SEMICONDUCTORS & MICROELECTRONICS
NEUROMORPHIC MATERIALS & DEVICES

University of Arizona researchers are pioneering neuromorphic computing by combining breakthroughs in quantum materials, nanofabrication, electronic and optical device design, circuit integration, and algorithm development. The Yan Lab develops materials and device architectures that mimic how the brain processes information. Their work aims to power the next generation of computing systems with ultralow energy consumption and bio-inspired intelligence, laying the foundation for faster, smarter and more efficient technologies**.**

Electronic Neuromorphic Materials & Devices

Low-dimensional van der Waals (vdW) materials offer a wealth of physical phenomena and serve as powerful building blocks for constructing bio-inspired nanodevices. To enable high-performance neuromorphic hardware, we have developed a suite of nanoscale devices that replicate key neural functions, including synaptic transmission, dendritic processing, and neuronal firing (**Figure 1, Figures 2 a,b,c**). These devices are fabricated through precise vdW stacking, allowing us to harness mechanisms such as charge trapping, oxygen vacancy dynamics, anti-ambipolar transport, and charge redistribution. Integration with CMOS platforms via PCB-based circuitry enables system-level demonstrations of neuromorphic capabilities in applications such as pattern recognition, personalized ECG arrhythmia detection, and combinatorial optimization. These research efforts have been featured in leading journals including *Nature* and *Nature Electronics*.

Topological Acoustic Phi-bits for Neuromorphic Computing

Phi bits, classical acoustic analogues of qubits, offer a promising path to overcome limitations in traditional neuromorphic electronics by enabling low-power, off-grid computation under extreme conditions. Leveraging their nonlinear topological phase dynamics and high-dimensional state space, the Yan Lab develops phi-bit-based neural networks (PBNNs) that emulate synaptic functions and support parallel information processing (**Figure 2d**). This research demonstrates key algorithms such as perceptron learning for handwritten digit recognition and Boltzmann machines for combinatorial optimization. By tuning phi-bit properties such as frequency and phase, this work aims to build efficient, scalable neuromorphic platforms that bridge physical hardware with advanced machine learning capabilities.

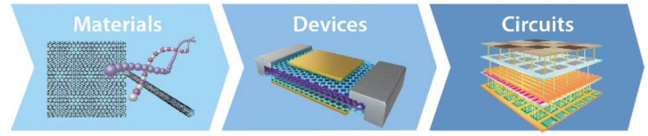

Figure 1: From materials to devices to circuits. The Yan Lab harnesses the properties and emergent neuromorphic functionalities in quantum materials, device architectures and integrated platforms.

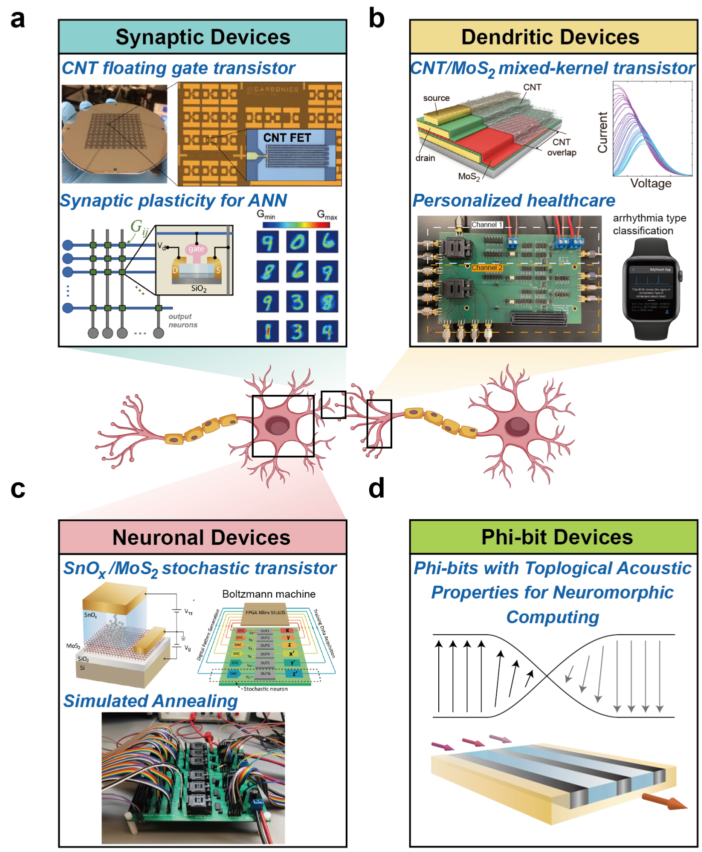

Figure 2: vdW nanodevices and circuits. Our prototypes mimic (**a**) synaptic (**b**) dendritic and (**c**) neuronal functionalities for neuromorphic computing applications. The Yan Lab also explores (**d**) topological acoustics as a new platform for neuromorphic computing.

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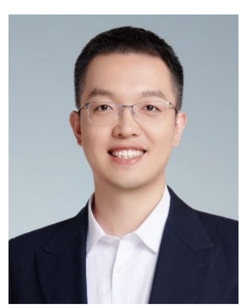

Xiaodong leads the Emerging Quantum Materials and Devices Lab. His focuses on semiconductor nanofabrication, electronic and photonic devices, two-dimensional materials and designs for low-power applications including neuromorphic computing, quantum computing, AI, and IoT. He is author or co-author of more than 40 scholarly publications.

More information:

X. Yan et al., Moiré synaptic transistor with room-temperature neuromorphic functionality. *Nature* (2023). doi: 10.1038/s41586-023-06791-1

X. Yan et al., Reconfigurable mixed-kernel heterojunction transistors for personalized support vector machine classification. *Nature Electronics* (2023). doi: 10.1038/s41928-023-01042-7