MA 43: Spin-Dependent Phenomena in 2D

Time: Thursday 9:30–11:15 Location: POT/0112

Invited Talk MA 43.1 Thu 9:30 POT/0112

Defect-Induced Phase Transitions in the 2D Magnetic Semiconductor CrSBr — •Shengqiang Zhou — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

As an air-stable van der Waals magnetic semiconductor, CrSBr has attracted great research interest due to its exceptional optical, electronic, and magnetic properties [1]. Below its Néel temperature of 132 K, CrSBr exhibits a typical A-type antiferromagnetic order consisting of antiferromagnetically coupled ferromagnetic monolayers [1, 2]. In this talk, I will present the magnetic phase transition from antiferromagnetic to ferromagnetic order in CrSBr induced by ion irradiation [3, 4]. We observe the emergence and subsequent suppression of the ferromagnetic phase in CrSBr as the irradiation fluence increases. Structural analysis combined with first-principles calculations suggests that the formation of interstitials promotes ferromagnetic coupling between the layers. At moderate irradiation fluences, the Curie temperature gradually decreases, reflecting the impact of crystalline degradation. Surprisingly, at even higher irradiation fluences, CrSBr does not amorphize but instead transforms into a new crystalline phase. These findings indicate that, by precisely tuning irradiation parameters and employing lithography techniques, one can selectively modulate the induced ferromagnetism in CrSBr in terms of magnetization strength, critical temperature, and spatial distribution. [1] E.J. Telford, et al. Adv. Mater., 32, 2003240 (2020). [2] F. Long, et al. Appl. Phys. Lett. 123, 222401 (2023). [3] F. Long, et al. Nano Lett. 23, 8468 (2023). [4] F. Long, et al. Adv. Phys. Res., 3, 2400053 (2024)

MA 43.2 Thu 10:00 POT/0112

Electric-field tunable valley excitons in proximity coupled WSe_2/CrI_3 heterostructures — Felix Hellenkamp[1], •Yiheng Li[1], Marc Schütte[1], Kenji Watanabe[2], Takashi Taniguchi[3], Lutz Waldecker[1], Christoph Stampfer[1,4], and Bernd Beschoten[1] — [1]2nd Institute of Physics and JARA-FIT, RWTH Aachen University, Germany — [2]National Institute for Materials Science, Tsukuba, Japan — [3]International Center for Materials Nanoarchitectonics, NIMS — [4]PGI-9, Forschungszentrum Jülich, Jülich, Germany

Two-dimensional (2D) transition metal dichalcogenides have attracted significant interest due to their unique optical properties. The possibility to address the K and K' valley selectively via σ^+ and σ^- polarized light enables optical initialization and readout of the valley degree of freedom. The valley degeneracy can be lifted via magnetic proximity coupling to a 2D magnet such as CrI_3. However, in the heterostructures the resulting exciton splitting lacks tunability, limiting its applicability in device architectures that demand adjustable valley splitting. Our work shows a large tunability of the exciton splitting in a WSe_2/CrI_3 heterostructure via external displacement fields. Reflection contrast measurements show a displacement field induced change in the exciton resonance energy which is asymmetric with respect to the excitons at the K and K' valleys, leading to a 35% increase in exciton splitting at a displacement field of -0.4V/nm. We attribute the change in resonance energy to a reduction in the optical bandgap, caused by a displacement-field-induced modification in the band alignment.

MA 43.3 Thu 10:15 POT/0112

Atomic-scale visualization of quasi-one-dimensional structure and magnetic-field-tunable electronic statesin CrSBr — •Keda Jin[1,2], Tobias Wichmann[1,3], F. Stefan Tautz[1,3], Felix Lüpke[1,4], Jose Martinez-Castro[1,2], and Markus Ternes[1,2] — [1]Peter Grünberg Institut (PGI-3), Forschungszentrum Jülich, 52425 Jülich — [2]Institut für Experimentalphysik II B, RWTH Aachen, 52074 Aachen — [3]Institut für Experimentalphysik IV A, RWTH Aachen, 52074 Aachen — [4]Institute of Physics II, Universität zu Köln, 50937 Köln

The anisotropic two-dimensional (2D) van der Waals magnet CrSBr is famous for hosting a quasi-one-dimensional (1D) electronic structure, but its direct visualisation has remained elusive.

Using low-temperature scanning tunnelling microscopy and spectroscopy, we present the atomic-scale characterisation of this quasi-1D conduction bands in monolayer CrSBr on $NbSe_2$. Our measurements reveal a spatial anisotropy in the local density of states, confirming the existence of conduction bands that are flat along one crystallographic direction but dispersive along the perpendicular direction. Moreover, we demonstrate that an applied magnetic field reconstructs its electronic structure, showcasing strong magneto-electronic coupling. Our work provides the real-space visualisation of the long-predicted electronic anisotropy and establishes its potential for developing magnetically-tunable low-dimensional electronic devices.

MA 43.4 Thu 10:30 POT/0112

Origin of Exchange Bias in Compensated and Orthogonal Spin Interfaces in vdW Heterostructures — •Aditya Kumar[1], Aravind Balan[1], Patrick Reiser[2], Sadeed Hameed[1], Thibaud Denneulin[3], Rafal E. Dunin-Borkowski[3], Patrick Maletinsky[2], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Staudinger Weg 7, 55128 Mainz, Germany — [2]Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland — [3]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Forschungszentrum Jülich, 52425 Jülich, Germany

Van der Waals heterostructures formed by mechanical stacking can create atomically flat, defect-free interfaces, yet exhibit exchange bias in expected compensated and orthogonal spin configurations. This work investigates the underlying spin-pinning mechanisms in heterostructures of out-of-plane ferromagnet Fe_3GeTe_2 interfaced with c-type out-of-plane antiferromagnet $MnPS_3$ and in-plane a-type antiferromagnet CrSBr. Using NV magnetometry and STEM holography imaging, we reveal distinct exchange bias origins: the spin reorientation transition in $MnPS_3$ induces large, robust exchange bias, while orthogonal coupling at the Fe_3GeTe_2/CrSBr interface generates circular flux closure domains that produce switchable exchange bias. [1] A. P. Balan et al., Advanced Materials 36, 2403685 (2024). [2] A. Kumar et al., Small 21, e06284 (2025).

MA 43.5 Thu 10:45 POT/0112

Spin-polarized scanning tunneling microscopy of antiferromagnetic spin ordering in a topological Hall material — Alexina Ollier[1,2], Valeria Sheina[1,2], Seik Pak[4], Corina Urdaniz[1,2], Muskan Sande[1,3], Soonhyung Lee[1,2], Lei Fang[1,2], Christoph Wolf[1,2], Woonghee Cho[6], Pyeongjae Park[7], Andreas Heinrich[1,3], Je-Geun Park[6], Moon jip Park[4,5], and •Won-Jun Jang[1,2] — [1]Center for Quantum Nanoscience (QNS), Institute for Basic Science (IBS), Seoul, Korea — [2]Ewha Womans University, Seoul, Korea — [3]Department of Physics, Ewha Womans University, Seoul, Korea — [4]Department of Physics, Hanyang University, Seoul, Korea — [5]Research Institute for Natural Science and High Pressure, Hanyang University, Seoul, Korea — [6]Department of Physics and Astronomy, Seoul National University, Seoul, Korea — [7]Materials Science and Technology Division, Oak Ridge National Laboratory, Tennessee, USA

We report spin-polarized scanning tunneling microscopy measurements on Co1/3TaS2. STM images acquired with a conventional tip reveal the triangular atomic lattice of the surface, whereas SP-STM uncovers additional symmetry features directly linked to the spin-polarized electronic structure of TaS2 arising from the triple-Q magnetic order. The spin-dependent contrast observed with the SP tip confirms the presence of spin-polarized van Hove singularities, a hallmark of the non-coplanar magnetic state. These results demonstrate that SP-STM can directly probe the modified electronic structure arising from chiral magnetic textures in non-coplanar magnets.

MA 43.6 Thu 11:00 POT/0112

Super-Moiré Spin Textures in Twisted 2D Antiferromagnets — •King Cho Wong[1], Ruoming Peng[1], Eric Anderson[2], Jackson Ross[3], Adam Wei Tsen[4], Elton Santos[3], Xiaodong Xu[2], and Joerg Wrachtrup[1] — [1]3rd Physics Institute, University of Stuttgart, Stuttgart, Germany — [2]University of Washington, Seattle, USA — [3]University of Edinburgh, Edinburgh, UK — [4]University of Waterloo, Canada

Stacking two-dimensional (2D) layered materials offers a platform to engineer electronic and magnetic states. In general, the resulting states - such as Moiré magnetism - have a periodicity at the length scale of the Moiré unit cell. Here, we study magnetic order in twisted double bilayer chromium triiodide (tDB CrI3) by means of scanning nitrogenvacancy microscopy. We observe long-range magnetic textures extending beyond the single Moiré unit cell, which we dub a super-Moiré magnetic state. At small twist angles, the size of the spontaneous magnetic texture increases with twist angle, opposite to the underlying Moiré wavelength. The spin-texture size reaches a maximum of about 300 nm in 1.1° twisted devices, an order of magnitude larger than the underlying Moiré wavelength. The vector field maps suggest the formation of antiferromagnetic Neel-type skyrmions spanning multiple Moiré cells. The twist angle dependent study combined with atomistic simulations suggests that magnetic competition between the Dzyaloshinskii-Moriya interaction, magnetic anisotropy, and exchange interactions produces the super-Moiré spin orders.