Demonstrating Band Tail Voltage Limitations in CZTSSe (PV-1)

A joint India-U.S. research consortium funded under the *Joint Clean Energy Research & Development Center (JCERDC)*

Scientific Achievement:

For the first time, we clearly demonstrate that band-tail defects in CZTSSe result in reduced carrier collection at forward bias and V_{OC} limitations through voltage-dependent external quantum efficiency (EQE) analyses.

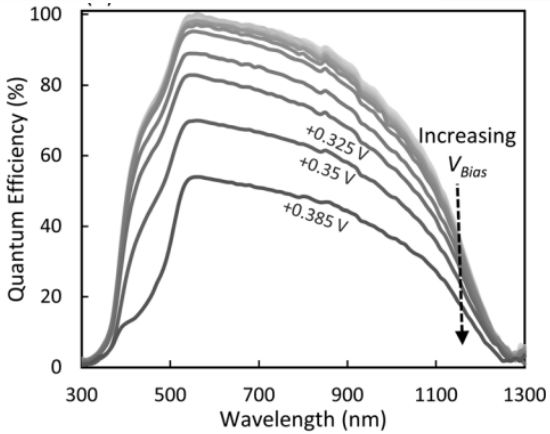
Significance and Impact:

Currently, there is no consensus on why CZTSSe devices suffer from low V_{OC}. Through detailed analyses, we show band-tail-state-limited recombination describes voltage-dependent collection limitations, whereas other proposed models such as space-charge and interface-limited recombination do not. This suggests band-tail states must be reduced or a different absorb material will be needed to produce high-efficiency solar cells.

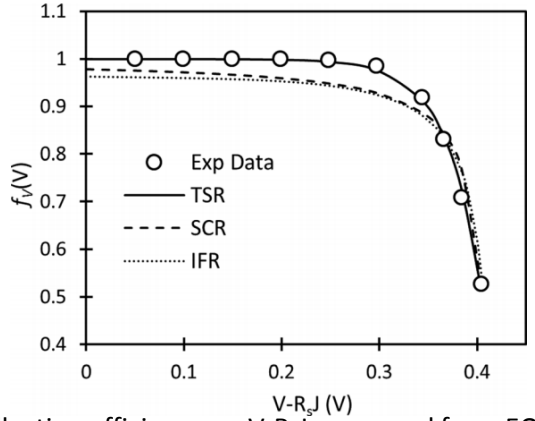
Research Details:

Using a 9.3% CZTSSe device fabricated from nanocrystal ink, reverse and forward bias voltage-dependent EQE was performed and analyzed:

- Voltage-dependent collection was separated from diffusion-limited collection. An analyses method is demonstrated to separate the absorption coefficient, diffusion length, and mobility as a function of the back-surface recombination.
- The voltage-dependent collection is shown to be limited by a derived band-tail-state recombination (TSR) model, as oppose to existing space-charge (SCR) and interface-limited (IFR) recombination models.



Voltage-dependent IQE data for CZTSSe from -1 V to +0.385 V.



Collection efficiency vs. V-R_SJ measured from EQE data (data points) and best fit for various V_{OC} limited models.

Publication: C.J. Hages, N.J. Carter, R. Agrawal, Generalized quantum efficiency analysis for non-ideal solar cells: Case of $Cu_2ZnSnSe_4$, J. Appl. Phys. **119**, 014505 (2016).

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