Altermagnets: An unconventional magnetic class

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Conventional magnets can be divided in two basic classes – ferromagnets and anti-ferromagnets. In the first part of the talk, we will recall that the ferromagnetic order offers a range of phenomena for energy efficient IT, while the vanishing net magnetization in antiferromagnets opens a possibility of combining ultra-high energy efficiency, capacity and speed of future IT [1-4]. In the main part of the talk we will move on to our recent predictions of instances of strong time-reversal symmetry breaking and spin splitting in electronic bands, typical of ferromagnetism, in crystals with antiparallel compensated magnetic order, typical of antiferromagnetism [5-8]. We resolved this apparent fundamental conflict in magnetism by symmetry considerations that allowed us to classify and describe a third basic magnetic class [6,7]. Its alternating spin polarizations in both crystal-structure real space and electronic-structure momentum space suggested a term altermagnetism. A d-wave spin-polarization order in altermagnets is a direct counterpart of the unconventional d-wave superconducting order in cuprates. We will discuss predictions and initial experimental verifications [9,10] in which altermagnets combine merits of ferromagnets and antiferromagnets, that were regarded as principally incompatible, and have merits unparalleled in either of the two conventional magnetic classes. We will introduce the broad materials landscape of altermagnetism and show how its unconventional nature enriches fundamental concepts in condensed matter physics, such as the Kramers theorem [10]. We will show that this underpins a development of a new avenue in spintronics, elusive within the two conventional magnetic classes, based on strong and conserving spin phenomena, without magnetization imposed scalability limitations.

References

[1] P. Wadley, T. Jungwirth et al., Science 351, 587 (2016)
[2] T. Jungwirth et al., Nature Nanotech. 11, 231 (2016)
[3] Z. Kaspar, T. Jungwirth et al., Nature Electron. 4, 30 (2021)
[4] F. Krizek T. Jungwirth et al., Science Adv. 8, eabn3535 (2022)
[5] L. Smejkal, T. Jungwirth et al., Science Adv. 6, eaaz8809 (2020)
[6] L. Smejkal, T. Jungwirth et al., Nature Rev. Mater. 7, 482 (2022)
[7] L. Smejkal, J. Sinova, T. Jungwirth, Phys. Rev. X 12, 031042 (2022)
[8] L. Smejkal, J. Sinova, T. Jungwirth, Phys. Rev X (Perspective) 12, 040501 (2022)
[9] Z. Feng, T. Jungwirth et al., Nature Electron. 5, 735 (2022)
[10] J. Krempasky, T. Jungwirth et al., Nature 626, 517 (2024)