Boosted exciton mobility approaching the Mott-Ioffe-Regel limit in a 2D Ruddlesden-Popper perovskite

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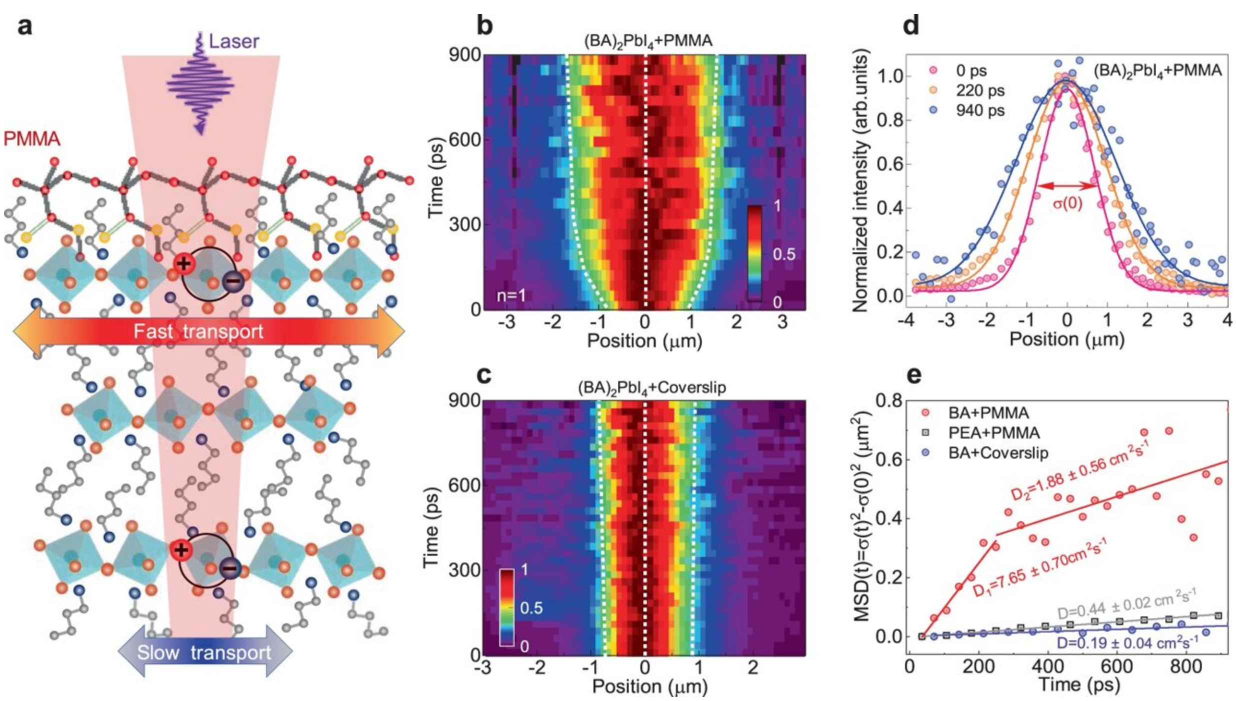

Exciton transport in exfoliated $(BA)_2PbI_4$ RPP flakes encapsulated by coverslip and PMMA. Credit: *Nature Communications* (2024). DOI: 10.1038/s41467-024-45740-y

A study, published in *Nature Communications* and led by Prof. Liu Xinfeng from the National Center for Nanoscience and Technology (NCNST) of the Chinese Academy of Sciences (CAS), recently reported an enhancement in exciton mobility in a two-dimensional (2D) Ruddlesden-Popper perovskite (RPP).

Exciton mobility is a critical factor influencing the optoelectronic properties of 2D RPP. However, the mobility of 2D RPP is observed to be one order of magnitude lower than that of the corresponding 3D perovskite. Various factors such as exciton-exciton annihilation, interlayer coupling, and defects can impact the exciton transport behavior in 2D RPP.

Despite substantial progress, the precise correlation between exciton transport and lattice properties, especially concerning exciton-lattice interactions, remains elusive. Furthermore, there is an urgent need to adjust exciton-phonon interactions to tailor exciton transport characteristics for applications in 2D perovskite-based optoelectronics.

Prof. Liu's group at NCNST, and the collaborators from South China Normal University and Peking University, achieved a boosted exciton mobility approaching the Mott-Ioffe-Regel Limit (MIR) in 2D RPP by anchoring the soft butyl ammonium cation with a polymethyl methacrylate (PMMA) network at the surface.

The researchers directly monitored ultrafast exciton propagation process in $(BA)_2(MA)_{n-1}Pb_nI_{3n+1}$ R-P perovskites by time-resolved photoluminescence microscopy. They revealed that the free exciton mobilities in exfoliated thin flakes can be improved from around 8 $cm^2V^{-1}s^{-1}$ to 280 $cm^2V^{-1}s^{-1}$. The mobility of the latter is close to the theoretical limit of Mott-Ioffe-Regel criterion.

Combining optical measurements and theoretical studies, the researchers revealed that the enhanced exciton mobility is attributed to the anchoring of surface BA molecules by the PMMA network, which significantly improves the lattice rigidity and reduces the disorder.

As a result, the deformation potential scattering rate reduces by eight times at room temperature, leading to the transition of exciton propagation from the hopping regime to the band-like transport regime.

These findings offer valuable insights into the mechanisms of exciton transport in 2D perovskites with a soft lattice and shed light on how to tune exciton transport properties through lattice engineering.

More information: Yiyang Gong et al, Boosting exciton mobility approaching Mott-Ioffe-Regel limit in Ruddlesden−Popper perovskites by anchoring the organic cation, *Nature Communications* (2024). DOI: 10.1038/s41467-024-45740-y

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