Department of Materials Science and Engineering Seminar Series 2025

NONLINEAR TRANSPORT AND ELECTRICAL SWITCHING OF SPIN ORDERS IN VAN DER WAALS AND CHIRAL ANTIFERROMAGNETIC SYSTEMS

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Date and time: 8th May 2026, 10:00 am – 12:00 pm

Venue: EA-02-15

Abstract

In spintronics and magnetic information technology, functional antiferromagnets offer the advantages of robust magnetic order, accessible electrical readout, and energy-efficient electrical switching. This thesis advances van der Waals and chiral antiferromagnetic materials as promising platforms toward that goal by showing how symmetry, interfacial spin-orbit coupling, and noncollinear spin textures can be harnessed to generate measurable nonlinear transport responses and controllable spin-orbit-torque-driven dynamics. This work establishes a pathway to overcoming the key read/write bottlenecks in antiferromagnetic spintronics while preserving the intrinsic advantages of antiferromagnets, including ultrafast dynamics, negligible stray fields, and robustness against external perturbations.

The study develops this theme in three stages. It begins with the van der Waals antiferromagnet $CrPS_4$, in which a pronounced unidirectional magnetoresistance is realized in $CrPS_4$/Pt heterostructures and shown to originate from the interplay between interfacial spin-orbit coupling and spin canting, enabling sensitive electrical detection of small variations in antiferromagnetic coupling. It then turns to the chiral antiferromagnet $Co_{1/3}TaS_2$, in which a nonvolatile third-order nonlinear Hall effect is observed and linked to a quantum-geometric intrinsic mechanism associated with magnetic spin chirality, providing an additional electrical readout channel for chiral order. Finally, the thesis demonstrates field-free, all-electrical switching of perpendicular chiral antiferromagnetic order in Mn_3Sn/WTe_2, achieving room-

temperature bidirectional switching with a switching ratio exceeding 80% and a markedly reduced critical current density. Taken together, these results present nonlinear transport and spin-orbit torque engineering not as isolated phenomena, but as a coherent strategy for realizing antiferromagnetic spintronic devices with both electrical readout and electrical writeability.

Biography

Jia Lanxin is currently a Ph.D. candidate in the Department of Materials Science and Engineering at the National University of Singapore under the supervision of Professor Chen Jingsheng. His doctoral research focuses on spintronics and van der Waals materials, reflecting a broad interest in the design and understanding of emerging functional materials for next-generation electronic and spin-based devices.

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