Carbon-Nanotube Conductive Layers for Thin-Film Solar Cells

Energy-conversion efficiencies could be increased.

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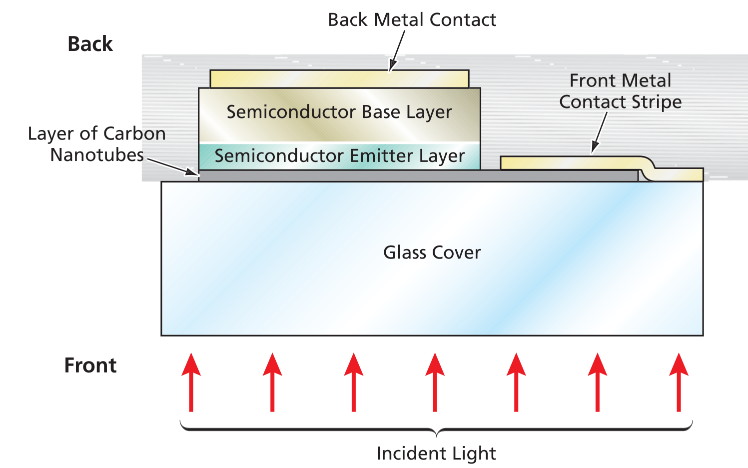
Thin, transparent layers comprising mats of carbon nanotubes have been proposed for providing lateral (that is, in-plane) electrical conductivities for collecting electric currents from the front surfaces of the emitter layers of thin-film solar photovoltaic cells. Traditionally, thin, semitransparent films of other electrically conductive materials (usually, indium tin oxide, zinc oxide, or cadmium sulfide) have been used for this purpose. As in the cases of the traditional semitransparent conductive films, the currents collected by the nanotube layers would, in turn, be further collected by front metal contact stripes.

Depending on details of a specific solar-cell design, the layer of carbon nanotubes would be deposited in addition to, or instead of, a semitransparent layer of one of these traditional conductive materials (see figure). The proposal is expected to afford the following advantages:

- The electrical conductivity of the carbon-nanotube layer would exceed that of the corresponding semitransparent layer of traditional electrically conductive material.
- The greater electrical conductivity of the carbon-nanotube layer would make it possible to retain adequate lateral electrical conductivity while reducing the thickness of, or eliminating entirely, the traditional semitransparent conductive layer. As a consequence of thinning or elimination of the traditional semitransparent conductive layer, less light would be absorbed, so that more of the incident light would be available for photovoltaic conversion.
- The greater electrical conductivity of the carbon-nanotube layer would make it possible to increase the distance between front metal contact stripes, in addition to (or instead of) thinning or eliminating the layer of traditional semitransparent conductive material. Consequently, the fraction of solar-cell area shadowed by front metal contact stripes would be reduced — again, making more of the incident light available for photovoltaic conversion.



A **Layer of Carbon Nanotubes** — instead of a traditional layer of indium tin oxide, zinc oxide, or cadmium sulfide — would conduct electric current from the front surface of the emitter layer to the front metal contact stripe.

- The electrical conductivities of individual carbon nanotubes can be so high that the mat of carbon nanotubes could be made sparse enough to be adequately transparent while affording adequate lateral electrical conductivity of the mat as a whole. The thickness of the nanotube layer would be chosen so that the layer would contribute significant lateral electrical conductivity, yet would be as nearly transparent as possible to incident light. A typical thickness for satisfying these competing requirements is expected to lie between 50 and 100 nm. The optimum thickness must be calculated by comparing the lateral electrical conductivity, the distance between front metal stripes, and the amount of light lost by absorption in the nanotube layer.

The diameters of carbon nanotubes — of the order of 10 nm — are smaller than the typical wavelengths of the light absorbed by solar cells. Carbon nanotubes can be made in either highly conductive "metallic" form or in a semiconducting form; for the present purpose, the highly conductive form would be best. Most preferable would be single-wall carbon nanotubes, which have the smallest diameters. It would also be preferable to align all the carbon nanotubes parallel to the desired direction of conduction, but such alignment may be difficult to achieve at low cost. Even without such alignment, it should be possible to attain adequate lateral electrical conductivity.

During fabrication, the layer of carbon nanotubes could be deposited (e.g., from a liquid suspension) onto either the front surface of the solar-cell emitter layer or on the glass cover prior to attachment of the cover by use of an adhesive. In either case the carbon nanotubes would adhere to the deposition surface by means of van der Waals forces.

This work was done by Geoffrey A. Landis of **Glenn Research Center**. *Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17562/3-1.