SEMICONDUCTORS & MICROELECTRONICS
NANOELECTRONICS & NANOSTRUCTURES

We develop graphene nanoribbons (GNRs), a tunable class of low-dimensional quantum materials with intriguing semiconducting properties, and **topological acoustic (TA) wave devices**, a promising platform for next-generation radio-frequency (RF) and sensing systems.

GNRs, synthesized through bottom-up, on-surface methods, offer high charge mobility and current-carrying capabilities, making them ideal candidates for field-effect transistors (FETs). GNR-based FETs could outperform Si transistors in performance and energy efficiency while enabling new functionalities. Today, a gap remains between theoretical potential and experimental performance. We improve GNR charge transport, with a focus on contact and dielectric interface engineering, bandgap tuning, and device architecture optimization. We develop scalable integration strategies, such as wafer-scale synthesis, ribbon alignment, etch-freetransfer, and growth on insulating substrates. Our goal is to incorporate GNRs into high-performance transistors and advanced systems capable of operating beyond silicon's limits, ultimately to create the first graphene-based microprocessor, with an output of, "`Hello, world. I am the first graphene computer.`"

We also develop **surface acoustic wave (SAW)** devices to realize TA phenomena, leveraging engineered band structures and topological protection for robust, low-loss acoustic wave propagation. We aim to establish SAW-based platforms for scalable communication, signal processing and quantum-enhanced sensing and biosensing technologies. We have demonstrated chip-scale SAW devices, using maskless lithography and laser-written periodic features to manipulate wave behavior. Femtosecond laser ablation enables precise surface features, such as trench patterns, to create acoustic bandgaps and tailored stop-band behavior, essential for topologically-protected states. Our research includes digital mask design, photolithography, micro-and nano-fabrication on piezoelectric substrates, and characterization such as S-parameter analysis. Our models guide optimization of design parameters that include trench width, pitch, and laser processing conditions.

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Zafer researches (i) the design, fabrication, and electrical characterization of atomically-precise electronic devices, including GNR-based FETs, to develop high-performance, energy-efficient logic technologies beyond silicon; and (ii) the development of TA wave phononic devices to advance RF technologies.

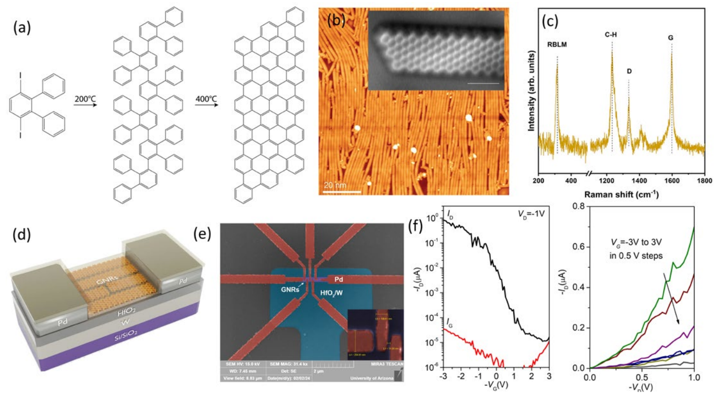

Figure 1: (**a**) Synthesis of nine-atom-wide armchair graphene nanoribbons (9-AGNRs) on Au(111)/mica using DITP precursors; (**b**) STM of 9-AGNRs (inset: nc-AFM image of a single ribbon; scale bar: 1 nm); (**c**) Raman spectrum of 9-AGNRs; (**d**) Schematic of a 9-AGNR FET with a local back gate; (**e**) Device SEM (inset: PD contacs at high-magnification); (**f**) Electrical performance of a representative device: transfer characteristics (ID–VGS, left) and output characteristics (ID–VDS, right).

More information: C. Dinh et al., Atomically Precise Graphene Nanoribbon Transistors with Long-Term Stability and Reliability. *ACS Nano* (2024) doi: 10.1021/acsnano.4c04097

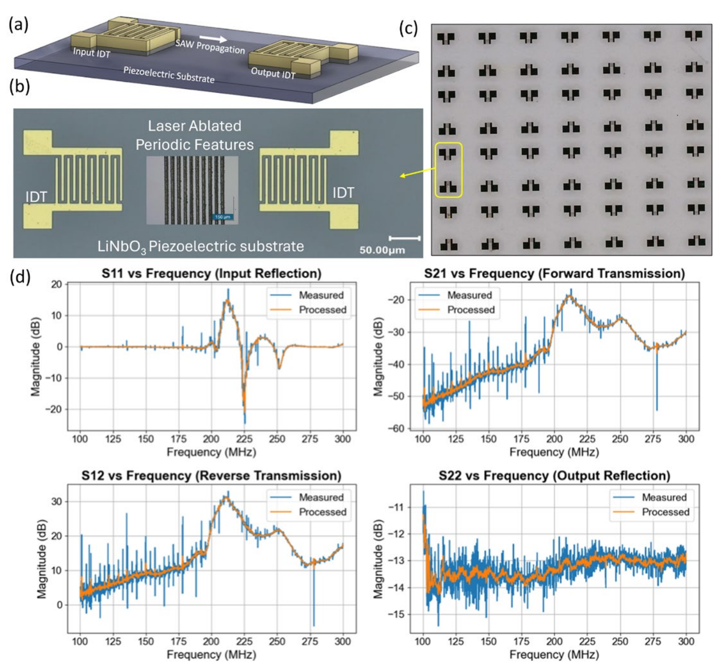

Figure 2: (**a**) SAW device schematic with input and output IDTs on a piezoelectric substrate for guided SAW propagation; (**b**) Optical micrograph of a SAW device on a $LiNbO_3$ substrate, with laser-ablated periodic features inducing acoustic bandgap effects; (**c**) Optical image of a centimeter-scale chip with an array of SAW devices for different frequencies; (**d**) S-parameter measurements from representative device.