Dopant profiles of p+ regions in Si wafers with photoluminescence at room temperature

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Background (1/2)

Traditional methods of determining dopant profiles of c-Si

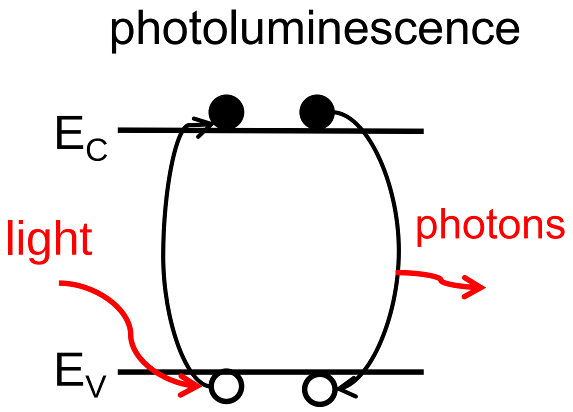
1. ECV (No spatial resolution, destructive)
2. SIMS (Expensive, destructive and slow)

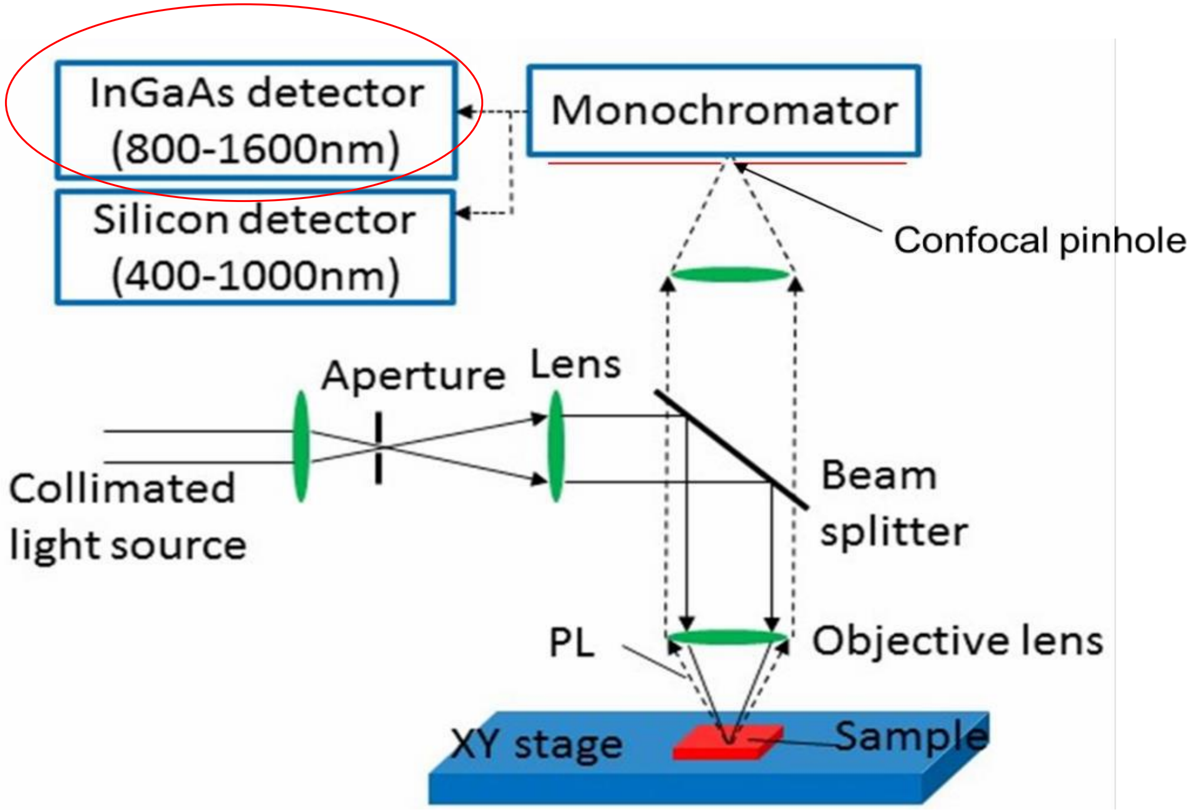
Photoluminescence measurements at room temperature

1. Fast
2. Contactless
3. Non-destructive
4. High spatial resolution (micron scale)

Background (2/2)

Micro-photoluminescence at room temperature





PL spectrum → dopant profiles

Methodology (1/4)

Calibration Samples

- Heavily boron diffused
- Dopant profiles measured with ECV technique

Micro-PL Setup

- 500 nm and 600 nm of excitation wavelengths
- ~1 µm of illumination spot size
- 1.5 mW of on-sample power
- 50x objective lens (numerical aperture of 0.55)

Methodology (2/4)

Gaussian fitting function

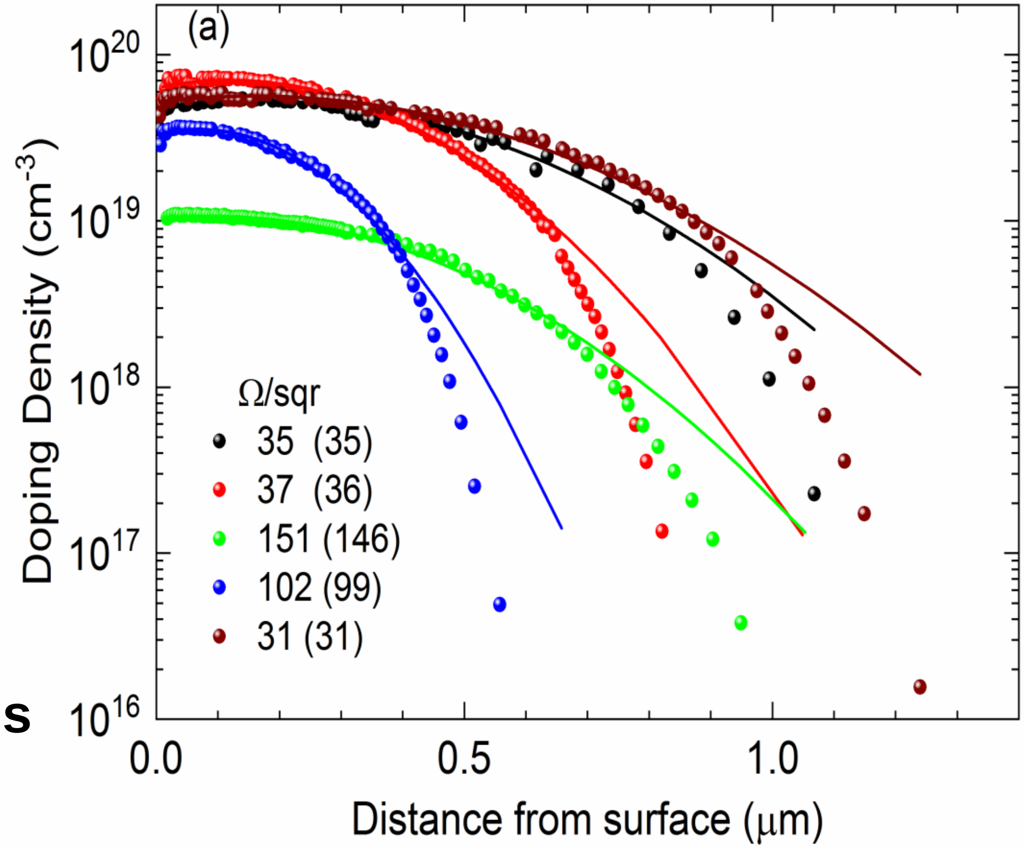
$$N(Z) = N_p \times \exp\left[\frac{-(Z - Z_p)^2}{{Z_f}^2}\right]$$

1. Peak dopant density: N_p
2. Depth factor: Z_f
3. Depth where peak dopant density occurs: Z_p

Parameters → Dopant profiles

Extract N_p, Z_f, Z_p for calibrations

ECV profiles of calibration samples



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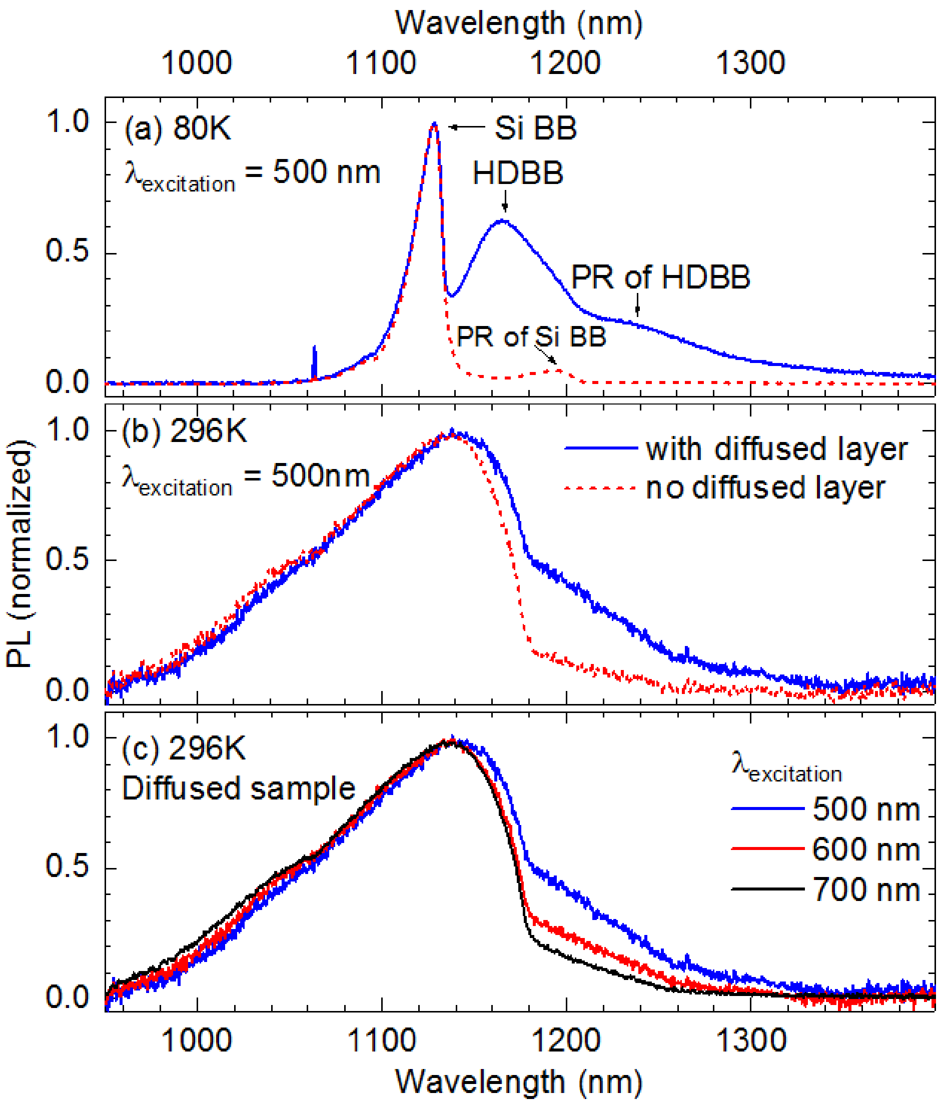
Methodology (3/4)

Principles

At 80 K, two peaks occur due to the diffused layer and the c-Si substrate

Indistinguishable peaks at room temperature

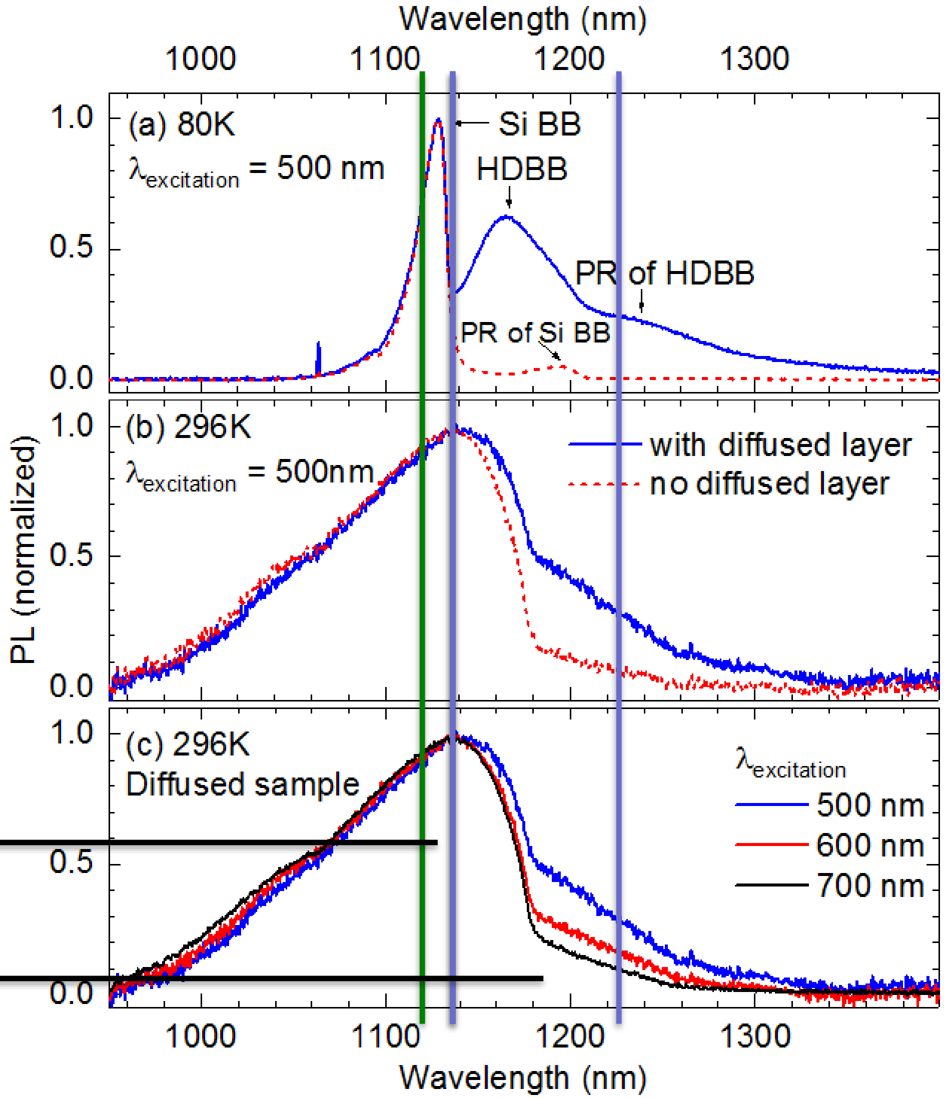
As the excitation wavelength increases, the PL intensity decreases



Methodology (4/4)

PL ratio

Take the ratio between integrated PL intensities of **1135–1250 nm** (diffused layer) and **1115–1135** nm (silicon substrate)



1115 – 1135 nm

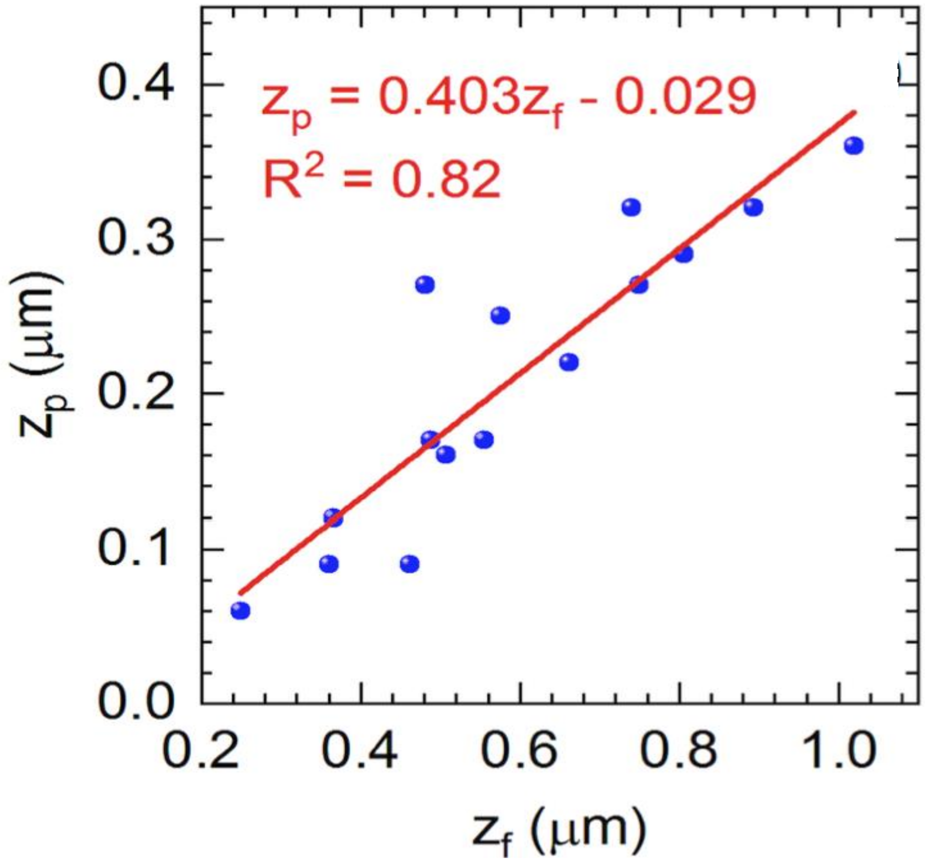
1135 – 1250 nm

Nguyen et al., Solar RRL 1, 1700088, 2017

Correlations (1/2)

Z_p vs Z_f

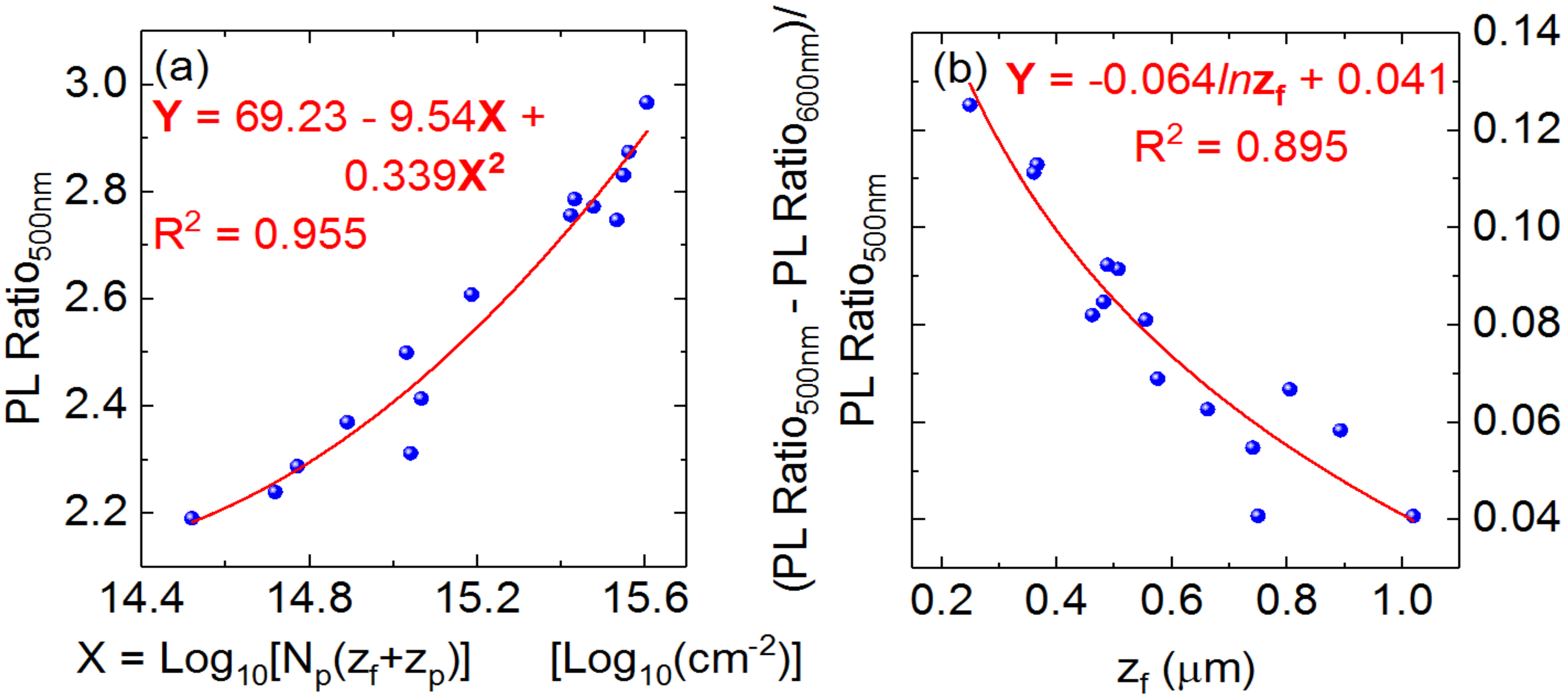
Inherently correlate because the deeper the peak dopant density is, the more dopant atoms diffuse into the silicon substrate.



Correlations (2/2)

{N_p, Z_f, Z_p} vs PL ratio at λ excitation of 500 nm

Z_f vs PL ratio change between λ excitation of 500 nm and 600 nm



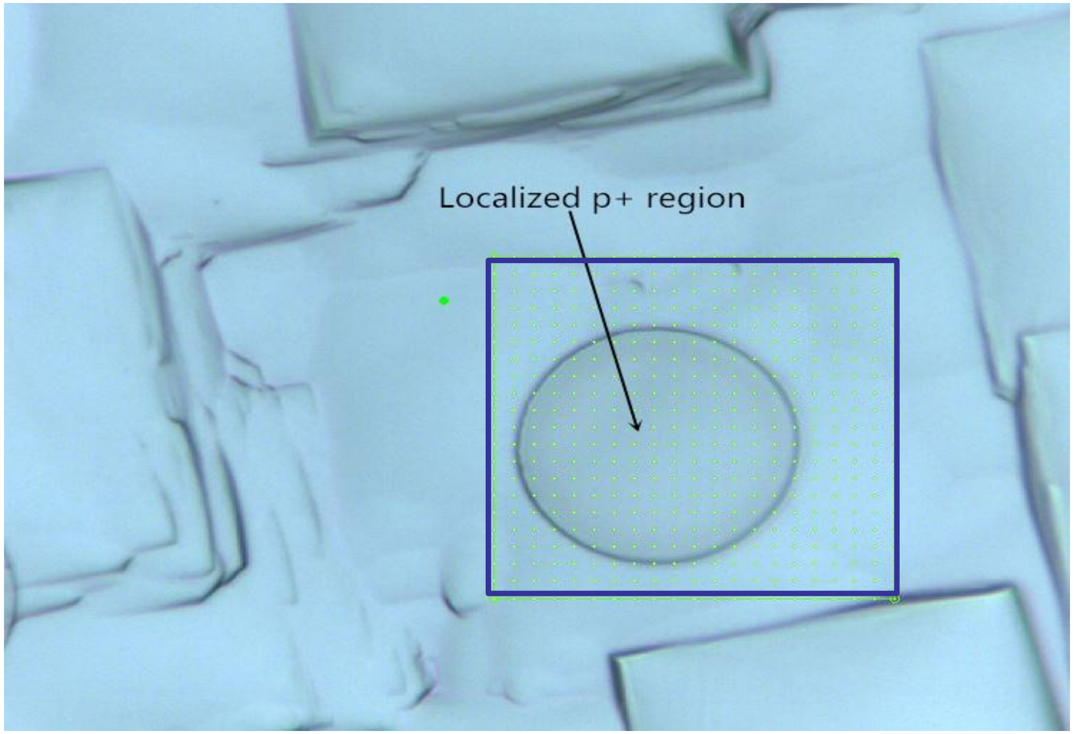
Reconstructing dopant profiles (1/3)

Methodology

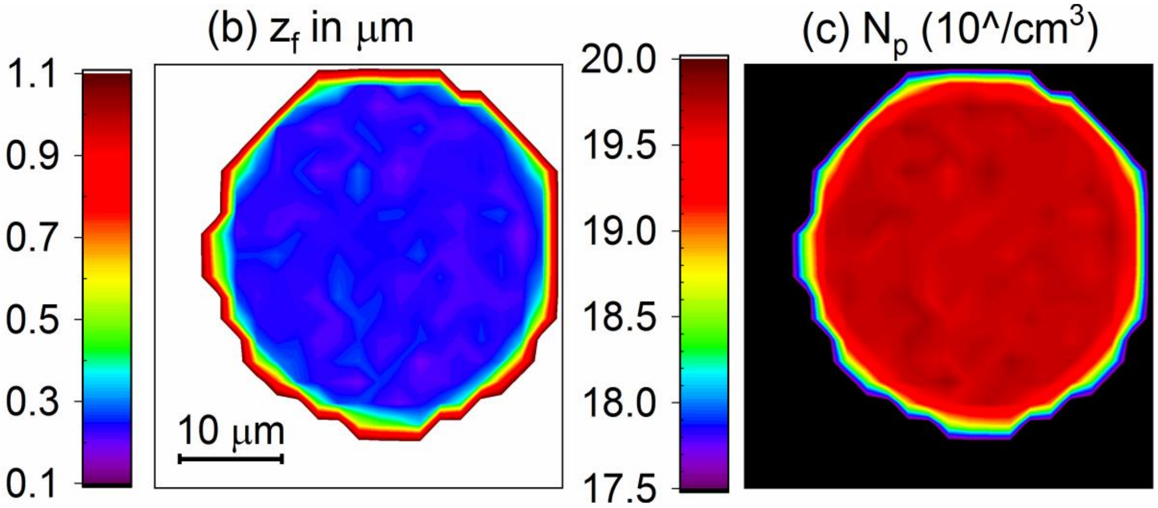
Micro-PL mapping

Sample

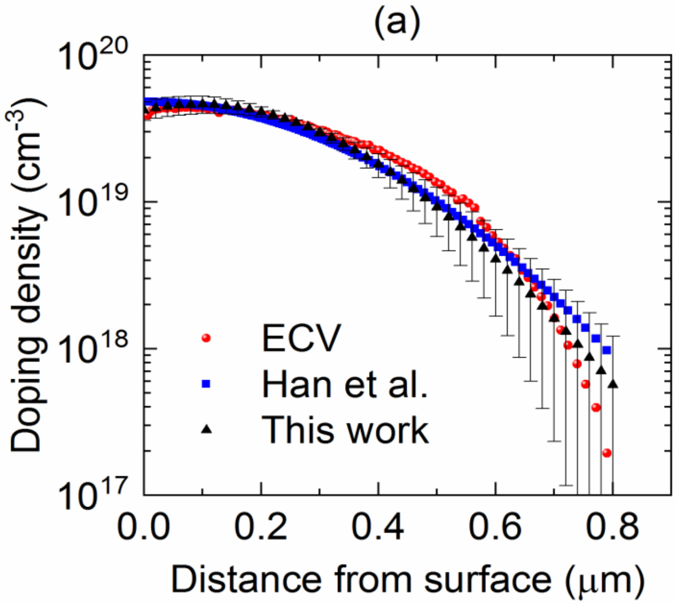
PERL solar cell precursor with localized diffused regions (30 µm in diameter)



Reconstructing dopant profiles (2/3)



Maps of depth factor and peak dopant density



The reconstructed dopant profile agrees with the ECV profile

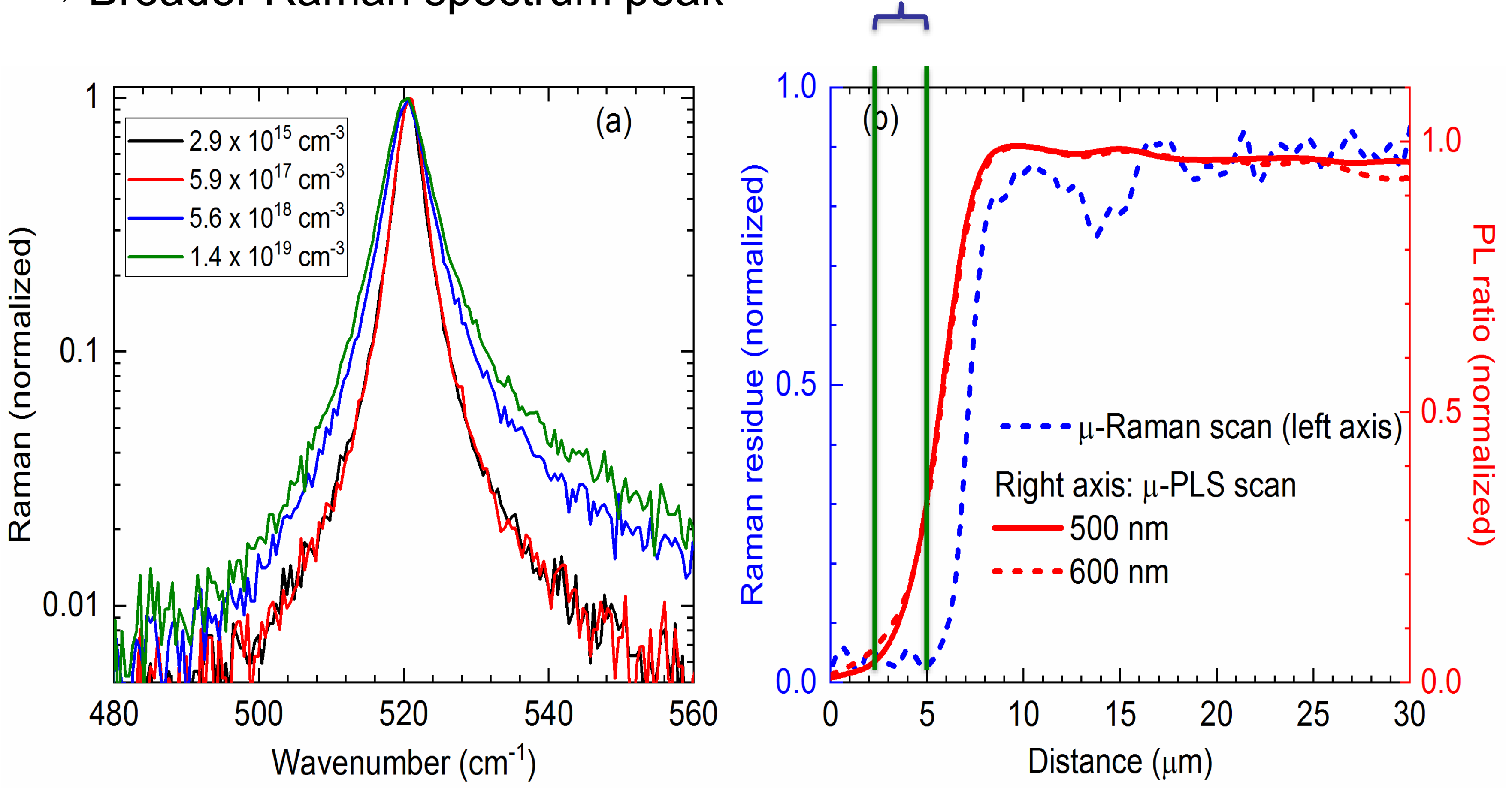
Han et al., IEEE J. Photovolt. 7, 1693-1700, 2017

Reconstructing dopant profiles (3/3)

Micro-Raman mapping

Higher dopant density
→ Broader Raman spectrum peak

~3μm limitation in resolution of μ-PL



Summary

Micro-PL at room temperature (296 K)

- Fast
- Contactless
- Non-destructive
- High spatial resolution

Acknowledgment

ARENA

Australian Government

Australian Renewable
Energy Agency

ACAP

Australian Centre for
Advanced Photovoltaics

ANFF

Australian National
Fabrication Facilities

Q & A

Backup 1

SIMS: secondary ion mass spectroscopy

- Dynamics: 100x micron, sensitivity = 10x higher than ToF SIMS
- Time of Flight (ToF): sub-micron (100x nano)

ECV: electrochemical capacitance-voltage

- Spot size: 4-5 mm in diameter
- Control sample measurement

Fabrication of calibration samples

Float zone 100 Ω.cm n-type silicon wafer

Diffusion steps:

1. Quartz tube-furnace deposition step
2. Wet-chemical etching
3. High-temperature drive-in step

Backup 3

PL Setup

Spectral correction for PL: Halogen light source
Supercontinuum NKT laser source (480 – 2000nm)

Raman Setup

CCD Si array detector (400 – 1000nm)
Solid-state 532-nm laser

Backup 4

PERL solar cell: passivated-emitter rear localized diffused solar cell (fabricated from a FZ 5 Ω.cm p-type Si wafer)

PERC: passivated-emitter rear contact

IBC: interdigitated back contact