NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Technique Reveals Critical Physics in Deep Regions of Solar Cells

Highlights in Research & Development

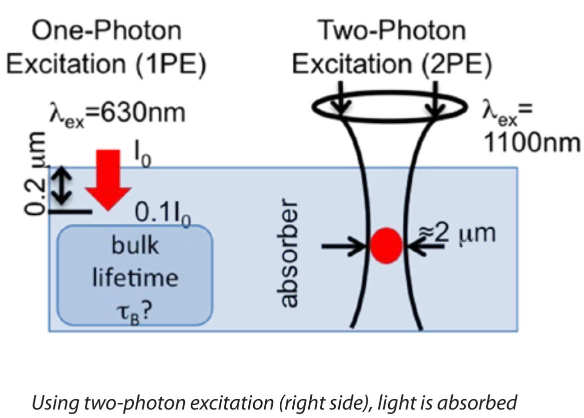
NREL's improved time-resolved photoluminescence method measures minority-carrier lifetime deep within photovoltaic samples to help develop more efficient solar cells.

When developing a solar photovoltaic (PV) cell, designers benefit from having tools that can characterize bulk properties of samples. For measuring minority-carrier lifetime, analysis tools such as time-resolved photoluminescence (TRPL) are available. Unfortunately, methods that use above-bandgap laser excitation are dominated by surface effects because of the very strong absorption and very shallow penetration depth of above-bandgap excitation. Therefore, the near-surface region of the sample can be examined, but the bulk properties are usually dominated by the effects of the surface.

To create a technique that can characterize bulk properties of samples with large surface recombination velocities, the National Renewable Energy Laboratory (NREL) developed a new TRPL analysis method—one that can determine minority-carrier lifetime in the bulk of semiconductor absorbers. The technique is based on sub-bandgap excitation—or two-photon excitation (2PE).

Scientists compared one-photon excitation and 2PE TRPL data for single-crystal and polycrystalline CdTe. The comparison showed that for single-crystal CdTe, minority-carrier lifetime could be determined even if surface recombination velocity was greater than 10^5 centimeters per second. NREL's two-photon excitation TRPL measurements indicated that radiative lifetime in undoped CdTe is much greater than 66 nanoseconds.

The 2PE TRPL method allows selective lifetime determination at the surface or in the bulk of semiconductor absorbers—and assessing the minority-carrier lifetime is critical to developing efficient PV devices.



Using two-photon excitation (right side), light is absorbed in the laser-beam focus region, which can be either at the sample surface or in the bulk.

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Reference: Kuciauskas, D.; Kanevce, A.; Burst, J.M.; Duenow, J.N.; Dhere, R.; Albin, D.S.; Levi, D.H.; Ahrenkiel, R.K. (2013). "Minority carrier lifetime analysis in the bulk of thin-film absorbers using subbandgap (two-photon) excitation." *IEEE Journal of Photovoltaics* (3:4); pp. 1319–1324.

Key Research Results

Achievement

NREL developed a characterization technique based on sub-bandgap (two-photon) excitation, and compared one- and two-photon excitation data for single-crystal and polycrystalline CdTe thin films.

Key Result

For single-crystal CdTe, minority-carrier lifetime could be determined even if surface recombination velocity was very high. Two-photon excitation TRPL measurements indicate that radiative lifetime in undoped CdTe is much greater than 66 nanoseconds.

Potential Impact

Minority-carrier lifetime can be determined at the surface or in the bulk of semiconductor absorbers, which is helpful in developing efficient PV devices.

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

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