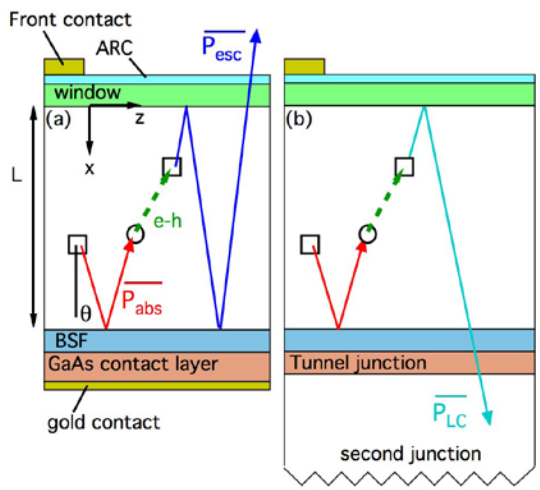
NATIONAL RENEWABLE ENERGY LABORATORY

Better Internal Optics Can Improve III-V Solar Cell Performance

Highlights in Science

NREL model that calculates external luminescent efficiency has potential to enhance performance of solar cells dominated by radiative recombination.

Researchers at the National Renewable Energy Laboratory (NREL) wanted to improve the internal optics of solar cells dominated by radiative recombination to significantly enhance cell performance. Considering real, non-idealized solar cells, the scientists developed a detailed model that calculates the external luminescent efficiency. It does so while accounting for optical properties in each layer that depend on wavelength, parasitic optical and electrical losses, multiple reflections within the cell, and isotropic internal emission.



Cell geometry and luminescent paths for (a) single-junction and (b) tandem solar cells. The solid lines represent the probabilities that an emitted photon escapes (dark blue), is re-absorbed (red), or is luminescently coupled (light blue). The green dashed line represents electron-hole pair diffusion.

Photons that are radiated internally can be emitted directly from the cell. But they can also be re-absorbed with a significant probability if they are confined by good internal reflectors at the front and back of the cell. This so-called "photon recycling" leads to an increase in the equilibrium minority-carrier concentration—and therefore, to increased open-circuit voltage (V_{OC}).

In multijunction cells, the internal luminescence from a particular junction can also be coupled into a lower-bandgap junction. There, it generates photocurrent in addition to the externally generated photocurrent, and can boost the overall performance of the tandem cell.

The calculation of external luminescent efficiency from the NREL model leads to a V_{OC} value, and NREL data on high-quality III-V cells—specifically, GaAs—agree with the trends in the model as the optics are varied systematically. For multijunction cells, the calculation also leads to the luminescent coupling efficiency. Again, NREL data on GaInP/GaAs tandems also agree with the model trends as the coupling is varied systematically.

NREL's model can be applied to any solar cell where the optical properties of each layer are well characterized, and it can be used to explore a wide phase space of design for single-junction and multijunction solar cells.

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Reference: Steiner, M.A.; Geisz, J.F.; García, I.; Friedman, D.J.; Duda, A.; Olavarria, W.J.; Young, M.; Kuciauskas, D.; Kurtz, S.R. (2013). "Effects of internal luminescence and internal optics on the V_{oc} and J_{sc} of III-V solar cells." *39th IEEE Photovoltaic Specialists Conference*; June 16–21, 2013, Tampa, Florida.

Key Research Results

Achievement

NREL developed a detailed model for non-idealized solar cells that calculates external luminescent efficiency, accounting for various optical properties, parasitic losses, multiple reflections, and internal emission.

Key Result

Open-circuit voltages from NREL model calculations agree with data on high-quality GaAs cells as the optics are varied. Calculated luminescent coupling efficiencies in multijunction cells also agree with GaInP/GaAs tandem data as the coupling is varied.

Potential Impact

The NREL model is applicable to any solar cell with layers having well-characterized optical properties and can help explore various designs for single-junction and multijunction cells.

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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