Low-cost quantum dot windows could power a solar future

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Solar cells are normally installed in the form of rooftop modules. Rooftop solar panels, however, suffer from a major roadblock on the path to a renewable energy future for one simple reason: rooftop space is severely limited in large, densely populated cities, such as New York or London.

On the other hand, modern skyscrapers feature enormous amounts of window space. Newly developed luminescent solar concentrators can help turn these large glass facades into power generation units. Window-based collectors have the potential to far exceed the output of rooftop panels in major cities as a result of the larger surface area.

To transform a window into a luminescent solar concentrator, a team at Los Alamos National Laboratory has developed a technique for depositing a layer of a fluorescent material on the glass surface.

The layer absorbs sunlight and re-emits longer-wavelength photons that are trapped in the window glass and guided to the edges, where they are collected by solar cells integrated into a window frame. The window in this scheme acts as a large-area sunlight collector. When coupled to photovoltaics that convert light into electrical current, it can become a source of electricity, much like common rooftop solar panels.

To accomplish this, the team is developing sunlight collectors based on quantum dots, nanoscale structures that can be customized to have properties desired for a specific application. They can be tuned to emit light of different colors, they are stable under long-term light exposure, and they are comparatively cheap and easy to manufacture.

Experiments demonstrate that large-area luminescent solar collectors performed well under broadband sunlight illumination. In addition, these devices exhibited a color-neutral appearance, much like looking through sunglasses, that is ideally suited for building-integrated solar windows.

The Laboratory team was able to further boost the efficiency of the luminescent solar concentrators by adding a second layer, which turned the devices into tandem sunlight collectors. The top layer is based on cadmium zinc sulfide quantum dots doped with a minute amount of manganese impurities that absorb a higher-energy portion of the solar spectrum. The lower-energy part of sunlight passes through to be absorbed by the bottom layer, which is composed of near-infrared-absorbing copper indium selenide quantum dots. This spectrum-splitting approach considerably increases the overall power output of the two-layer device, and boosts the overall efficiency of the tandem devices compared to standard single-layer luminescent sunlight collectors.

The tandem architecture is especially well suited for applications in double-pane windows, where the two different quantum dot layers can be applied to the inner surfaces of the front and the back panes. This approach could enable a new, interesting class of multifunctional double-glazed solar windows that, in addition to providing heat insulation and a desired degree of shading, will also serve as a source of electricity.

Estimates show that by using optimized quantum-dot solar windows, it should be possible to satisfy at least half the energy needs of a standard office or a household. The amount of generated electricity can be increased further by extending this approach to the entire building envelope and surrounding structures. This can be done, for example, by installing luminescent sunlight collectors in the form of solar sidings or solar fences.

Recent breakthroughs in the area of quantum dot luminescent solar concentrators demonstrate the tremendous potential of this emerging solar energy technology. Due to the low per-square-meter cost of these devices, their use as high-efficiency sunlight collectors may help reduce the cost of solar electricity.

Luminescent sunlight collector technology is a vital element of ongoing efforts toward the realization of net-zero-energy buildings.

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