Next Generation Electronic Materials for Ultratronics
2D Transition Metal Dichalcogenides

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2D materials, particularly transition metal dichalcogenides (TMDs), have unique properties that make them highly suitable for next-generation electronic applications. These applications range from advanced logic and interconnects to innovative in-memory computing architectures and power delivery network. In my talk, I will comprehensively introduce the fundamental material properties of 2D TMDs, emphasizing how their layer thickness affects electronic performance. Differences between sulfides and selenides, the two prominent TMD family members, will be highlighted.

Next, I will present statistical studies of high-performance 2D TMD transistors and discuss the key design parameters and process conditions that substantially impact the performance of these “interface only” devices. Notably, new interfacial engineering techniques for top gate stacks have been developed for both n-FETs and p-FETs, resulting in the successful passivation of interface defect states, doping introduction, and enhancements in device stability. Through these advancements, we have achieved record-high on-state and off-state performance in ultra-scaled 2D transistors, underscoring their potential for complementary FET (CFET) implementations.

Furthermore, I will introduce a powerful machine learning approach designed to optimize the device design and process conditions. This ML approach employs a detailed analysis of over a thousand device characteristics to achieve multiple threshold voltages that are required for modern digital applications. By utilizing a design and process co-optimization framework, this approach expedites the identification of optimal parameters, reducing the experimental turnaround time and enhancing the overall device performance.

Finally, I will briefly present our evaluation of 2D materials as an alternative barrier/liner to replace the conventional TaN/Ta bilayer in the back end of line applications, showing these 2D materials are capable of efficiently blocking Cu diffusion while improving the line resistance of ultra-scaled Cu interconnects.