INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

We study the evolution of the topological properties of Chern insulators subjected to band engineering for a variety of systems, such as, the honeycomb lattice, dice lattice, bilayer honeycomb lattice etc. Since topology is inextricably related to band properties, engineering band deformities results in the evolution of the topological invariants and may even induce phase transitions. In particular, a honeycomb lattice under deformation demonstrates vanishing of the Dirac electrons, and eventually yields a scenario where the electronic dispersion is linear in one direction and quadratic along the other one. This is known as the semi-Dirac dispersion. A variety of materials and cold atomic systems, demonstrate such a dispersion. Further, the inclusion of the Haldane flux breaks the time-reversal symmetry (TRS) and creates an energy gap in the spectrum which makes the system a topological (Chern) insulator. The topological gap vanishes in the semi-Dirac limit, which, however reopens upon further deformation. The nature of the gaps prior to, and beyond the semi-Dirac limit have distinct features (TRS remains broken all the while), and have been elaborately studied in the thesis. Going a step ahead of the traditional Haldane model, we have considered a third neighbour hopping, in presence of which the system exhibits higher Chern number C, such as, $C=\pm 2$, along with $C=\pm 1$. Further, a bilayer Haldane system with Bernal stacking exhibits differential behaviour of the bands that are closer to the Fermi level than the ones further away from it. Multiple topological phase transitions are realized for such a bilayer model. Moreover, a dice lattice, which not only is an interesting extension of the honeycomb structure of graphene, it also hosts a flat band that is in general relevant for studying strong electronic correlations. As in the earlier case, the system possesses topological regions with higher Chern numbers, however, it shows topological phase transitions straight from $C=\pm 2$ phases to a $C=0$ phase (trivial insulator). In all of these cases, we have depicted the phase diagrams to support the topological phase transition occurring therein via the presence or the absence of edge currents in semi-infinite ribbon geometries, and evolution of the plateau in the anomalous Hall conductivity in presence of band engineering. The corresponding scenario in a quantum spin Hall insulator described by a Kane-Mele model has been explored and the spin resolved bands respond in no different manner to the band deformation as shown via computing the Z_2 invariant. The evolution of the spin Hall response shows vanishing of the quantum spin hall phase in the semi-Dirac limit.