Magnetic topological insulators and heterostructures

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Three-dimensional topological insulators (TIs) are narrow gap nonmagnetic semiconductors with the bulk band gap inverted due to the spin-orbit coupling [1]. Because of that, at their surfaces there appear conducting two-dimensional states with linear dispersion, called topological surface states. The electron spins of the topological surface state are locked within the surface plane perpendicular to the momentum and the electrons are therefore protected from elastic backscattering on defects unless the time-reversal symmetry is preserved. Curiously, although it is the latter symmetry that endues TIs with such an extraordinary property, the TI community has been chasing ways of breaking that symmetry ever since the discovery of these materials. The central goal here is to achieve the surface metal-insulator transition by splitting the topological surface state due to introduction of magnetism to a TI, which would give rise to many fascinating and technologically promising phenomena.

In this *tutorial*, we will discuss the purposes for the time-reversal symmetry breaking in TIs by considering the exotic phenomena that can be achieved in this way, such as quantized anomalous Hall and magnetoelectric effects [2]. Then, an extensive overview of the most common ways of introducing magnetism to TIs will be given. Namely, we will start by considering two types of magnetic doping approaches (i.e., the surface and the bulk ones), continue by magnetic proximity effect and novel magnetic topological interfaces, and conclude by consideration of the recently discovered intrinsic magnetic TIs. For all of these cases, the current experimental state-of-the-art will be overviewed with an emphasis on the latter class, represented by the compounds of the $MnBi_2Te_4$ family [3] that attract a great deal of attention nowadays. Finally, an outlook will be given, summarizing the preceding parts and discussing further possible directions of development of the field.

References

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