HYBRID SOLAR CELLS

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The Hybrid Solar Cell group develops the next generation of solar cells using hybrid materials like metal halide perovskites. We develop a deep understanding of material properties and their impact on device performance.
Our focus is on improving the stability of perovskite solar cells, addressing ion migration as a key challenge. We have developed unique techniques to study and suppress ion migration, and explore new applications for ion migration. By combining the excellent semiconducting properties of perovskites with mobile ions, we develop devices for memory applications like artificial synapses.

Highlights

- We demonstrated the transfer of triplet excitons from tetracene into silicon, a technique that could double the photocurrent from high-energy photons in a solar cell.
- We developed a new technique to study ion migration, the main factor making perovskite solar cells unstable and used it to develop strategies that reduce ion migration in perovskite solar cells.
- We invented a direct patterning method for semiconductor quantum dots using photolithography and electron-beam lithography.
- We developed an artificial synapse from halide perovskite with the lowest energy consumption reported to date.

Plans

Ions are the key in determining perovskite device operation and stability. We will use simulations in combination with advanced impedance measurements to understand the role ions play for devices. With lateral devices and XRF measurements we quantitatively study which ions migrate, and how fast. The resulting structural change is measured using EBSD. With this comprehensive approach, we can determine ion characteristics and their effects on optical and structural properties of the material and devices. We use this knowledge to stabilize solar cells and expand our research to memristor devices for artificial neural networks.

Key research items

1. M.H. Futscher, J.M. Lee, L. McGovern, L.A. Muscarella, T. Wang, M.I. Haider, A. Fakharuddin, L. Schmidt-Mende and B. Ehrler, *Quantification of ion migration in $CH_3NH_3PbI_3$ perovskite solar cells by transient capacitance measurements*, Mater. Horiz. 6, 1497-1503 (2019)

2. L. McGovern, M.H. Futscher, L.A. Muscarella and B. Ehrler, *Understanding the Stability of $MAPbBr_3$ versus $MAPbI_3$: Suppression of Methylammonium Migration and Reduction of Halide Migration*, J. Phys. Chem. Lett. 11, 17, 7127–7132 (2020)

3. C.D. Dieleman, W. Ding, L. Wu, N. Thakur, I. Bespalov, B. Daiber, Y. Ekinci, S. Castellanos and B. Ehrler, *Universal direct patterning of colloidal quantum dots by (extreme) ultraviolet and electron beam lithography*, Nanoscale 12, 11306-11316 (2020)

4. L.A. Muscarella, E.M. Hutter, F. Wittmann, Y.W. Woo, Y.-K. Jung, L. McGovern, J. Versluis, A. Walsh, H.J. Bakker and B. Ehrler, *Lattice Compression Increases the Activation Barrier for Phase Segregation in Mixed-Halide Perovskites*, ACS Energy Lett. 5, 10, 3152–3158 (2020)

5. B. Daiber, S. Maiti, S.M. Ferro, J. Bodin, A.F.J. van den Boom, S.L. Luxembourg, S. Kinge, S.P. Pujari, H. Zuilhof, L.D.A. Siebbeles, and B. Ehrler, *Change in tetracene polymorphism facilitates triplet transfer in singlet fission-sensitized silicon solar cells*, J. Phys. Chem. Lett. 11, 20, 8703–8709 (2020)

(Left) Illustration of the effect of strain on perovskite semiconductors. (Right) Patterning of semiconductor quantum dots into photonic structures.