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

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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)
Micro-photoluminescence at room temperature

PL spectrum $\rightarrow$ dopant profiles
Calibration Samples

➢ Heavy 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)
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
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.
PL ratio

Take the ratio between integrated PL intensities of $1135 - 1250$ nm (diffused layer) and $1115 - 1135$ nm (silicon substrate).
$Z_p \text{ vs } Z_f$

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

\[ z_p = 0.403z_f - 0.029 \]
\[ R^2 = 0.82 \]
Correlations (2/2)

\{N_p, Z_f, Z_p\} vs PL ratio at $\lambda$ excitation of 500 nm

\[ Y = 69.23 - 9.54X + 0.339X^2 \]
\[ R^2 = 0.955 \]

$Z_f$ vs PL ratio change between $\lambda$ excitation of 500 nm and 600 nm

\[ Y = -0.064\ln z_f + 0.041 \]
\[ R^2 = 0.895 \]
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
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

AREN

Australian Government
Australian Renewable Energy Agency

ACAP

Australian Centre for Advanced Photovoltaics

ANFF

Australian National Fabrication Facilities
Q & A
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
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
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