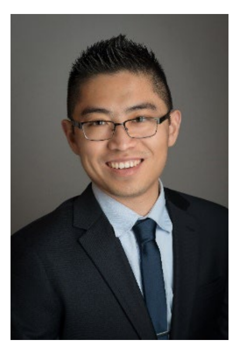
Interfacial Design of Two-dimensional Nanoelectronics

Huamin Li, PhD, Associate Professor
Department of Electrical Engineering
School of Engineering and Applied Sciences
Center for Advanced Semiconductor Technologies
University at Buffalo, The State University of New York
Buffalo, New York 14260, USA
Email: huaminli@buffalo.edu, Website: https://ligroup.eng.buffalo.edu/

Abstract:
Since the advent of graphene, the Nobel-winning "magic material", two-dimensional (2D) layered crystals have emerged as promising candidates for energy-efficient nanoelectronics, owing to their unique charge transport properties. Here from the perspective of interfacial design, I will take 2D semiconducting MoS_2 as an example to review our recent accomplishments, ranging from material synthesis to structure engineering and device innovation. Various novel charge transport phenomena and electronic interaction mechanisms have been unveiled at critical interfaces such as 2D/dielectric, 2D/metal, 2D/semiconductor, and 2D/substrate. **First**, by functionalizing the growth substrate, we can achieve location-on-demand selective-growth of 2D MoS_2 using chemical vapor deposition (CVD) and the electron mobility can be up to 20 cm^2/Vs at room temperature. At the interface between MoS_2 and SiO_2 substrates, an interfacial tension can be induced due to a mismatch of thermal expansion coefficients, which creates an anisotropy of in-plane charge transport as well as a self-formed nanoscroll structure. **Second**, at the interface between MoS_2 and metal contact, a monolayer h-BN decoration can enable novel manipulation of charge transport through quantum tunnelling, in contrast with conventional thermionic emission. The contact resistance can be suppressed by both localized and generalized doping using transition metals. **Third**, at the interface between MoS_2 and other 2D materials, band-to-band Zener tunnelling and cold-source charge injection can be enabled, giving rise to a superior transport factor (<60 meV/decade) in the field-effect transistor (FET) configurations. These novel charge transport can be utilized to overcome the fundamental limit of "Boltzmann tyranny", and realize tunnel FETs and cold-source FETs with sub-60-mV/decade subthreshold swings or novel anti-ambipolar FETs. The integration of 2D MoS_2 with 3D Si also shows excellent rectification, even with a sub-1-nm thickness of the monolayer. **Fourth**, at the interface between MoS_2 and ferroelectric or ionic dielectrics, excellent electrodynamic gating leads to a superior body factor (<1), and also improves the energy efficiency for transistor operation. These findings underscore the potential of 2D materials, even at sub-nanometer thicknesses, to extend Moore's law through advanced interfacial engineering.

Biographical sketch:



Huamin Li earned his Ph.D. from Sungkyunkwan University, Korea, and conducted postdoctoral research at the University of Notre Dame, USA. He joined the University at Buffalo (UB) in 2017, where he leads research on 2D materials and their applications in nanoelectronics. Dr. Li serves as an Editor for *IEEE Access*, *Nano Express*, *Materials Research Letters*, and *Moore and More*. Additionally, he is a Technical Committee Member (Nanoelectronics), Region 1 Young Professionals (YP) Representative, and YP Ambassador for the IEEE Nanotechnology Council (NTC). His contributions have been recognized with numerous accolades, including the NSF CAREER Award; Young Investigator, Exceptional Scholar, and Early Career Research Awards from UB; and the IEEE Region 1 YP Award.