Charge transport in hybrid perovskite field-effect transistors

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Hybrid organic-inorganic halide perovskites have recently and quite rapidly emerged as one of the most promising contenders for large scale, low-cost opto-electronic applications. Thee materials were incorporated in a wide variety of devices ranging from solar cells to light emitting diodes, lasers, spintronic devices and more. By careful device design, we were able to fabricate the first working perovskite field-effect transistor (FET), which allowed us to directly measure the intrinsic electrical properties of such materials. We obtained ambipolar transport, with mobilities around 1 cm^2/Vs for both electrons and holes at room temperature.[1] The results expanded the use of these hybrid perovskites towards other low-cost thin film electronic circuits besides solar cells, thus widening the spectrum of possible applications of these materials.

To study the impact of electronic traps on device performance, we measured the dependence of the carrier mobility on the electric field, i.e. the Poole-Frenkel (PF) effect. Since one of the main sources for the traps arises from the microstructure of the hybrid perovskite film, we tuned the processing parameters to vary the quality of this layer. We found an inverse correlation between mobility and trap density, suggesting that trapping of charge carries is an important source of scattering in hybrid perovskite devices. In devices of high room-temperature mobility and low defect density, we were able to measure an increase in mobility with lowering the temperature. The reduction of the trap densities at the semiconductor/dielectric interface was achieved by carefully controlling the perovskite film microstructure, coupled with the use of an inert organic dielectric, and the use of self-assembled monolayers to control the film order and charge injection.

With a few exceptions, the properties of perovskite devices reported in the literature can only be reproduced over small areas. Achieving good performance and uniformity over large-areas is hard due to the lack of processing methods that maintains film quality over large areas. We employed 'spray-coating' for the deposition of the hybrid perovskite layer. This is a fast, high-throughput manufacturing method that is easily scalable to large areas.[2-4] We obtained mobilities as high as 4 cm^2/Vs for both electrons and holes. This work emphasize the compatibility of hybrid perovskite solutions with processing methods that can allow fast deposition over large areas and at low cost.

1. Y. Mei, C. Zhang, Z.V. Vardeny and O. D. Jurchescu, MRS Commun 5, 297 (2015).
2. N. A. Azarova, J. W. Owen, C. A. McLellan, M. A. Grimminger, E. K. Chapman, J. E. Anthony, and O. D. Jurchescu, Org. Electron. 11, 1960 (2010).
3. Y. Mei, M. A. Loth, M. Payne, W. Zhang, J. Smith, C. S. Day, S. R. Parkin, M. Heeney, I. McCulloch, T. D. Anthopoulos, J. E. Anthony, and O. D. Jurchescu, Adv. Mater. 25, 4352 (2013).
4. S. Hunter, J. W. Ward, M. M. Payne, J. E. Anthony, O. D. Jurchescu and T. D. Anthopoulos, Appl. Phys. Lett. 106, 223304 (2015).