ARIZONA

SEMICONDUCTORS & MICROELECTRONICS
SPINTRONICS & QUANTUM DEVICES

University of Arizona researchers develop advanced memory and logic devices with unprecedented energy efficiency.

The Wang Lab is at the forefront of research into energy-efficient, high-speed semiconductor devices, focusing on spintronics—a field that leverages the quantum mechanical property of electron spin rather than charge alone for information processing. Traditional CMOS (complementary metal-oxide-semiconductor) devices rely on storing and manipulating electrical charge to represent binary states (0 and 1). However, as these devices are scaled down to nanometer dimensions, they suffer from significant charge leakage due to much reduced thickness of gate oxides, leading to power inefficiency. To overcome this limitation, the Wang Lab explores spin-based memory and logic devices that store information in the orientation of electron spins.

Non-volatile electronics

These spintronic devices, such as magnetic tunnel junctions (MTJs), can be switched efficiently using voltage-based mechanisms. A major advantage of spintronic devices is their non-volatility—information is retained even when power is removed, which significantly reduces standby power consumption. The Wang Lab has demonstrated record-high on/off ratio in voltage-controlled MTJs and achieved record-low energy-efficient switching. Beyond memory and logic, the lab also explores spintronic devices as magnetic field sensors. The resistance of MTJs is sensitive to spin orientation, enabling detection of extremely small magnetic fields—down to the range of hundreds of pico-Tesla. This technology has already been used in magnetic storage, and it has wide potential in biomedical sensing, and even in detecting weak signals such as brain magnetic waves.

Superconductivity and quantum computing

The Wang Lab investigates superconducting electronics, particularly Josephson junctions, which are crucial building blocks for quantum computing. In superconductors, electrons form Cooper pairs, consisting of two electrons with opposite spins that move without resistance below a critical temperature (Tc). These pairs enable dissipationless current flow, making superconductors highly desirable for low-power, high-speed electronic systems.

We developed advanced Josephson junctions, aiming to enable scalable superconducting circuits through enhanced thermal stability and integration compatibility. This research involves exploring new physical mechanisms and engineering novel material systems and device structures to optimize key parameters—critical for both classical superconducting electronics and quantum bits (qbits) in quantum computing.

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Weigang's studies the nanoscale transport of charge and spin and researches emerging quantum and semiconductor devices. His lab has demonstrated record high on/off ratio and ultralow energy switching in voltage-controllable magnetic tunnel junctions, and developed Josephson junctions for scalable integration and quantum computing.

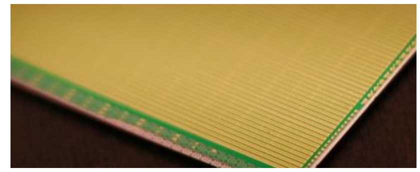

Figure 1: Spin-based nonvolatile memory made in the Wang Lab.

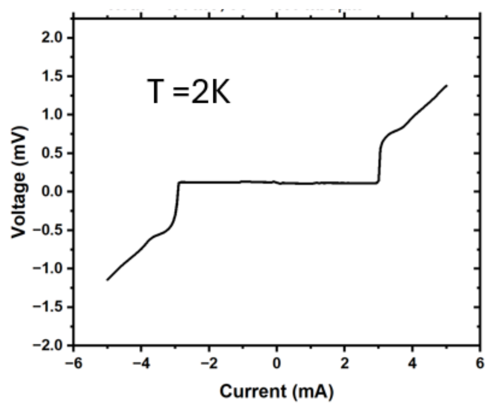

Figure 2: Advanced superconducting Josephson junction at 2 K (-456°F). Voltage vs. current curve demonstrates the characteristic current flow at 0 V.

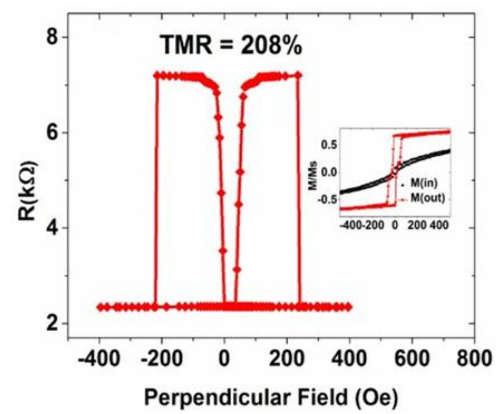

Figure 3: Ta/CoFeB magnetic tunnel junction exhibits high tunneling magnetoresistance (TMR). Unlike thick Mo layers at the interface that exhibit a strong crystalline texture, our Mo dusting layer combines the advantages of Mo as a good thermal barrier and Ta as a good boron sink, yielding TMR of 208% with superior thermal stability at 500°C.

More information: WG Wang et al., Electric-field-assisted switching in magnetic tunnel junctions. *Nature Mater* (2012) doi: 10.1038/nmat3171