

## Welcoming the First Decade for Perovskite Solar Cells

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The swift emergence of perovskite solar cells (PSCs) is a ‘miracle development’ in the history of photovoltaics that has revolutionized the optoelectronic field. Since Miyasaka and coworkers (Toin University of Yokohama, Japan) reported the first use of halide perovskites (HPs) in solar cells in 2009,<sup>1</sup> the past ten years have witnessed a skyrocketing increase in power conversion efficiency (PCE) of PSCs from 3.8 % to 24.2 % and even 28% for perovskite on silicon tandems.<sup>2</sup> Meanwhile, the stability, the Achilles heel of this technology, has been enhanced very substantially. While the early versions of PSCs were stable just for a few days, the state-of-the-art PSCs have now demonstrated more than 10,000 hours operational stability and a few thousand hours outdoor stability, advancing the practical deployment of PSCs significantly.<sup>3,4</sup> Such impressive progress in the PCE and stability of PSCs has been not only attributed to the creative technological innovation in device structures, perovskite processing, charge-transport-layer engineering, interface modification, *etc.*, but also related to the fascinating understanding of fundamental sciences in HP materials that include crystal structure, defect chemistry, crystallization, photophysics, and light-matter interaction.

In this context, an important, fruitful discussion on both fundamental and technological progresses in HPs, PSCs, and the broader perovskite optoelectronics was performed in the perovskite-focused ‘twin’-symposia of *ET04: Perovskite Solar Cells — Challenges and Opportunities* and *ET05: Fundamental Aspects of Halide Perovskite (Opto)electronics and Beyond* at the 2018 Materials Research Society (MRS) Fall Meeting (Nov. 26-30, 2018, Boston, MA, USA) which were summarized earlier.<sup>5</sup> Here, we introduce a collection of papers from the leading scientists from the twin symposia where reporting their most recent research progress and critical opinions on PSCs. We have also invited worldwide contributions from other outstanding perovskite research groups (China, United States, Germany, Sweden, Switzerland, Israel, Brazil, etc.). All these contributions constitute this special issue of *Perovskite Photovoltaics and Optoelectronics* of *Solar RRL*, that we are delighted to put together for the 10<sup>th</sup> anniversary celebration of perovskite photovoltaics.

This special issue has had a great reception by the researchers and numerous contributions have been received and consequently will be divided into two part. Here, we introduce the first part that collects 5 review- and 25 research-type articles. For the 5 review-type contributions, (i) Wojciechowski *et al.* discussed the industrial opportunities of PSCs; (ii) Yin *et al.* and Pang *et al.* reviewed the progresses of PSCs based on formamidinium-based HPs and inorganic CsPbIBr<sub>2</sub> HPs, respectively; (iii) Liu *et al.* summarized the strategies for making high-performance tin-based PSCs; (iv) Fan *et al.* provided prospects on environmentally-friendly and stable lead-free perovskites. Regarding the research-type contributions, the following key topics are covered.

*Tailoring perovskite properties and stability.* Yan *et al.* reported the use of block copolymers for grain boundary passivation in MA<sub>0.7</sub>FA<sub>0.3</sub>PbI<sub>3</sub> HPs. Ma *et al.* used bifunctional dye molecules for enhancing inorganic CsPbIBr<sub>2</sub> HPs properties and stability. Zhao *et al.* showed black phosphorus can promote the photo-stability of MAPbI<sub>3</sub> HPs. Chen *et al.* and Liu *et al.* demonstrated new perovskite composition engineering strategies. Etgar *et al.* showed how to tailor the optical properties in already crystallized HPs. Flávia Nogueira *et al.* revealed the mechanisms underlying the property enhancement of 3D HPs via layered HPs incorporation.

*Improving charge-transporting layers and electrodes.* Various new types of electron-transporting layers for high-performance PSCs were demonstrated (water-based TiO<sub>2</sub> nanocrystals Zhao *et al.*, UV-treated SnO<sub>2</sub> by Mora-Seró *et al.*,  $\gamma$ -Ga<sub>2</sub>O<sub>3</sub> nanocrystals by Wang *et al.*, Co-doped TiO<sub>2</sub> by Liu *et al.*, PCBM/conjugated polymer composite by Yang *et al.*, and molecular-engineered PCBM by Troshin *et al.*). New hole-transporting materials (HTMs) were also designed by Z. Xu *et al.*, Yip *et al.*, B. Xu *et al.*, Getautis *et al.*, and Nazeeruddin *et al.*, which may mitigate the existing issues associated with the commonly-used Spiro-OMeTAD HTMs. Furthermore, Huang *et al.* and Lin *et al.* showed the promise of sputtered Au and carbon quantum-dots as conducting contacts for PSCs, respectively.

*Modifying device interfaces.* Unger *et al.* and Song *et al.* demonstrated alkali salts and Zwitterionic polymers for interface modification in PSCs, respectively. An interesting *in-situ* interface-modification approach was demonstrated by Hu *et al.* for enhancing the PSC stability.

*Developing lead-free perovskites.* Yao *et al.* showed a new vapor-assisted solution method for making sulfur-incorporated bismuth-based lead-free PSCs. Jen *et al.* employed trihydrazine-dihydriodide additive for boosting formamidinium tin iodide PSCs to 8.48 % PCE.

In closing, this collection of papers have demonstrated the most recent progress in understanding and developing PSCs from various scientific and technological aspects. We envision they will bring broad attention from the field of photovoltaics and stimulate more significant effort towards more efficient, stable, eco-friendly PSCs in the future. We are also looking forward to releasing the second part of the special issue of *Perovskite Photovoltaics and Optoelectronics* later this year, and to share more research progress and opinions on perovskite sciences and technologies.

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