THE MATERIALS SCIENCE AND ENGINEERING DEPARTMENT
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Uncovering the Behavior and Limits of Nanoscale Ferroelectric Switching

The ferroelectric switching speed is a critical metric behind the operations per second or latency possible in a computing technology. The fundamental limits to the switching speed are believed to be rooted in domain nucleation and growth but it has been experimentally obfuscated by the interaction between the measurement circuit and the ferroelectric switching itself. Here, I will discuss our recent investigation into sub-nanosecond polarization switching in nanoscale ferroelectrics and present two complementary models that elucidate the scaling behavior of switching dynamics across materials and circuit levels. A physics-based circuit model captures the coupling between intrinsic ferroelectric switching transients and the extrinsic response of the measurement circuitry, providing a framework to disentangle material kinetics from circuit-limited effects. Upon lateral scaling of island capacitors from micron to nanoscales, a clear transition from circuit-limited switching to a material-limited switching regime is observed. From here, we observe a switching speed limit in many-grain HZO thin film capacitors around 200 ps. The second model is a generalized and physically grounded model of polarization reversal under time-varying electric fields and extends the classical Kolmogorov–Avrami–Ishibashi (KAI) formalism. This approach produces more accurate dimensionality exponents and extraction of intrinsic materials parameters. The generalized framework recovers a classical KAI exponent as a limiting case but provides improved agreement with experimental transients including regions where a square pulse is ramping. Together, these models bridge the gap between material-level and circuit-level descriptions of ferroelectric switching, offering new insights into the mechanisms that govern sub-nanosecond polarization dynamics. From these we indicate what materials coefficients impact metrics for computing most significantly.

John Heron is now Associate Professor of Materials Science and Engineering at the University of Michigan where he leads the ferroelectronics group. The group focuses on understanding and designing ferroic properties (such as ferroelectricity and ferromagnetism) typically with an application focus toward next-generation energy efficient microelectronic devices. He is best known for his work on the pulsed laser deposition thin film ferroic and multiferroic oxides and the characterization of magnetoelectric and multiferroic materials. Particular interest resides in interface, spin, structure, and charge effects that occur in layered structures with ferroic materials, such as (anti)ferromagnets, (anti)ferroelectrics, and multiferroics. Recent interest has also emerged in novel high entropy oxide materials where composition leads to local disorder and highly tunable properties.

Tuesday, May 5th • 4 pm CT • Tech L211

In person only; no Zoom

Questions? Contact allison.macknick@northwestern.edu

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