Cross-cutting recombination metrology for expediting V_{OC} engineering

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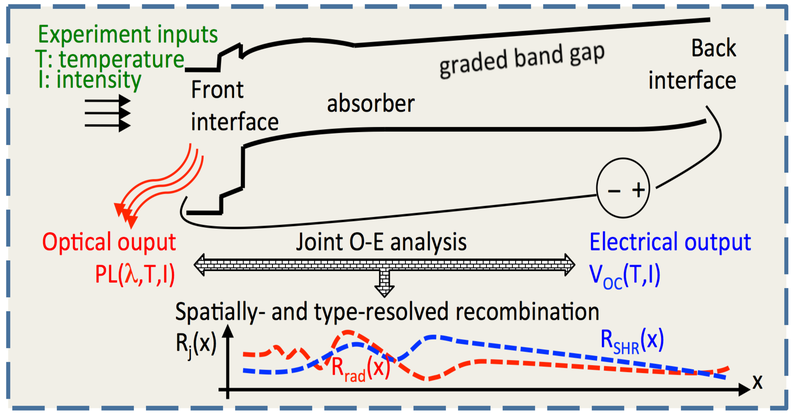
Overview

Technology Addressed: **Topic area 3: Pushing the limits of established PV technologies**

Motivation

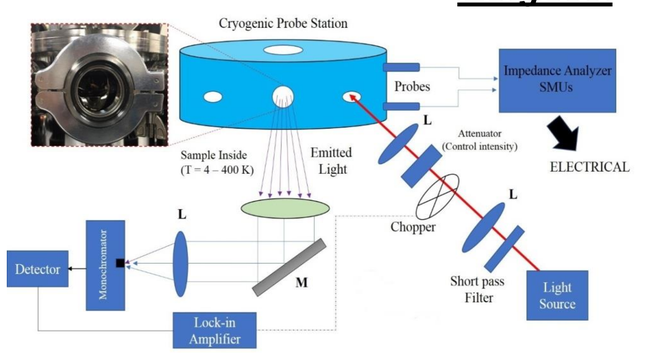
• Voc engineering is only as good as the metrology employed whereas a metrology is only as good as the metrics it uses. State-of-the-art metrologies use 3rd-level metrics, e.g., saturation current density J_0 and carrier lifetime τ. These single lumped parameters cannot describe the ***spatially distributed and non-uniform*** recombination in TFPV, which calls for the 4th-level metric of spatially- and type-resolved recombination $R_j(x)$.



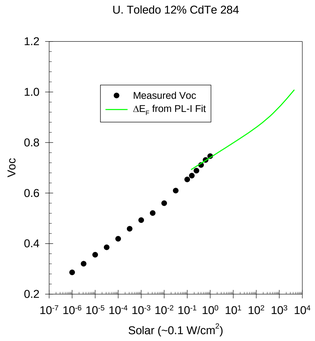
Impact

- Advance the state-of-the-art of recombination metrology
- Enable metrology-guided V_{OC} engineering for TFPV
- Catalyze the advancement of Voc and materially improve module performance, manufacturability, and reliability towards the $0.06/kWh SunShot goal.

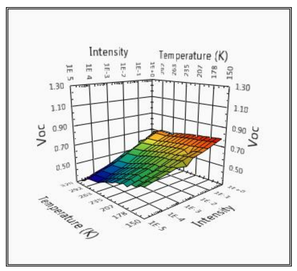
Progress



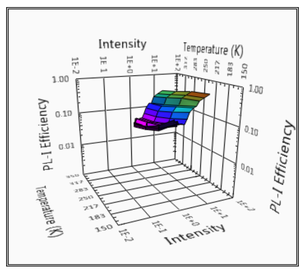
Electrical and optical measurement setup at Texas State University



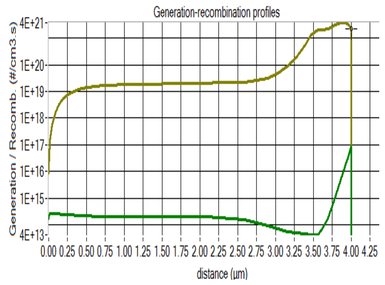
Extraction of Fermi level splitting from PLI



Voc(T,I) data from a CdTe device



PL(T,I) data from a CdTe device

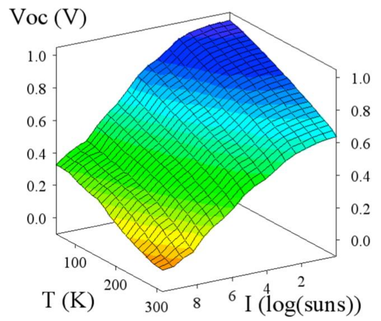


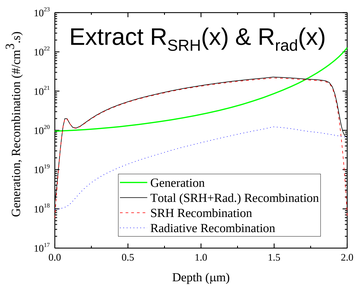
$R_{SRH}(x)$ and $R_{rad}(x)$ extracted for the idea scenario

Technical Approaches

Electrical Char. Voc(T,I):
$R_{SRH}(x)$ + $R_{rad}(x)$

Predecessors:
Voc(T), Suns-Voc, Voc(T,I)

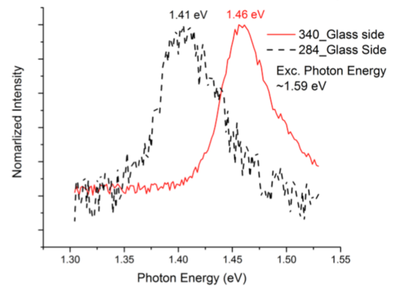




Analysis @ Voc Generation= Recombination

Optical Char. PL(λ,T,I):
R_{rad} (x) only

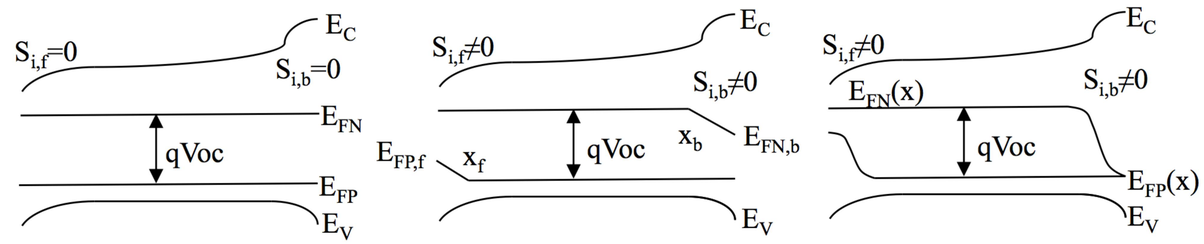
Predecessors:
Conventional PL(T,I)
Generalized Planck's equation



Innovative Aspect

We develop a transformative metrology based on the 4th-level metric – the spatially and type-resolved recombination rate $R_j(x)$. This metrology is built upon joint electrical-optical analysis that simultaneously solves the SRH and radiative recombination.

Future work



Year 1 objectives

Extract $R_{rad}(x)$ and $R_{SRH}(x)$ profiles with:

- spatial resolution dx<50 nm;
- dynamic range $R_{SRH,max}/R_{SRH,min}$>10 for the approximate scenario in thin-film PV devices;
- calibration with J_0 method to within a factor of 3 in Si devices.

Future Work

•Proposed work is to develop the $R_j(x)$ metrology for TFPV
1)Develop a $R_j(x)$ metrology for the approximate scenario for TFPV and validate with Si
2)Develop a $R_j(x)$ metrology for exact-solution scenario and use it to guide Voc improvement for industrial partners
3)Develop a rapid $R_j(x)$ metrology for module manufacturing

SunShot U.S. Department of Energy
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