VIDEO ARTICLE

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Two-dimensional Halide Perovskite Lateral Epitaxial Heterostructures

Letian Dou[1]

Davidson School of Chemical Engineering, Purdue University, West Lafayette, IN, USA

Corresponding and Presenting Author. E-mail: dou10@purdue.edu

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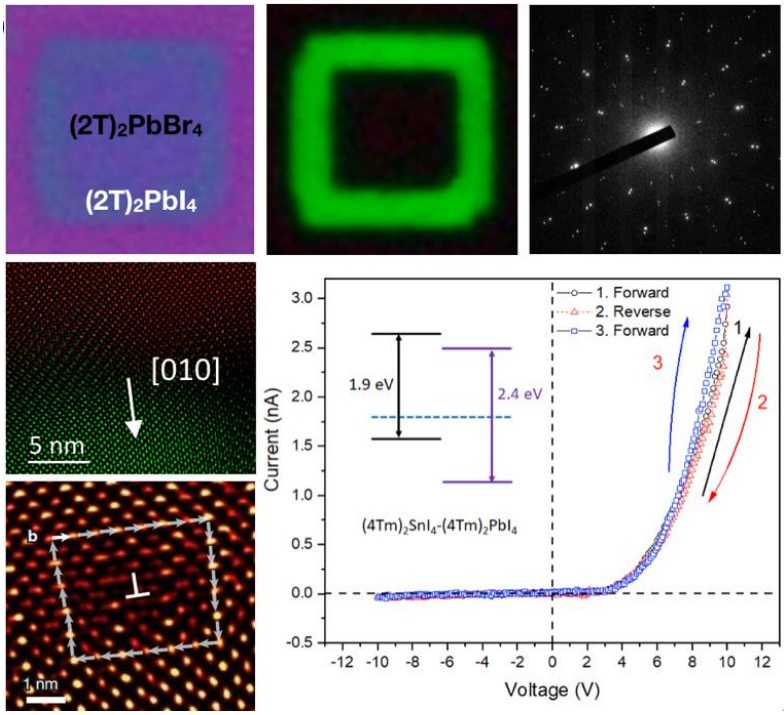
Graphical Abstract

First two-dimensional halide perovskite lateral epitaxial heterostructures pointing toward widely tunable and integrated nanoelectronics and nanophotonics.



Abstract

Atomically sharp epitaxial heterostructures based on oxide perovskites, III-V, II-VI, and transition metal dichalcogenides semiconductors form the foundation of modern electronics and optoelectronics. As an emerging family of tuneable semiconductor materials with exceptional optical and electronic properties, halide perovskites are attractive for applications in next-generation solution-processed solar cells, LEDs, photo/radiation detectors, lasers, etc. The inherently soft crystal lattice allows for greater tolerance to lattice mismatch, making them promising for heterostructure formation and semiconductor integration. However, epitaxial growth of atomically sharp heterostructures of halide perovskites has not yet been achieved so far owing to two critical challenges. First, the fast intrinsic ion mobility in these materials leads to interdiffusion and large junction widths. Second, poor chemical stability in these materials leads to decomposition of prior layers during the fabrication of the subsequent layers. Facile ion diffusion and poor stability are currently limiting the commercialization of any halide perovskite-based electronic devices. Therefore, understanding the origins of the halide perovskite instability and identifying effective approaches to suppress ion diffusion are of great significance and urgency.
In this talk, I will present an effective strategy to substantially inhibit in-plane ion diffusion in two-dimensional (2D) halide perovskites via incorporation of rigid π-conjugated organic ligands. For the first time, we demonstrate highly stable and widely tunable lateral epitaxial heterostructures, multi-heterostructures, and superlattices of 2D halide perovskites via a solution-phase synthetic strategy. Near atomically sharp interfaces and epitaxial growth are revealed from low dose aberration-corrected high-resolution transmission electron microscopy (AC-HRTEM) characterizations. Molecular dynamics (MD) simulations reveal that the suppressed halide anion diffusivity is attributed to a combination of reduced heterostructure disorder and larger vacancy formation energies for 2D perovskites with conjugated ligands. These findings represent critical fundamental insights into the immobilization and stabilization of halide perovskite semiconductor materials and provide a new materials platform for complex and molecularly thin superlattices, devices, and integrated circuits.

Keywords: Halide perovskties; heterostructures; epitaxial; hybrid materials.

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Biography of Presenting Author

Letian Dou is currently an assistant professor at the Davidson School of Chemical Engineering of Purdue University. He obtained B.S. in Chemistry from Peking University in 2009 and Ph.D. in Materials Science and Engineering from University of California – Los Angeles in 2014. From 2014 to 2017, he was a postdoctoral fellow at the Department of Chemistry, University of California – Berkeley and Materials Science Division, Lawrence Berkeley National Laboratory, and BASF – California Research Alliance. His research interest includes the synthesis of organic-inorganic hybrid materials and low-dimensional materials, fundamental understanding of their structure-property relationships, as well as applications in high performance optoelectronic devices. He is a recipient of Office of Naval Research Young Investigator Award (2019), Highly Cited Researcher in Cross-Fields (2019), MIT Technology Review Innovators Under 35-China Award (2018), and Materials Research Society Graduate Student Award (2014). He has published over 50 research papers with more than 15000 citations.

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