# Electronic, Thermal, and (Some) Unusual Applications of 2D Materials

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This talk will present recent highlights from our research on two-dimensional (2D) materials, including graphene, boron nitride (h-BN), and transition metal dichalcogenides (TMDs). Our results span from material growth and fundamental measurements, to simulations, devices, and system-oriented applications. We have grown monolayer 2D semiconductors over large areas, including $MoS_2$ [1], $WSe_2$, and $MoSe_2$ [2]. We also uncovered that $ZrSe_2$ and $HfSe_2$ have native high-κ dielectrics $ZrO_2$ and $HfO_2$, which are of key technological relevance [3]. Improved electrical contacts [4] led to the realization of monolayer $MoS_2$ transistors with high current density [5,6], near ballistic limits [7]. We have also demonstrated new memory devices based on layered Mo-, Sb-, and Ge- tellurides [8,9]. These could all play a role in 3D heterogeneous integration of nanoelectronics, which presents significant advantages for energy-efficient computation [10]. I will also describe a few less conventional applications, where we used 2D materials as highly efficient thermal insulators [11] and as thermal transistors [12]. These could enable control of heat in "thermal circuits" analogous with electrical circuits. Combined, these studies reveal fundamental limits and some unusual applications of 2D materials, which take advantage of their unique properties.

**Refs:** **[1]** K. Smithe et al., ACS Nano 11, 8456 (2017). **[2]** K. Smithe et al., ACS AMI 1, 572 (2018). **[3]** M. Mleczko et al., Science Adv. 3, e1700481 (2017). **[4]** C. English et al., Nano Lett. 16, 3824 (2016). **[5]** C. McClellan et al. ACS Nano 15, 1587 (2021). **[6]** A. Daus et al., Nature Elec. 4, 495 (2021). **[7]** C. English et al., IEDM, Dec 2016. **[8]** I. Datye et al., Nano Lett. 20, 1461 (2020). **[9]** A. Khan et al. Science 373, 1243 (2021). **[10]** M. Aly et al., Computer 48, 24 (2015). **[11]** S. Vaziri et al., Science Adv. 5, eaax1325 (2019). **[12]** A. Sood et al. Nature Comm. 9, 4510 (2018).