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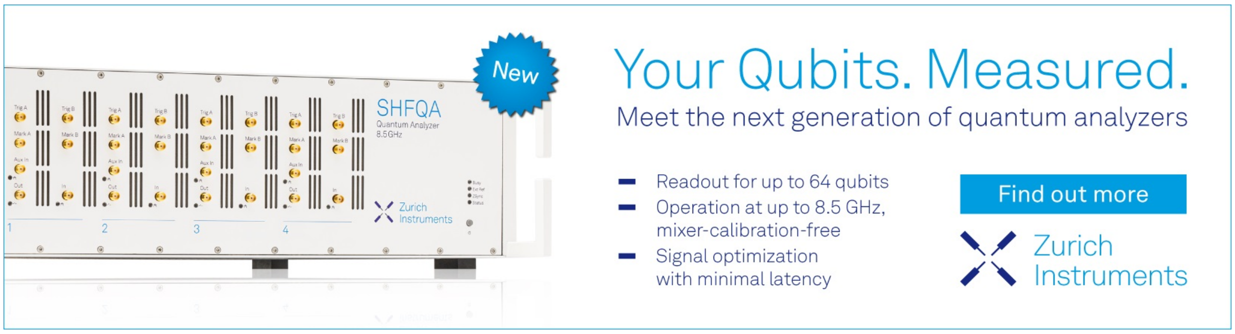

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Yuanyuan Zhou[1,a)] and Wei Chen[2]

AFFILIATIONS

[1]Department of Physics, Hong Kong Baptist University (HKBU), Hong Kong SAR, China
[2]Wuhan National Laboratory for Optoelectronics, Huazhong University of Science and Technology, Wuhan 430074, China

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[a)]**Author to whom correspondence should be addressed:** yyzhou@hkbu.edu.hk

Hybrid organic–inorganic halide perovskites (OIHPs) are an emerging class of semiconducting materials that have been revolutionizing the field of optoelectronics.[1,2] In contrast with conventional semiconductors, OIHPs are formed with ionic and secondary bonds instead of covalent bonds, which endow them with relatively soft characteristics.[3] Especially, these materials can be easily processed into thin films using various low-temperature methods, and their microstructures can be highly tailorable at multiple scales.[4] Also, there is a huge composition space in this material family, leading to versatile crystalline structures (Fig. 1) and (opto)electronic properties.[3,5] While the most matured application of OIHPs is a solar cell that has thus far demonstrated a record certified efficiency of 25.5%,[6] other OIHP-based energy and electronic applications are catching on.[2] We have witnessed that such fruitful technological developments in OIHPs are driven by fundamental discoveries and understandings of emerging materials physics among this fascinating family of materials, and thus, continued effort in fundamental OIHP research will be key to addressing the remaining challenges in the commercialization of perovskite semiconductor technologies, including stability, as well as enriching the broad field of materials physics.

This Special Topic collects the prominent recent findings focusing on a spectrum of subjects centered at OIHPs as follows.

Characterization. Gao and co-workers[7] reviewed electron microscopy of halide perovskites, which is crucial to gaining insights into the OIHP structures at the nanoscale; Nienhaus and co-workers[8] applied scanning tunneling microscopy to investigate the effect of electric bias on OIHPs; and Kurt used Raman spectroscopy to study the pressure-dependent $CsPbI_3$ phases at room temperature.

Defect. Zhou and co-workers[9] reviewed the recent progress in understanding defect chemistry for PSCs; Liu and co-workers[10] showed that grain surface passivation can lead to a high device voltage of 1.16 V in perovskite solar cells (PSCs); Yip and co-workers[11] demonstrated Zn-doping as an alternative method for defect control in OIHPs; and Yadav and co-workers[12] showed the surface defects of methylammonium lead bromide can be passivated by lead sulfate.

Materials and device mechanisms. Stiff-Roberts and Barraza[13] studied the mechanisms of OIHP film formation based on the RIR-MAPLE method; Anta and co-workers[14] explored the intensity modulated photocurrent spectroscopy of PSCs; Chen and co-workers[15] provided insights into the properties of Spiro-OMeTAD, a key device component in efficient PSCs; Birgersson and co-workers[16] applied a scaling analysis for studying recombination in PSCs; Schmidt and co-workers[17] used external quantum efficiency measurements for revealing the degradation mechanism in PSCs; and Sarkar and Raj[17] investigated the potassium incorporation induced non-capacitive effects in PSCs.

Emergent physics. Zhang and co-workers[18] investigated the Rashba band splitting in the prevailing 2D Ruddlesden–Popper OIHPs; Singh, Jha, and co-workers[19] studied the phenomena of hysteric photo-conduction and negative differential resistance in cesium lead bromide perovskite, an extended member to the OIHP family; Das and co-workers[20] investigated the temperature and frequency dependent dielectric response of propylammonium lead iodide; and Araújo and co-workers[21] reported an unusual frequency dispersion of the dielectric permittivity maxima at phase–transition temperatures of methylammonium lead iodide.

Properties and functions. Priya and co-workers[22] reviewed the ferroelectric properties of 2D OIHPs; Sonvane, Gupta, and co-workers[23] systematically studied the relationship of structure, property, and solar cell device performance in 2D OIHPs; Kawano and co-workers[24] studied scintillation properties of glass–OIHP nanocomposites; and Masuda and co-workers[25] showed the excellent properties of cesium lead halide perovskite nanocrystals for lasering applications.

In closing, this collection of articles has brought freshly new thinking into the structure, properties, and device functions of hybrid perovskites. We envision that the new fundamental sciences introduced here will show lasting impacts on the development of perovskite semiconductor technologies and beyond.

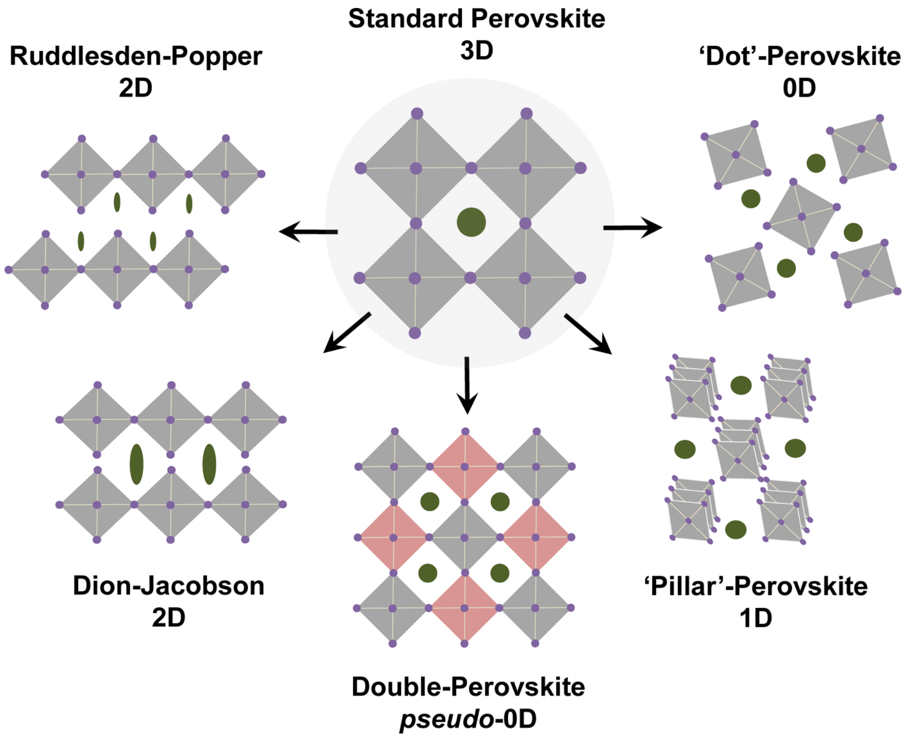

FIG. 1. Schematic crystal structures of the broad family of hybrid perovskites that not only include standard 3D perovskite, 2D Ruddlesden–Popper or Dion–Jacobson perovskite, and 0D double perovskite, but also embrace pseudo-members of 1D "pillar" perovskite and 0D "dot" perovskite. Reproduced with permission from Y. Zhou *et al.*, Matter **2**, 360–377 (2020).[3] Copyright 2020 Elsevier.

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