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Physical chemistry of hybrid perovskite solar cells

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Hybrid perovskite solar cells have provided a steep change in photovoltaics research. They combine the key advantages of all emerging photovoltaic technologies, including: inorganic thin-film photovoltaics (high efficiency); organic photovoltaics (ease and economy of deposition and diversity of materials) and dye-sensitized solar cells (chemical versatility and architecture). For this reason, they have attracted a large community of researchers working at the interface of chemistry, physics and engineering.

These materials have not been an overnight success, but are the result of four decades of research effort and progress. In brief, the synthesis and characterization of methylammonium lead iodide was first reported in 1978 by Weber.[1] The chemical diversity of these materials was explored extensively in the 1990s, with reports of organic–inorganic perovskites with variable composition and dimensionality.[2] The first perovskite-sensitised solar cell was published in 2009 by Miyasaka and co-workers,[3] with reports of high-efficiency solid-state perovskite solar cells appearing from 2012.[4–7]

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The past five years have seen a significant increase in light-to-electricity conversion efficiency, with the champion perovskite solar cells now on par with well-established inorganic thin-film photovoltaic technologies (*e.g.* CdTe).[8] There is now a chance to step back and probe deeper into the physical chemistry and chemical physics of hybrid halide perovskite materials and solar cells. There exist a large number of fundamental challenges in the field and many opportunities for physical scientists, including:

- Hysteresis – how to limit time-dependent current–voltage behavior;
- Charge transport – identifying the dominant scattering mechanism;
- Charge recombination – understanding why electron–hole recombination is so slow;
- Ionic conductivity – identifying its role in working devices;
- Dynamic disorder – connecting vibrations/rotations to optoelectronic properties;
- Chemical stability – protection from oxygen and water;
- Ferroelectricity – the role of lattice polarization in high performance devices;
- Surfaces and interfaces – understanding how crystals terminate;
- Band gap engineering – avoiding photoinstability of alloys;
- Beyond 3D – exploring the performance of lower dimensional perovskites;
- Pb-free – maintain high performance with lead-free materials.

Several of these issues are touched upon in the contributions found in this special issue. Solving them requires reliable and quantitative data, and the collaboration between theory, simulation and experiment. It is worth recalling the situation in the dye-sensitised solar cell community where, despite over 1000 research publications produced per year, the photovoltaic efficiencies have become stagnant. As summarized by L. M. Peter in his 2011 review,[9] just before the emergence of perovskite solar cells: "we do not need just more research; we need *better focused* research".

We thank all of the contributors to this special issue for sharing their latest results, which were supported by a rigorous peer review process, and to the editorial team at PCCP for facilitating this process. We acknowledge the global community of hybrid perovskite researchers for making this such a vibrant field to work in. The pressure is high to make the next breakthrough, but this does not diminish the joy of discovery and progress towards a world powered by solar energy.

References

1 D. Weber, *Z. Naturforsch., B: Anorg. Chem., Org. Chem.*, 1978, **33**, 1443–1445.
2 D. B. Mitzi, S. Wang, C. Feild, C. Chess and M. Guloy, *Science*, 1995, **267**, 1473–1476.
3 A. Kojima, K. Teshima, Y. Shirai and T. Miyasaka, *J. Am. Chem. Soc.*, 2009, **131**, 6050–6051.

4 H.-S. Kim, C.-R. Lee, J.-H. Im, K.-B. Lee, T. Moehl, A. Marchioro, S.-J. Moon, R. Humphry-Baker, J.-H. Yum, J. E. Moser, M. Grätzel and N.-G. Park, *Sci. Rep.*, 2012, **2**, 591.
5 M. M. Lee, J. Teuscher, T. Miyasaka, T. N. Murakami and H. J. Snaith, *Science*, 2012, **338**, 643–647.
6 J. H. Heo, S. H. Im, J. H. Noh, T. N. Mandal, C.-S. Lim, J. A. Chang, Y. H. Lee, H. Kim, A. Sarkar, M. K. Nazeeruddin, M. Grätzel and S. Il Seok, *Nat. Photonics*, 2013, **7**, 486–491.
7 N. J. Jeon, J. H. Noh, W. S. Yang, Y. C. Kim, S. Ryu, J. Seo and S. Il Seok, *Nature*, 2015, **517**, 476–480.
8 M. Green, K. Emery, Y. Hishikawa, W. Warta and E. D. Dunlop, *Prog. Photovoltaics*, 2016, **24**, 905–913.
9 L. M. Peter, *J. Phys. Chem. Lett.*, 2011, **2**, 1861–1867.