SYSD 1: SKM Dissertation Prize Symposium

Time: Monday 9:30–12:00 Location: H2

Invited Talk SYSD 1.1 Mon 9:30 H2

Nanoscale Chemical Analysis of Ferroic Materials and Phenomena — •Kasper Aas Hunnestad — Department of Materials Science and Engineering, Norwegian University of Science and Technology, Trondheim, Norway

The discovery of new physical phenomena in materials is closely linked to the progress in characterization, and is propelled by the ability to observe and study physical processes occurring at the atomic level. In this talk, I will present how atom probe tomography (APT) can be incorporated into the toolkit of nanoscale research to study ferroelectric oxide materials. The aim is to demonstrate its feasibility and power to unravel correlations between the local chemical composition and emergent functional properties.

A range of systems with fundamental importance to ferroelectrics are investigated, including solute dopants in bulk, naturally occurring interfaces in ferroelectrics, such as grain boundaries and domain walls, and artificially grown interfaces in heterostructures. Using a correlative microscopy approach, a complex and diverse defect chemistry is revealed in 3D, which further clarify the origin of anomalous electronic properties. The work presented demonstrates the outstanding potential and general feasibility of applying APT to study ferroelectric oxide systems. Correlations between defect chemistry and ferroic phenomena can be experimentally probed with nanoscale spatial resolution, opening an avenue to obtain a deeper understanding of ferroic materials.

Invited Talk SYSD 1.2 Mon 10:00 H2

Advanced Excitation Schemes for Semiconductor Quantum Dots — •Yusuf Karli — Cavendish Laboratory, University of Cambridge, Cambridge, UK — Institut für Experimentalphysik, Universität Innsbruck, 6020, Innsbruck, Austria

Semiconductor quantum dots are nanometer-scale structures that confine electrons in three dimensions, creating discrete energy levels similar to those in atoms. This unique property makes them an excellent platform for generating high-quality single photons with high purity and indistinguishability. As such, they are critical for advancing quantum technologies, serving as essential building blocks for quantum communication, quantum computing, and photonic quantum networks.

In this talk, I address practical challenges associated with traditional excitation methods for semiconductor quantum dots by introducing innovative approaches. These include below-bandgap excitation (the SUPER scheme), a two-pulse technique (Stimulated TPE), and Adiabatic Rapid Passage (ARP). These methods enhance robustness, improve photon indistinguishability, and enable efficient population transfer, positioning semiconductor quantum dots as reliable and scalable sources for quantum photonic systems.

Invited Talk SYSD 1.3 Mon 10:30 H2

Aspects and Probes of Strongly Correlated Electrons in Two-Dimensional Semiconductors — •Clemens Kuhlenkamp — Harvard University, Cambridge, USA

Due to their high level of control two-dimensional (2D) materials are emerging as fascinating platforms to explore correlated electronic phases of matter. In this talk, I will discuss opportunities to control, prepare, and probe exotic states in structures of transition metal dichalcogenides (TMDs), a class of 2D semiconductors. Remarkably, already a single TMD layer can reach an interaction-dominated regime upon doping electrons. By analyzing the optical response of the material, we directly reveal the formation and properties of an electronic Wigner crystal—a state where electrons break translational symmetry by arranging in a triangular lattice. Moving on to multi-layer TMDs, I will demonstrate how Moiré patterns—arising from misalignments between the layers—can realize highly tunable, frustrated Hubbard models in the presence of large magnetic fields. Our theoretical analysis predicts that such materials can exhibit exotic insulator-to-insulator transitions and give rise to exceptionally robust spin liquid phases in the Mott insulating limit. I will conclude with an outlook on future directions, particularly highlighting opportunities to realize unconventional superconductivity.

Invited Talk SYSD 1.4 Mon 11:00 H2

Mean back relaxation and mechanical fingerprints: simplifying the study of active intracellular mechanics — •Till Münker — Third Institute of Physics - Biophysics, University of Göttingen, 37077 Göttingen

Vital cellular functions rely on the interplay between the viscoelastic mechanical properties of the cytoplasm and the active force generated by the consumption of metabolic energy. However, quantifying these properties poses significant challenges due to the complexity of the physical quantities and the elaborate, low-throughput experimental methods required for their investigation. We propose two techniques to meet these challenges. Firstly, we introduce a mechanical fingerprint that reduces the complexity of intracellular active mechanical properties to six parameters. We demonstrate how the fingerprint captures changes in mechanics upon disrupting cytoskeletal components and enables identification of individual cells through their unique fingerprint. By introducing a phase space of resistance, activity, and fluidity, we observe how position in phase space correlates with expected cell function. Secondly, we introduce the Mean Back Relaxation (MBR) as a novel statistical tool to determine the breaking of detailed balance in confined systems. In living cells, we observe surprising relations between the MBR and intracellular activity. Strikingly, by deploying this relation, we determined the mechanical properties of MDCK cells by purely passive observations. Together, these techniques simplify the quantification of intracellular mechanics, reducing experimental complexity while enhancing throughput.

Invited Talk SYSD 1.5 Mon 11:30 H2

Coherent Dynamics of Atomic Spins on a Surface — •Lukas Veldman — TU Delft, Department of Quantum Nanoscience, Delft, The Netherlands — University of Stuttgart, Institute for Functional Matter and Quantum Technologies, 70569 Stuttgart, Germany

Studying dynamical interactions between individual spins is vital for understanding exotic magnetic materials as well as for development of applications that require control over solid state spins like spintronics and quantum computation. Here, we introduce the possibility to inject a single spin flip with atomic precision into a magnetic nanostructure and trace the resulting coherent spin dynamics. We achieve this by combining electron spin resonance (ESR) and DC pump-probe techniques with scanning tunneling microscopy (STM). In our first proof-of-concept measurement, we apply this method to two coupled Ti atoms and resolve the resulting coherent flip-flop oscillations between their electron spins [1]. Next, we investigate larger structures up to 6 spins and study magnon dynamics in the few-atom limit [2]. Lastly, we resolve the magnetic dynamics between an electron and a nucleus within a single atom [3,4], further expanding the potential of this new measurement scheme to nuclear spins. These experiments add to the understanding of the microscopic mechanism behind magnetic interactions and open the door to detailed control of individual spins on surfaces for quantum coherent applications. [1] L.M. Veldman et al., Science 372 (2021) [2] L.M. Veldman et al., in preparation [3] L. Farinacci, L.M. Veldman et al., Nano Lett. 22 (2022) [4] L.M. Veldman et al., Nat. Commun. 15 (2024)