  - → Different N doping concentrations (proven by Hall effect measurements; not shown here)
- UV excitation wavelength: 305 nm
- Integration time (spectrometer) fixed: 5 seconds

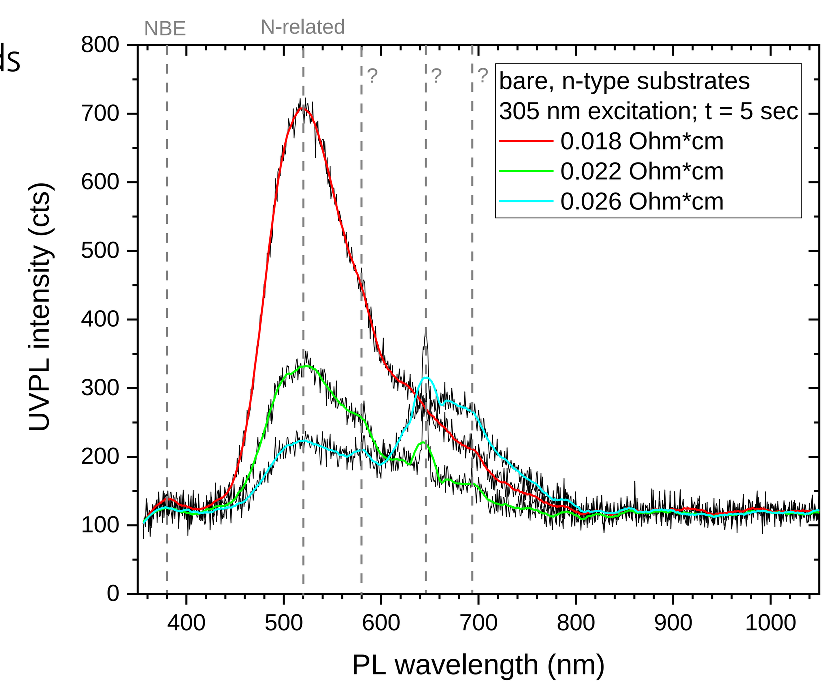
→ Near band edge emission (NBE) at 380 nm almost comparable

→ Strong peak at 520 nm → intensity relates to N doping concentration

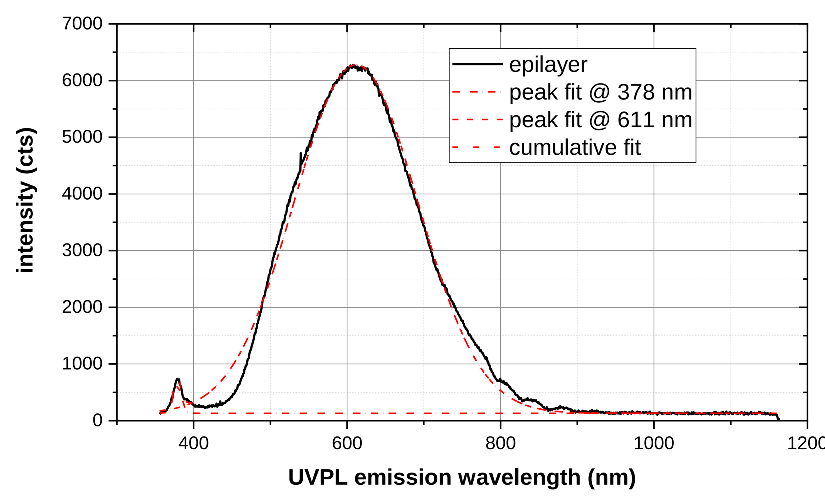
→ Other peaks arise between 550 to 800 nm: typical wavelength range for dislocations and stacking faults [4]

→ Further investigations needed

✓ UVPL spectroscopy useful for n-type substrate characterization

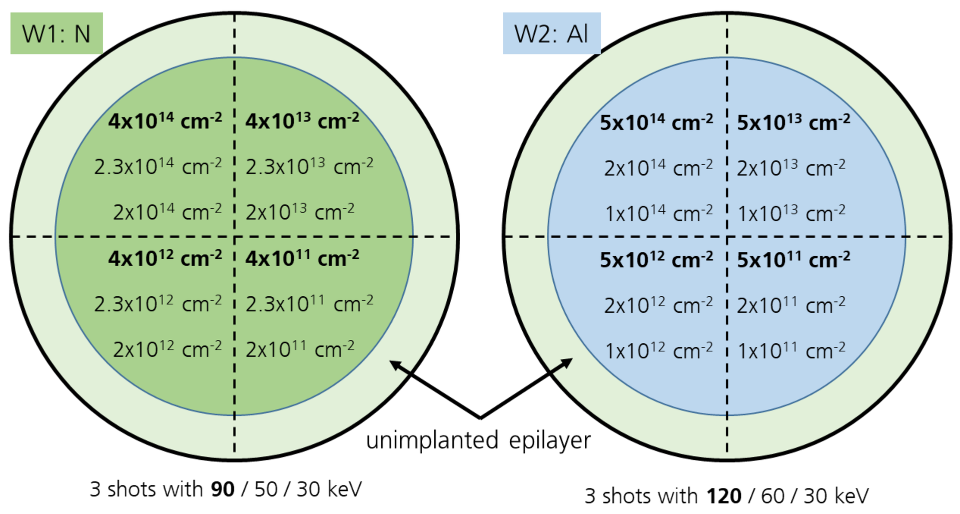


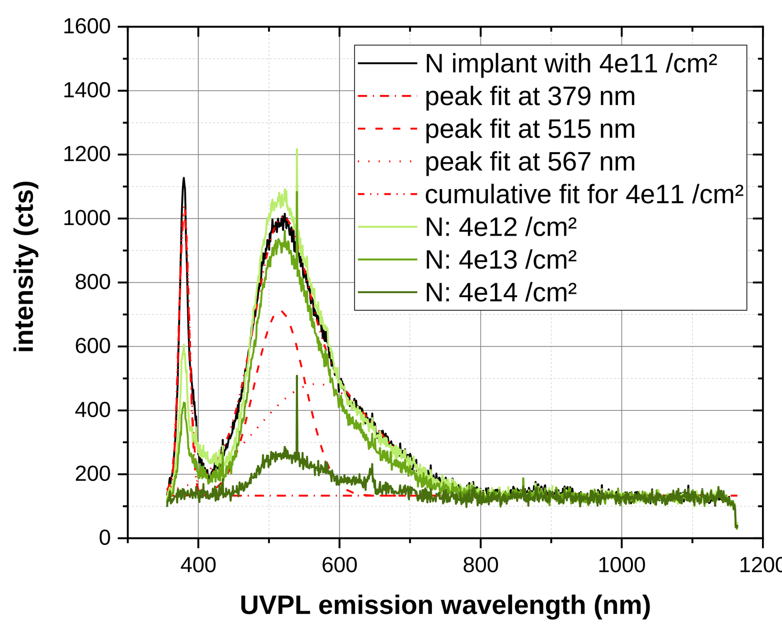
Implantation results on epiwafers

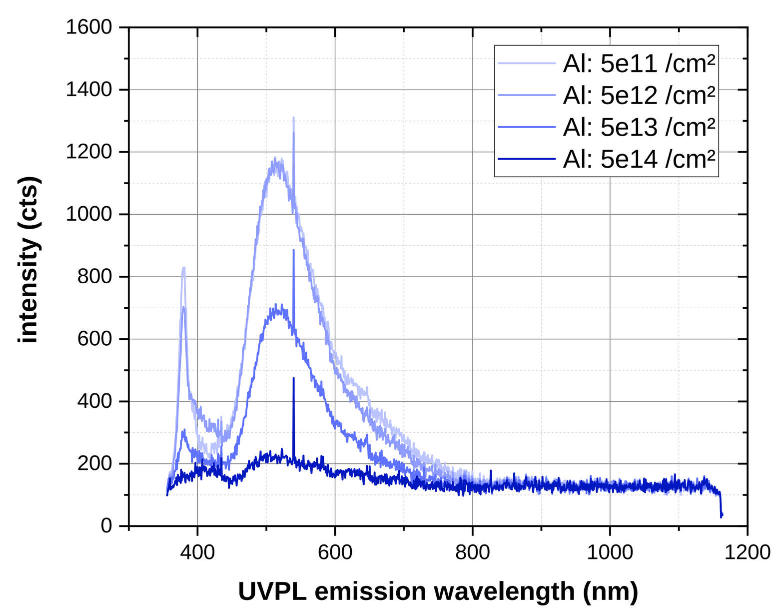


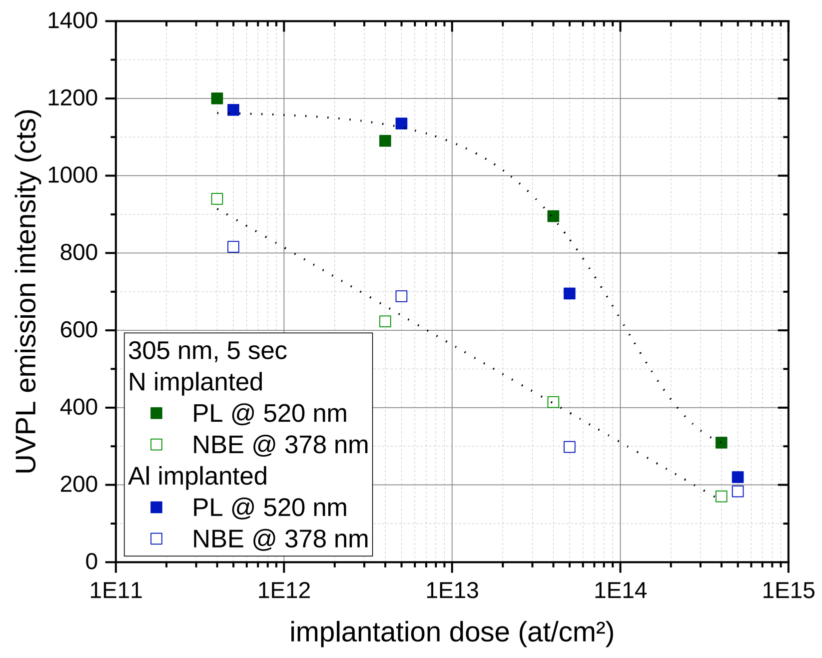
Unimplanted epilayer:

- High peak intensity > 6000 cts
- Near-band edge emission @ 378 nm
- Broad, intense peak @ 611 nm
- Several small peaks at λ > 750 nm









N and Al ion implantation leads to:

- Same peaks for N and Al implantation
- Peak fitting reveals that 520 nm peak consists of peaks at 515 nm and 570 nm

→ Lattice damage (point defects) after ion implantation "visible"

- The larger the implantation dose (N a/o Al), the lower the remaining UVPL intensity (peak / total intensity)

→ Characteristic change in peak/total intensity related to implantation dose

Conclusions

Intego's 2nd generation, multi-channel SiC inspection tool allows for UVPL spectral measurements

✓ Usable for in-line substrate characterization

✓ Characteristic spectra after N and Al ion implantation → high potential for in-line testing

- Further investigations needed for variation of implanted element, doses and subsequent high temperature annealing

References & acknowledgements

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