

Moving beyond the 80-year-old solar cell equation

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(a) Simulated dark current densities at different mobilities with 22 of 10^{10} cm³/s. (b) Normalized dark current densities relative to the idealized expected dark current density in the limit of high mobilities. Credit: *PRX Energy* (2024). DOI: 10.1103/PRXEnergy.3.023008

Physicists from Swansea University and Åbo Akademi University have made a significant breakthrough in solar cell technology by developing a new analytical model that improves the understanding and efficiency of thin-film photovoltaic (PV) devices.

For nearly eight decades, the so-called Shockley diode equation has explained how current flows through solar cells; the <u>electrical current</u>



that powers up your home or charges the battery bank. However, the new study challenges this traditional understanding for a specific class of nextgeneration solar cells, namely: thin-film solar cells

These thin-film solar cells, made of flexible, low-cost materials have had limited efficiency due to factors that the existing analytical models couldn't fully explain.

The <u>new study</u>, published in *PRX Energy*, sheds light on how these solar cells achieve optimal efficiency. It reveals a critical balance between collecting the electricity generated by light and minimizing losses due to <u>recombination</u>, where electrical charges cancel each other out.

"Our findings provide key insights into the mechanisms driving and limiting charge collection, and ultimately the power-conversion efficiency, in low-mobility PV devices," said the lead author, Dr. Oskar Sandberg of Åbo Akademi University, Finland.

Previous analytical models for these solar cells had a <u>blind spot</u>: "injected carriers"—charges entering the <u>device</u> from the contacts. These carriers significantly impact recombination and limited efficiency.

"The traditional models just weren't capturing the whole picture, especially for these thin-film cells with low-mobility semiconductors," explained the principal investigator, Associate Professor Ardalan Armin of Swansea University.

"Our new study addresses this gap by introducing a new diode equation specifically tailored to account for these crucial injected carriers and their recombination with those photogenerated."

"The recombination between injected charges and photogenerated ones is not a huge problem in traditional solar cells such as silicon PV which



is hundreds of times thicker than next generation thin film PV such as <u>organic solar cells</u>," Dr. Sandberg added.

Associate Professor Armin said, "One of the brightest theoretical physicists of all times, Wolfgang Pauli once said 'God made the bulk; the surface was the work of the devil.' As thin film solar cells have much bigger interfacial regions per bulk than traditional silicon; no wonder why they get affected more drastically by 'the work of the devil'—that is recombination of precious photogenerated charges with injected ones near the interface."

This new <u>model</u> offers a new framework for designing more efficient thin solar cells and photodetectors, optimizing existing devices, and analyzing material properties. It can also aid in training machines used for device optimization marking a significant step forward in the development of next-generation thin-film solar cells.

More information: Oskar J. Sandberg et al, Diode Equation for Sandwich-Type Thin-Film Photovoltaic Devices Limited by Bimolecular Recombination, *PRX Energy* (2024). <u>DOI:</u> <u>10.1103/PRXEnergy.3.023008</u>

Provided by Swansea University

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