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Nanoscale Impedance Imaging of Novel Quantum Materials

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The research of complex quantum materials, in which a dazzling number of emergent phenomena take place in the nanoscale, is a major theme in modern condensed matter physics. For real-space mapping of complex systems, electrical impedance microscopy fills an important void that is not well represented by the existing local probes. Using shielded cantilever probes and sensitive microwave electronics, we can now perform non-invasive electrical imaging with unprecedented resolution (10-100nm) and sensitivity (sub-aF). To date, this powerful technique has enabled us to visualize the electronic inhomogeneity in colossal magnetoresistance manganites, spatially resolve the topological edge channels, image the metal-insulator transition in novel field-effect transistors, and probe the anomalous conduction in multiferroic domain walls. The sub-surface imaging capability is also ideal for understanding the evolution of chemical reaction involving low-dimensional layered materials. Further development of the technique will allow us to perform local dielectric spectroscopy across a large frequency span, explore the localized microwave magnetic resonance, and study the nanoscale nonlinear electromagnetic response in complex materials.