Electronic charge transport in solution-processed vertically stacked 2D perovskite quantum wells

Hsinhan Tsai[1,2], Reza Asadpour[3], Mercouri Kanatzidis[4] Muhammad Ashraful Alam[3], Aditya D. Mohite[1*] and Wanyi Nie[1*]

1Los Alamos National Laboratory, Materials Physics and Application, Los Alamos, New Mexico 87545, USA
2Rice University, Material Science and Nano Engineering Department, Houston, Texas 77005, USA
3Purdue University, School of Electrical and Computer Engineering, West Lafayette, Indiana 47907, USA.
5Department of Chemistry, Department of Materials Science and Engineering, Northwestern University, Evanston, IL, 60208, USA

State-of-the-art quantum well based devices such as photovoltaics, photodetectors and light emission devices were enabled by understanding the nature and the exact mechanism of electronic charge transport. Ruddlesden-Popper halide perovskites are two-dimensional solution-processed quantum wells and have recently emerged as highly efficient semiconductor for solar cell approaching 13% in power conversion efficiency. However, further improvements will require an understanding of charge transport mechanisms, which are currently unknown and further complicated by the presence of strongly bound excitons. In our study, we discovered that the carrier transport is closely related to the structure and stacking of those quantum wells. Combining systematic device characterization and simulation, we conclude that the photo generated electron-hole pairs need to overcome the multiple internal potential barriers for collection to occur. The potential barriers that block the efficient separation of electron-hole pairs are attributed to the miss-alignment between crystalline slabs. Both of those properties are unfavorable for photovoltaic cell operation. Here we elucidate the critical role of field-assisted charge carrier separation that overcomes these bottlenecks leading to the efficient photocurrent collection. On the other hand, the structure of the 2D perovskites could promote the radiative recombination by spatially localizing the electrical injected carriers, which makes them an excellent material for light emitting diodes.

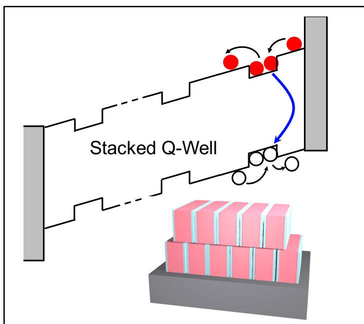

Fig. Schemetic illustration of vertically stacked quantum well and carrier transport

+ Author for correspondence: wanyi@lanl.gov