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The Interplay of Electron Correlation, Electron-Phonon Coupling, and Nontrivial Topology in High Temperature Superconducting FeSe/SrTiO₃ Heterostructure

Monday 1 December 2025 11:00 (30 minutes)

High-temperature superconductivity and topological phase transition are among the most debated and intriguing phenomena in modern condensed matter physics. Their combined manifestation in either a single or hybrid material structure is of great interest for exhibiting Majorana zero modes. So far, the study of topological materials and the role of electron-phonon coupling in superconductivity has been focused mostly on the single-particle regime. Two fundamentally unaddressed questions are: (a) how the correlation affects the coupling with phonon and vibrational properties to determine high-temperature superconductivity [1, 2], and (b) what will happen when strong electron-electron interactions drive a topological system far from the single-particle limit, potentially causing electrons to be localized [3]. Here, by exploiting the interplay between electron and lattice through the combination of first principles embedded dynamical mean field theory (eDMFT) calculations and epitaxial growth, ARPES, and STM/S measurements, we demonstrate (a) sensitivity of superconducting transition temperature (T_c) as a function of tetrahedral bond angle and (b) the evidence of topological superconductivity in FeTe_{1-x}Se_x thin film grown on a SrTiO₃(001) substrate [3]. We demonstrate a unique topological superconducting phase in competition with electronic correlations [3]. Additionally, we show that the measured superconducting gap and eDMFT computed phonon coupling with correlated electrons follow a similar superconducting dome as a function of a Se-Fe-Se angle [4]. Our work demonstrates that doping FeSe thin films can create a unique platform where electronic correlations sensitively modulate both superconductivity and topological superconductivity, offering opportunities to tune electron-electron interactions and engineer new topological phases in a broad class of materials [3-5].

References:

- [1] S. Mandal, et al. PRB 89, 220502(R) (2014).
- [2] S. Gerber et al. Science 357, 71 (2017).
- [3] H. Lin, et al. arXiv:2503.22888 Nature (under review)
- [4] Q. Zou, et al. arXiv:2506.22435
- [5] S. Mandal, et al. PRL. 119, 067004 (2017).

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