Sonderforschungsbereich 1277

Emergent Relativistic Effects in Condensed Matter -
From Fundamental Aspects to Electronic Functionality

SFB – Colloquium

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Topic: Designing quantum materials with strong spin-orbit interaction

Abstract:

Oxide compounds constitute a wide material class featuring a wealth of quantum phenomena and functionalities governed by the interplay of various degrees of freedom and electron correlation effects. Particularly, materials with a large spin-orbit coupling interaction (SOI) are nowadays in the spotlight. Large SOI affects both electronic and magnetic structure and is anticipated to lead to the emergence of novel electronic quantum phases laying the ground to future technologies. Thereby, the control of materials and their interfaces is a pivotal way to engineer artificial structures where new electronic phases can emerge. A serious leap forward has been achieved in epitaxial control of oxide thin films, that lead to the observation of the quantum Hall effects in ZnO and $SrTiO_3$, testimony of a high interface quality [1, 2].

In this talk, I will discuss a surprising observation of the SOI in a high mobility two-dimensional electron system of ZnO heterostructures [3], which constitutes perhaps one of the tantalizing aspects of rich spin physics found in ZnO [4, 5]. SOI appears in the regime of strong Coulomb interaction, where the SOI can profoundly compete against Coulomb interaction and lead to the emergence of unconventional electronic and spin phases. Furthermore, I will present the recent result on the systematic emergence of an interfacial superconducting state in epitaxial heterostructures of Mott insulator $LaTiO_3$ and band insulator $KTaO_3$ with large spin-orbit coupling [6]. The $LaTiO_3$ layer has a non-trivial impact on the emergence of the superconducting phase. With increasing $LaTiO_3$ thickness, the superconducting transition temperature decreases and a finite resistance remains below the transition. Such $LaTiO_3/KTaO_3$ interface enables to explore the interplay between correlation effects and the spin-orbit coupling, one of the outstanding problems in modern solid state physics [7].

[1] A. Tsukazaki et al., *Nat. Mater*. **9**, 889 (2010).
[2] Y. Matsubara et al., *Nat. Commun.* **7**, 11631 (2016).
[3] D. Maryenko et al., *Nat. Commun.* **12**, 3180 (2021).
[4] D. Maryenko et al., *Nat. Commun.* **8**, 14777 (2017).
[5] D. Maryenko et al., *Phys. Rev. Lett.* **115**, 197601 (2015).
[6] D. Maryenko et al., *APL Mater.* **11**, 061102 (2023)
[7] W. Witczak-Krempa et al., *Annu. Rev. Condens. Matter Phys.* **5**, 57 (2014).

Host: Prof. Dr. Jörg Wunderlich