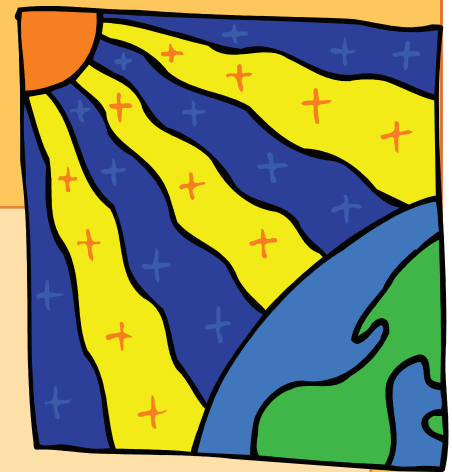
Math Matters

Apply It.

The math behind... Solar Cell Design



Technical terms used:

electrode, exciton, electrodynamics, Maxwell's equations, finite difference time domain numerical method

Uses and applications:

Carbon-based solar cells have much lower materials and manufacturing costs than the alternative. However, their energy conversion efficiency is only about 8%, which is poor compared to a rate of about 40% for other, more expensive solar devices. If the efficiency can be improved, the use of carbon-based solar power can be greatly increased, more cheaply and innovatively.

How it works:

There are four basic parts to a carbon-based solar cell. On top there is a clear electrode for light to pass through. The bottom is also an electrode; this creates an electric field inside the device. The middle consists of two layers, called donor material and acceptor material. The donor material is where light energy is absorbed and converted to charge carriers called excitons. Some excitons may travel to the acceptor material, where they can split into one positively and one negatively charged particle (charges). The charges are attracted to their respective electrode due to the electric field, where they are collected for use.

The efficiency of a solar cell is influenced by many factors, but the physical structure of the device has the strongest effect on its performance. We want to maximize the amount of energy collected. This involves absorption of light energy, conversion of energy to charge carriers, and collection of charges.

Absorption of light energy happens only in the donor material, and is related to the distribution of light throughout the device. Exciton generation is directly dependent on the electrical field distribution, and excitons tend to split mainly at the interface between the donor and acceptor material. All of these factors are affected by the physical structure of the device; therefore, the design of the solar cell has the largest impact on its efficiency.

To optimize a solar cell, we need to calculate the electrical field distribution inside the device. In the study of electrodynamics, the electrical field is described by Maxwell's equations. A mathematician can use a computer simulation to send an electromagnetic wave through the proposed device and measure the results. These results are plugged into Maxwell's equations, which are solved using a Finite Difference Time Domain numerical method. The results indicate the efficiency of the solar cell, which are used to optimize the design.

Interesting fact:

Because of the materials used, carbon-based solar cells can be manufactured on low-cost, flexible sheets. These can be utilized to cover any structure and be replaced cheaply and easily if damaged. In addition, the sheets could easily be colored and patterned for aesthetics.

References:

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Second place, *Math Matters, Apply it!* contest, February 2014