Title

Berkeley Lab Sheds Light on Improving Solar Cell Efficiency

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Typical manufacturing methods produce solar cells with an efficiency of 12-15%; and 14% efficiency is the bare minimum for achieving a profit. In work performed at the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley, CA, 510-486-5771) - a US Department of Energy national laboratory that conducts unclassified scientific research and is managed by the University of California - scientist Scott McHugo has obtained keen insights into the impaired performance of solar cells manufactured from polycrystalline silicon.

The solar cell market is potentially vast, according to Berkeley Lab. Lightweight solar panels are highly beneficial for providing electrical power to remote locations in developing nations, since there is no need to build transmission lines or truck-in generator fuel. Moreover, industrial nations confronted with diminishing resources have active programs aimed at producing improved, less expensive solar cells.

"In a solar cell, there is a junction between p-type silicon and an n-type layer, such as diffused-in phosphorous," explained McHugo, who is now with Berkeley Lab's Accelerator and Fusion Research Division. "When sunlight is absorbed, it frees electrons, which start migrating in a random-walk fashion toward that junction. If the electrons make it to the junction; they contribute to the cell's output of electric current. Often, however, before they reach the junction, they recombine at specific sites in the crystal" (and, therefore, cannot contribute to current output).

McHugo scrutinized a map of a silicon wafer in which sites of high recombination appeared as dark regions. Previously, researchers had shown that such phenomena occurred not primarily at grain boundaries in the polycrystalline material, as might be expected, but more often at dislocations in the crystal. However, the dislocations themselves were not the problem. Using a unique heat treatment technique, McHugo performed electrical measurements to investigate the material at the dislocations. He was purportedly the first to show that they were "decorated" with iron.

"When I came to Berkeley Lab as a postdoc, I was able to employ a technique using x-rays at the Advanced Light Source (ALS), which is orders of magnitude better than what can be done with standard techniques that use an electron beam," stated McHugo, who worked with the x-ray fluorescence microprobe beamline built and operated at the ALS synchrotron radiation facility by the Center for X-Ray Optics, part of the Lab's Materials Sciences Division. The one-micron spot of hard x-rays produced by the beamline allowed McHugo to align the resulting x-ray fluorescence spectra with maps of the defects made with a scanning electron microscope, thereby comparing defects and impurities directly. "That's when I found that not only iron but copper and nickel were also concentrated in these high-recombination sites."

Metal from valves, couplings, and other machinery can contaminate solar cells, as they are grown from molten silicon, cut into wafers, and finished by adding dopants and attaching contacts. In an industry with a narrow profit margin, where inexpensive polycrystalline silicon must be used instead of easy-to-purify but considerably more costly single-crystal silicon, maintaining rigorous cleanliness at every step of the process would be too expensive.

However, cleanliness is not the only variable involved in purifying solar cells. Doping with phosphorus, as well as sintering aluminum contacts onto the wafers (heating them almost to the melting state) facilitate "gettering" the silicon - chemically removing the contaminants. Such standard processes could be optimized by adjusting time and temperature. McHugo has shown that briefly annealing the finished solar cell at high temperatures (500 °C to 800 °C) is sufficient to remove copper and nickel precipitates of moderate size, although dissolved copper and nickel or very small precipitates of such metals may remain.

McHugo is presently investigating the specific techniques that are required to remove stubborn iron impurities from their hiding places in crystal defects. "We are looking at a two-step process," McHugo stated; "first, subjecting the wafer to very high temperatures (up to perhaps 1000 °C), and then lowering the temperature to finish the proper processing of the solar cell."

McHugo - who has collaborated with American and Japanese manufacturers (such as ASE America), and is currently working with a consortium (DIXSI) of government, university, and industry researchers in Germany - noted, "If a dirty manufacturing run produces solar cells of 12% efficiency, and a manufacturer can make money at 15%, think how profitable cells of 18% would be. Investigators have already achieved 18% in the lab with small samples; the challenge is to do it on the production line with full-sized solar cell wafers. It's a goal we are close to achieving."

US demand for solar (or photovoltaic) cells is projected to increase at an 11.5% annual rate to reach $125 million in 2000, from $65 million in 1994, according to The Freedonia Group, Inc.'s (Cleveland, OH, 216-921-6800) Flat Screen Displays & Other Optoelectronics study (#728).

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