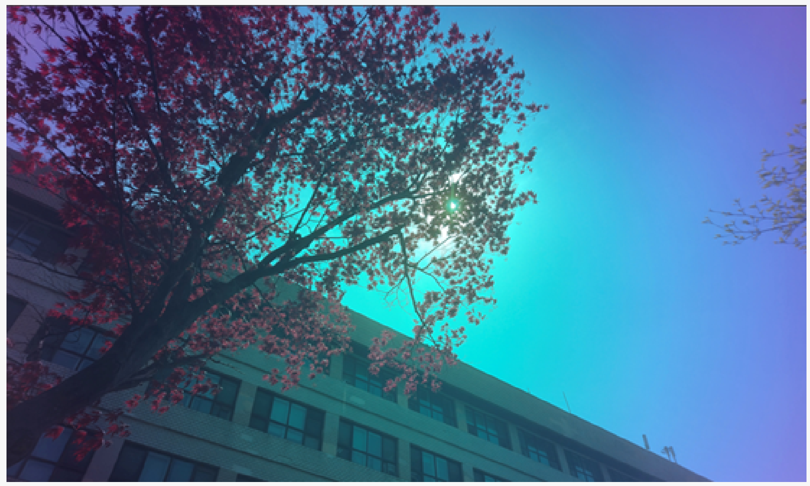
An AI design strategy unlocks full-color tunability in solar windows

SHANNON, CLARE, IRELAND, February 27, 2026 /EINPresswire.com/ -- Announcing a new publication from Opto-Electronic Advances; DOI 10.29026/oea.2026.250218. As cities become taller, denser, and more energy-hungry, integrating solar energy directly into the surfaces of buildings and vehicles provides a powerful and space-efficient solution to the climate crisis.



Real-world image seen thorough a cyan-colored solar window.

Particularly, windows represent a vast but underused opportunity for urban energy harvesting. However, most semitransparent solar technologies today suffer from two key problems: poor color aesthetics and efficiency losses. This limits their acceptance in architecture, automotive design, and consumer electronics. This work addresses this problem with an AI design strategy that unlocks full-color tunability in solar windows using non-metallic, non-absorbing coatings. By merging optical modeling with AI–guided inverse design, the authors of this article created coatings that transform the color of semitransparent perovskite solar cells without compromising energy output. This enables user-defined window colors such as red, green, cyan, magenta, and even gray while increasing power generation by up to 20%.

Specifically, a new design strategy was explored that allows transparent solar cells to display vivid, customizable colors (for example, cyan) without using metal filters that waste light and reduce efficiency. Instead, the color is produced using carefully designed, transparent dielectric coatings, similar to those used in high-quality optical devices. Importantly, these coatings not only improve appearance but also increase the amount of electricity generated, rather than compromising performance. This means that solar windows no longer have to be a trade-off between beauty and function. The colored devices demonstrated here are more visually appealing and up to 20% more efficient than conventional transparent solar cells. The approach also works on both rigid glass and flexible plastic, showing its potential for real-world use in diverse settings. From a broader perspective, this technology could transform how solar energy is integrated into daily life. Buildings could generate power through windows that match architectural designs. Vehicles could incorporate solar surfaces without altering their look. Even wearable electronics and greenhouse panels could benefit from tailored transparency and color control. By making solar technology more adaptable, attractive, and practical, this work supports global efforts toward net-zero cities, sustainable construction, and decentralized clean energy generation. It offers a realistic pathway to expanding renewable energy adoption without forcing compromises in design, comfort, or user experience, an essential step toward carbon-neutral urban environments.

Keywords:
semitransparent device, building-integrated photovoltaic, color engineering, inverse design, active learning, dielectric coating, interference optics

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Prof. Sun-Kyung Kim's group currently explores the use of high-index-contrast dielectric or metal/dielectric hybrid photonic materials for manipulating light absorption, light emission, and thermal radiation across the ultraviolet, visible, infrared, and microwave spectra. In addition, its research includes the realization of optical materials with exceptional dispersions through the concepts of metamaterials and surface plasmons. Prof. Kim's group also has expertise in designing functional photonic materials, fabricating complex photonic structures, and characterizing optical performances, which have been successfully incorporated into diverse light absorption, light emission, and thermal radiation devices. For example, regarding light absorption devices, they demonstrated a three-dimensional Si grating nanowire photovoltaic system that achieved a record power conversion efficiency at the single nanowire level. In terms of light emission devices, they developed strong-diffraction hollow-cavity growth substrates that enabled high-efficiency InGaN/GaN LED devices, surpassing state-of-the-art commercial LED devices. Finally, for thermal radiation devices, they reported directional radiative coolers that amplified side thermal emissions, thereby providing thermal comfort to users of personal optoelectronic devices such as smart phones.
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