Tunability of the critical width of a 2D-TI

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Topological Insulators (TI) is a new class of materials that exhibit bulk-insulating properties [1] but possess conducting states on the surface. These conducting surface states, hitherto undiscovered, are determined to be a new class of materials. These surface states are spin-polarized, and their spin texture [2] protected through time reversal symmetry forbids electron back scattering and induces high mobility channels. Several materials exhibit these properties and are subject of intense research worldwide.

One of the key requirements to produce TI like states in materials is band inversion. An inversion of the band structure has to pass through a Dirac point [3] where the conduction and valence bands touch before splitting up in a negative energy-gap region. The Dirac cone produced at a certain material dependent dimension is the precursor to TI surface states. We demonstrate that the critical dimension for a CdTe/HgTe/CdTe heterostructure, which is found to support TI states [3] on the edge, is tunable through suitable external parameters. Tunability offers scope for practical use of TIs either as building blocks for transistors of varying dimensions or as a switch in an electric circuit.

The Dirac cone is observed to appear for a 6.3nm thick HgTe quantum well flanked by CdTe barriers of equal dimensions. We apply several techniques to alter this critical dimension (CD), including 1) Temperature. Alteration of the band-gap (which is temperature dependent) varies the CD. A lower temperature is found to be better suited in our case 2) Substitution of the HgTe well with a $Cd_xHg_{1-x}Te$ alloy and adjustment of the stoichiometric composition 3) A combination of temperature and stoichiometry 4) The CdTe barriers are changed to $Cd_xHg_{1-x}Te$ alloy and the barrier band-gap is influenced through temperature and stoichiometry 5) Application of electric field. A sufficiently strong electric field can invert the band-structure and induce conducting states in a normal insulator 6) Crystallographic orientation of the quantum well and barrier material 7) External strain to quantum well and barrier interface.

Simulations are performed on multiple heterostructures of various dimensions within the 8-band k.p band model [4]. Strain is added to the k.p Hamiltonian by Bir-Pikus deformation potentials.

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