Strain engineering 2D van der Waals based devices

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Abstract

Strain has long been known as a mechanism to engineer the properties of materials by modifying atomic interaction, crystal symmetry, spin-orbit coupling, and other effects. Because of this fact, strain engineering in electronic devices has been wildly utilized over the last 20 years, typically used to enhance silicon mobility in most standard CMOS fabrication processes. In fact, strain engineering is so ubiquitous it has been used in one form or another in every piece of integrated electronics since the 2004 era. In this talk, we explore past concepts associated with statically strain engineering 3D-bonded systems and discuss how to apply them to 2D materials. Additionally, we will add the concept of dynamic controllability of strain in 2D systems using oxide piezoelectric gating. Using strain to dynamically control materials properties has been more challenging for 3D bonded systems due to substrate limitations and defect formation. Systems involving 2D materials are freed from substrate constraints and have high elastic limits, but have not been heavily explored for dynamic strain engineering due to the difficulty in transferring strain into a material that is weakly bonded out-of-plane. We focus on challenges in achieving dynamically controllable strain in 2D-bonded materials and how these challenges can be overcome in a scalable on-chip device. We introduce one implementation of such a device using both static thin film stress capping layers and ferroelectric oxide gate-dielectrics. Here, $MoTe_2$ can be reversibly switched with electric-field induced strain between the 1T'-$MoTe_2$ (semimetallic) phase to a semiconducting $MoTe_2$ phase in a three-terminal field effect transistor geometry. Using strain, we achieve large non-volatile changes in channel conductivity (G_{on}/G_{off}~10^7 vs. G_{on}/G_{off}~0.04 in control devices) at room temperature. Using this implementation as a starting point, other phase transitions in 2D materials may be explored using this 'straintronic' device concept, which may enable low-power, high-speed, non-volatile, gate-controllability over a wide variety of exotic states of matter.

Bio

Stephen M. Wu is an Assistant Professor at the University of Rochester in the Department of Electrical and Computer Engineering and the Department of Physics and Astronomy. His research interests involve using new quantum materials to create novel electronic and magnetic devices. For this work in this area, he has won the NSF CAREER award in the year of 2020. Before Rochester, he was a postdoctoral researcher at Argonne National Laboratory within the Materials Science Division. He received his Ph.D. in Physics at the University of California, Berkeley in 2012, as well as a B.S. in Electrical Engineering and Computer Science in 2006 and B.A. in Physics in 2006 from the same institution.

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