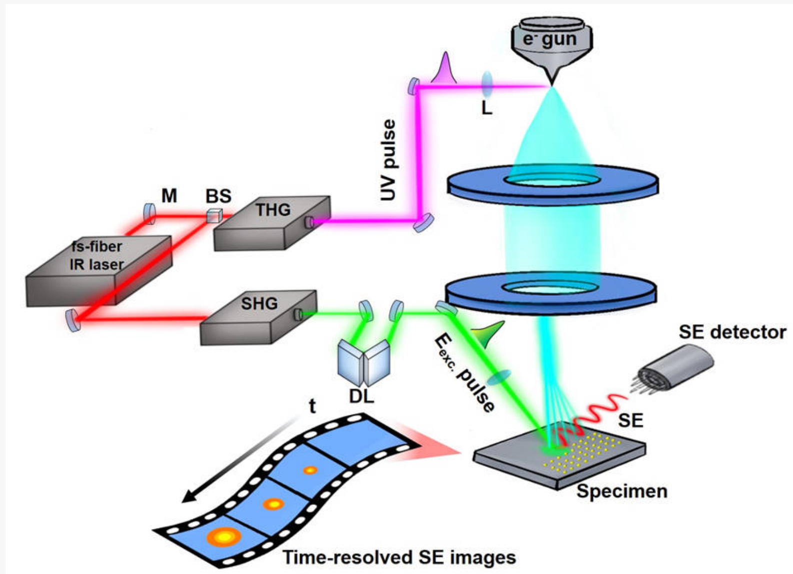
Real-Space Imaging of Surface Carrier Transport in 2D Perovskites

GA, UNITED STATES, March 19, 2025 /EINPresswire.com/ -- Understanding photogenerated carrier transport in [2D perovskites](), especially surface states, is challenging with conventional time-resolved techniques. Scientists at KAUST utilized scanning ultrafast electron microscopy (SUEM) with groundbreaking surface sensitivity to disclose carrier diffusion rates of ~30 cm^2/s for n=1, 180 cm^2/s for n=2, and 470 cm^2/s for n=3, which are notably higher than bulk. This highlights the SUEM's potential for advancing the understanding of carrier dynamics. Density Functional Theory (DFT) confirms broader carrier transmission channels at the surface, offering key insights for optimizing 2D perovskite optoelectronic devices.



Schematic illustration of probing photo-generated surface charge carriers using ultrafast scanning electron microscopy.

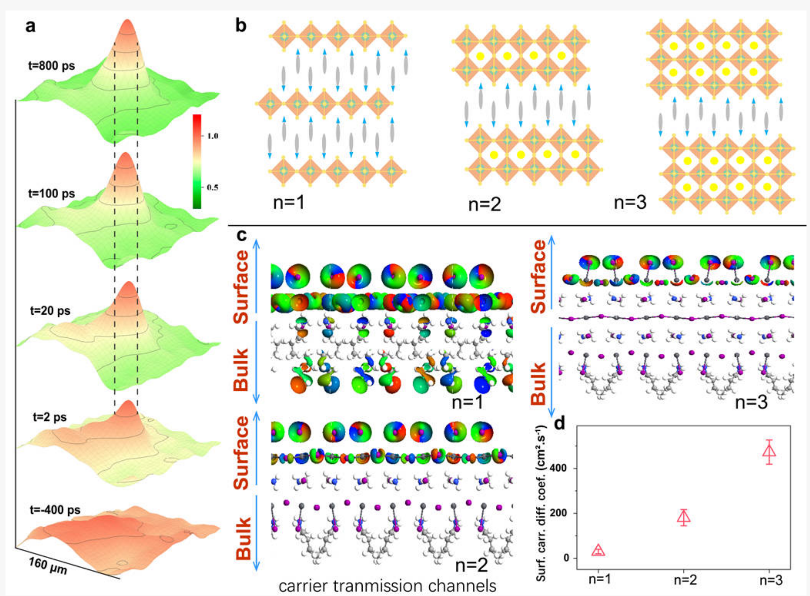


Photo-generated carrier transport properties on the surface of 2D perovskite materials.

Efficient carrier transport is essential for high-performance light-conversion devices, yet two-dimensional (2D) perovskites face significant challenges due to their quantum well (QW) structures. The inorganic perovskite layers, confined by organic cation spacers, exhibit high exciton binding energies that hinder the dissociation of excitons into free carriers. This limitation strongly affects carrier transport properties, thereby constraining device efficiency. Gaining a deeper understanding of the underlying physics—which includes the significant influence of surface states—has been particularly challenging, largely due to the absence of real-time, surface-sensitive characterization techniques.

To address this, in a new paper published in Light Science & Applications, a team of scientists, led by Professor Omar F. Mohammed from King Abdullah University of Science and Technology (KAUST), and co-workers have employed scanning ultrafast electron microscopy (SUEM), a cutting-edge technique capable of mapping surface carrier diffusion with unprecedented surface sensitivity. Their work revealed photo-induced surface carrier diffusion rates of ~30 cm^2/s for n=1, ~180 cm^2/s for n=2, and ~470 cm^2/s for n=3, exceeding bulk rates by over 20 times. Density Functional Theory calculations confirmed that the enhanced diffusion arises from broader charge carrier transmission channels at the surface compared to the bulk. These scientists summarized:

‘We have directly imaged the transport of photo-generated charge carriers on 2D perovskite materials at ultrafast timescales using SUEM, which has the unique surface-sensitive capability. By utilizing SUEM, we are able to accurately explore carrier diffusion in the local region of a material's top surface following photoexcitation. This method provides a clear distinction from traditional bulk or ensemble spectroscopic techniques, which may not accurately distinguish surface-to-bulk states in 2D perovskites.’

‘These findings not only highlight the notable difference between surface and bulk transport, but also offer valuable insights into optimizing 2D perovskite-based optoelectronic devices through advanced interface engineering.’ they added.

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