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# Feature issue introduction: Optical Devices and Materials for Solar Energy and Solid-state Lighting (PVLED) 2019

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**Abstract:** This special feature issue of *Optics Express* highlights contributions from authors who presented their latest research in the Optical Devices and Materials for Solar Energy and Solid-state Lighting (PVLED) topical meeting of the OSA Advanced Photonics Congress, held in Burlingame, California, from 29 July – August 1, 2019. This feature issue is comprised of nine contributed papers, expanding upon their respective conference proceedings to cover timely research topics applying optics and photonics to solar energy and solid-state lighting.



## 1. Introduction

The 2019 OSA Advanced Photonics Congress [1], held in Burlingame, California, brought together researchers with expertise across several related areas in optics and photonics. Specifically, the co-located OSA topical meetings were: Integrated Photonics Research, Silicon and Nanophotonics; Novel Optical Materials and Applications; Photonic Networks and Devices; Signal Processing in Photonic Communications; and Optical Devices and Materials for Solar Energy and Solid-State Lighting (PVLED). The conference program included a diverse group of keynote, invited, and contributed speakers from around the world who discussed current research trends at the intersection of advanced photonics.

In previous years [2–6], the OSA supported a feature issue following each Congress as a whole, which covered a wide range of topics. For the first time this year, a special issue solely dedicated to Optical Devices and Materials for Solar Energy and Solid-state Lighting (PVLED) has been prepared. This call attracted nine accepted papers that extend on talks given at the congress to further advance specific research questions on the cutting edge of solid state lighting and solar energy technologies. In the following sections, we introduce each paper and provide context for how they fit within the broader PVLED topical meeting themes.

## 2. Solar energy

Solar energy is a field that has over the last several decades transitioned from a relatively niche area into an increasingly mainstream technology. Nonetheless, many opportunities for higher performance remain, and optics is still a key area of research for enabling improvements in efficiencies and performance in novel systems. In this issue, five papers are presented that address some of these challenges. First, Gao and colleagues [7] present their approach to capturing more

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infrared photons in solar via upconversion photoluminescence. They design a diffractive array of aluminum nanopillars to concentrate incoming infrared illumination to enable a 9x enhancement in the generation rate of higher-energy photoluminescent photons. Second, Xuenan Zhao and colleagues [8] study the challenge where tandem organic solar cells deployed in real-world conditions are vulnerable to current mismatch, as solar input angles change with the time of day as well as the seasons. To address this challenge, they design an all-angle tandem organic solar cell. In real-world testing, they find 4.9% relative enhancement of the total energy generated, compared to a system optimized only for normal incidence. Third, Hossain et al. [9] consider challenges in another type of tandem solar cell, the perovskite/crystalline silicon tandem, and determine that current deficiency in the bottom (silicon) cell is a key bottleneck. To mitigate this problem, they design a nanostructured front electrode, and show that it improves transmittance by 7%, current density by 2.9 mA/cm$^2$, and power conversion efficiency up to 10% relative under certain conditions. Fourth, Jäger and colleagues [10] explore the potential for improving photovoltaics at a higher level via bifacial modules designs in the context of a solar field. They develop and share an openly-accessible model to calculate the minimal irradiance onto a PV module, which determines its performance in many scenarios. Finally, Isoda and colleagues [11] examine a slightly different solar energy challenge – namely, minimizing building energy use in temperate climates. Since solar reflection is desired during the summer, whereas solar absorption is preferred during winter, the authors devise an angularly-selective cooling surface that is tailored to maximize the seasonal response through sensitivity to the declination angle of the sun.

## 3. Solid-state lighting and illumination

Solid-state lighting is a field that has also recently transitioned from a more modest size to rapid growth because of improvements in performance and cost. It has potential to substantially reuse power consumption from lighting in a range of application, but improvements in device performance, usage, and the resulting environments are still needed. In this special issue, four approaches to addressing this challenge are presented. First, Si-Yuan Chan and colleagues [12] consider the challenge of creating high-performance UV light emitting diodes (LEDs). While it is possible to create these with zinc oxide (ZnO) from a gallium nitride (GaN)/sapphire base, the photoluminescence and electroluminescence is not always stable or high in performance. Here, they report how ZnO nanoparticles can substantially enhance photoluminescence and electroluminescence in GaN-based UV LEDs. Second, Walter Shin and colleagues [13] also consider the same problem of improving UV LEDs from a slightly different angle, by employing photonic crystals to improve the wall-plug and external quantum efficiency in AlGaN-based LEDs. They find that the light extraction efficiency is enhanced a factor of 2, resulting in a peak wall-plug efficiency of 3.5% and external quantum efficiency of 5.4%. Third, Jin-Young Na and colleagues [14] consider the problem of using these LEDs from lighting applications. Here, they develop a hybrid optical model that allows one to accurately model both the small-scale wave optical behavior of the LED itself, the diffractive elements, as well as the far-field distribution generated by these designs. This allows the authors to report that high-index gratings have potential to integrate with existing and future LEDs to design highly-directional illumination and micro-LED displays. Finally, Abeysekera and colleagues [15] consider the human element of LED usage; namely, the need for uniform illuminance and color uniformity for clarity and consistency. Through the use of a genetic optimization algorithm, the authors find that the color consistency for users can be maintained within a relatively narrow range of values under certain conditions.

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## 4. Outlook: New forums for light, energy and the environment

The next OSA Advanced Photonics Congress [16] will be held in Montreal, Quebec from 13-16 July 2020. Many of the topics initiated in the inaugural 2019 topical meeting on Optical Devices and Materials for Solar Energy and Solid-state Lighting (PVLED) will carry over to this year. Co-located meetings that will join PVLED this year at Advanced Photonics will include Bragg Gratings, Photosensitivity, and Poling in Waveguides and Materials (BGPP), Integrated Photonics Research, Silicon, and Nanophotonics (IPR), Nonlinear Photonics (NP), Novel Optical Materials and Applications (NOMA), Photonics in Switching and Computing (PSC), Photonic Networks and Devices (NETWORKS), Signal Processing in Photonic Communications (SPPCom), and Specialty Optical Fibers (SOF).

The joint feature issue guest co-editors, along with all the Advanced Photonics Congress and topical meeting co-chairs, would like to thank our numerous committee members as well as the OSA professional staff for their support in creating a fantastic scientific program in 2019. We hope to see them all again at another OSA Congress.

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