Abstract

The discovery of topological insulators (TIs) established that quantum phases can be characterized by global topological invariants rather than local order parameters. While topological band theory has been highly successful in describing noninteracting systems, the role of strong electron–electron interactions remains an important open problem. This thesis explores how electronic correlations can both generate new topological phases and reconstruct existing topological states beyond the conventional band-theory framework.

In the first part of this thesis, we investigate interaction-driven topological phases in a two-dimensional generalized Su–Schrieffer–Heeger (SSH) model using a self-consistent Hartree–Fock approach. We chart out the phase diagram of a semimetal with a quadratic band-touching point and identify an interaction-induced quantum anomalous Hall (QAH) phase characterized by a nonzero Chern number. Besides the QAH phase, interactions stabilize several competing charge- and bond-ordered states, including a bond-nematic Dirac semimetal (BNDS) phase not reported in earlier mean-field studies. We further show that an onsite potential suppresses the interaction-driven QAH phase while significantly enlarging the stability region of the BNDS phase, highlighting the rich interplay between symmetry breaking and topology in systems with an enhanced low-energy density of states.

The second part of the thesis focuses on the impact of strong correlations at interfaces two between distinct insulators. We investigate a heterostructure composed of a ferrimagnetic Mott insulator and a time-reversal-invariant topological insulator on a Lieb lattice. By combining Hartree–Fock and slave-rotor mean-field methods, we show that topological boundary modes can survive in a buried form at the interface despite the presence of strong correlations. Furthermore, proximity-induced magnetization generates a spin imbalance in the helical edge states. Owing to spin–momentum locking, this imbalance converts a dissipationless spin current into a topologically protected charge current, providing a novel interaction-driven mechanism for controlling interfacial transport.

Overall, this thesis demonstrates that electron–electron interactions can both create and reconstruct topological phases. The results provide new insights into correlated topological matter and broaden the understanding of topological phenomena in strongly interacting

systems.