Editorial

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Photonics for enhanced perovskite optoelectronics

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Metal halide perovskite semiconductors have attracted extensive attention in the past decade for their outstanding optoelectronic properties, such as high defect tolerance, long carrier lifetime and diffusion length, and tunable optical bandgap. In addition, halide perovskites can be easily processed using cost-effective and low-temperature solution fabrication. They have been successfully applied in various high-performance optoelectronic devices, including photovoltaics, lighting, lasers, detectors and so on. This special issue on "*Photonics for enhanced perovskite optoelectronics*" aims to capture some of the most exciting advances in the perovskite optoelectronics field, with special attention paid to discuss how photonic materials and structures hold the promise of enhancing the device performance and promoting high impact applications.

Understanding the fundamental photophysics is crucial to explore strategies of enhancing device performance. The special issue starts with three articles on the ultrafast carrier dynamics of lead halide perovskites. Yu et al. summarize the recent progress on the photoinduced carrier dynamics of perovskite nanocrystals studied by various time-resolved spectroscopic methods to underpin the photophysics for light emitting diodes and solar cells [1]. Liu et al. study the modulation of charge transfer rates from all-inorganic $CsPbBr_3$ perovskite nanocrystals to mesoporous TiO_2 films by using different surface ligands [2]. Heimbrook et al. demonstrate an automated micropipetting synthesis platform to explore the physics of perovskite quantum dots via Bayesian inference of the photoluminescence spectra [3]. In-depth study toward a comprehensive picture of the excited-state dynamics in perovskite materials can provide key knowledge of the device operation mechanism, enlighten the direction for device optimization and stimulate the adventure of new optoelectronic devices.

Perovskite/silicon tandem solar cells hold the promise of achieving greater than 35% practical efficiencies, surpassing the limit of single-junction photovoltaic devices. Tremendous progress in perovskite solar cells (PSCs) have been witnessed in the last decade and close to 30% efficiency has been demonstrated in perovskite/silicon tandem solar cells. However, present perovskite/silicon tandem cells still suffer from optical losses. Jäger et al. discuss the prospects of light management in perovskite/silicon tandem solar cells and illustrate a way to push efficiencies beyond 30% via improved optical designs [4]. Meanwhile, Li et al. provide an overview of current research on perovskite/silicon heterojunction tandems and other tandem configurations [5]. Also, Raja et al. review the photon recycling in state-of-the-art PSCs and propose photonic design strategies to invoke light trapping for exploiting photon recycling in PSCs efficiently [6]. Next, Singh et al. show that careful photonic optimization of the tandem devices is crucial in achieving a higher energy yield under real-world conditions [7]. He et al. study the doping of a bromine-rich molecule as defect passivator to reduce the voltage loss in wide-bandgap perovskite solar cells [8]. Efficiency is not everything for PSCs and long-term stability is required for commercial viability. For this regard, Niu et al. review the exploitation of Dion–Jacobson low-dimensional perovskites in photovoltaic applications to improve environmental stability [9].

In addition to the photovoltaic applications, halide perovskites are promising for light emission devices. Rapid progress in materials engineering has led to the demonstration of external quantum efficiencies over 20% in green and red and higher than 10% in blue. However, there remains much space to further optimize the photonic designs within the device stacks to maximally exploit the excellent light-emitting capabilities. Kar et al. present the recent advances and perspectives on light management for high-performance perovskite light-emitting diodes (PeLEDs) [10]. Zhang et al. use alternating cations in the

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interlayer space to improve the stability of 2D PeLEDs [11], while Sun et al. tailor the hardness–softness of the Lewis-base additives to obtain efficient and stable all-inorganic PeLEDs [12]. Also, Zhao et al. summarize the advances of optical pumping lasers using quasi-2D perovskites as gain medium and discuss the key issues to realize electrical pumping lasing [13].

Lead halide perovskites have demonstrated excellence in photo/radiation detection. However, the structural instability and Pb toxicity may hinder their commercialization. Ghasemi et al. comprehensively review the optoelectronic properties of lead-free metal halide double perovskites, and the progress of the materials in various applications is explicated in view of the material structure-function relationship [14]. Then, Cao et al. present an overview of lead-free halide perovskite materials for photodetectors ranging from near-infrared to X-ray and discuss the challenges and visions in related research fields [15]. Finally, Tan et al. investigate the tailoring of electron and hole dimensionality in lead-free halide perovskites to achieve efficient and stable scintillators [16].

In summary, this special issue provides a good overview of research activities by leading scientists in the fast-moving field of halide perovskite optoelectronics. Perspectives, reviews and research articles covering diverse optoelectronic devices, such as solar cells, light emitting diodes, lasers, and photo/radiation detectors are presented. We hope that this collection of articles will stimulate young students and researchers as well as established scientists and industrial partners. This special issue has been initiated and successfully accomplished during the COVID-19 pandemic. We would like to sincerely thank all the authors who contributed to this special issue at the special moment. The publishing editor Dennis Couwenberg and publishing assistant Tara Dorrian are gratefully acknowledged for their constant support and assistance.

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