

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). The results span from material growth and fundamental measurements, to simulations, devices and system-oriented applications that take advantage of unusual 2D material properties. We have grown monolayer 2D semiconductors over large areas, including MoS₂ [1], WSe₂, and MoSe₂ [2]. We also uncovered that ZrSe₂ and HfSe₂ have native high- κ dielectrics ZrO₂ and HfO₂, which are of key technological relevance [3]. Improved electrical contacts [4] led to the realization of 10 nm monolayer MoS₂ transistors with the highest current reported to date, near ballistic limits [5]. These could play a role in 3D heterogeneous integration of nanoelectronics, which presents significant advantages for energy-efficient computation [6]. In less conventional applications, we utilized 2D materials as computing fabrics for analog dot product circuits [7], as highly efficient thermal insulators [8], and as the basis of thermal transistors [9]. The last two examples 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. English et al., IEDM, Dec 2016. [6] M. Aly et al., Computer 48, 24-33 (2015). [7] N. Wang et al., Symp. VLSI, Jun 2016. [8] S. Vaziri et al., Science Adv. 5, eaax1325 (2019). [9] A. Sood et al. Nature Comm. 9, 4510 (2018).

Bio: Eric Pop is Professor of Electrical Engineering (EE) and Materials Science & Engineering (by courtesy) at Stanford, where he leads the SystemX Heterogeneous Integration focus area. He was previously on the faculty of UIUC (2007-13) and worked at Intel (2005-07). His research interests are at the intersection of electronics, nanomaterials, and energy. He received his PhD in EE from Stanford (2005) and three degrees from MIT (MEng and BS in EE, BS in Physics). His honors include the Presidential Early Career Award (PECASE), Young Investigator Awards from the Navy, Air Force, NSF and DARPA, and several best paper and best poster awards with his students. He is an Editor of the journal 2D Materials, has served as General Chair of the Device Research Conference, and on program committees of IEDM, VLSI, APS, and MRS. In his spare time he tries to avoid injuries while snowboarding and in a past life he was a DJ at KZSU 90.1 FM, from 2000-04. Additional information about the Pop Lab is available online at <http://poplab.stanford.edu>.

