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Topological Structures of Novel Quantum System – Views from Scanning Microwave Impedance Microscope

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Understanding and controlling local conductivity have been a corner stone for important scientific breakthroughs and technological inventions, as exemplified by transistor, integrated circuit, Anderson localization, quantum hall effect and fractional quantum hall effect. In these cases, local visualization and control of doping, mobility, gating, dielectric, heterostructure, and inter-diffusion are important. Microwave Impedance microscope provides a new platform to measure local electrical properties.

Microwave has several inherent advantages. It is coherent so both amplitude and phase information can be analyzed to gain quantitative insight. Its high frequency naturally leads to efficient capacitive coupling, thus no contact is needed for electrical measurement. It has much higher inherent contrast for electrical properties than optical microscopy, for conductivity diverges for metal but approaches zero for insulator. However, it also has two disadvantages –relatively poor spatial resolution and stray field coupling that compromises quantitative analysis.

We will report our progress in developing an AFM based, and scalable (batch processed tip) non-resonance microwave impedance microscope that achieves a resolution ~ 50 nm and reduces stray field coupling. The non-resonance approach and merge with the AFM platform also greatly reduce many of the "practical problems" that severely compromises advances of the earlier resonator based scanning microwave microscope, such as thermal drift, height control, and tip consistency –all critical for quantitative and repeatable measurements. We will show samples images from a range of materials –semiconductors, dielectrics, complex oxides, phase change memory materials, graphene, and topological insulators, also functional properties such as metal-insulator transition, semiconductor metrology, photoconductivity, imaging in water and bio-cells .

The highlight of this talk will be the physics insight we gain by applying this technique to investigate topological structures of novel quantum systems, including edge state of topological order in QHE system, the percolation pathways in colossal magnetoresistive manganites and domain walls and vertex of ferroelectric and multi-ferro systems.

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