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Topological Insulators, Superconductors and Majorana Fermions

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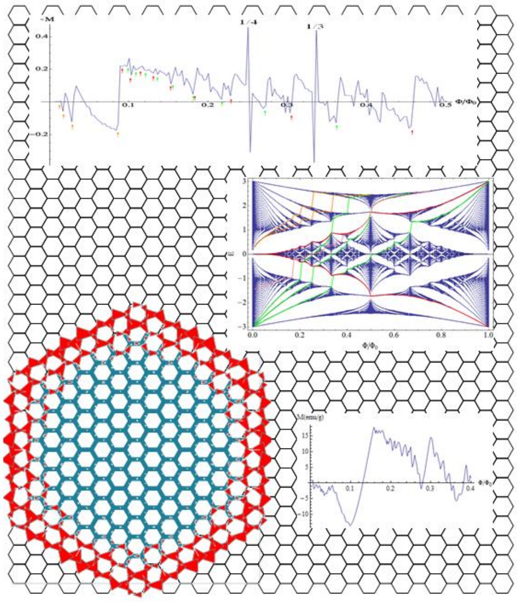
I am going to present a short introduction into physics of Dirac materials and Majorana fermions. In particular I will shortly review the main physical properties of various two-dimensional crystals such as graphene, silicene, germanene and others. I will comment on the origin of their buckled two-dimensional shape, and address the main issues created by Mermin-Wagner theorem prohibiting the existence of strictly two-dimensional crystals. Then I will describe main ideas which were leading to the discovery of two and three-dimensional topological insulators and Weyl fermions. I will describe some of their outstanding electronic properties which have been originating due to the existence of the Dirac gapless spectrum. I will also discuss possible realization of Dirac materials in super-cooled gases. Analogies and differences between Dirac materials and optics will be also addressed. Following original idea[1] leading to a discovery of Topological Insulators we describe the recent developments of the subject in a detail. In particular we focus on Topological Superconductors and Majorana Fermions. Such Majoranas have strong potential to be used in various graphene devices[2] as well as in future topological adiabatic quantum computers[3] due to their non-Abelian braiding statistics. We describe the theory of topological insulators and superconductors and show how Majorana fermions and topological superconductivity may arise. Graphene is not flat and has microscopic lattice nano-corrugations inherent to all two-dimensional crystals[4]. We show that such corrugations may provide channeling opportunities used in a new design of a creation of Majoranas. The graphene lattice distortions can not only generate the state of topological insulator but also induce the magnetization oscillations and the Hofstadter butterfly in graphene flakes[5]. We discuss also physical properties of Zener tunnelling nano-devices[6,7] and Aharonov-Bohm effect in graphene nanoring focusing on the case when there are arising levitons[7]. Graphene bubbles is another example where topological states may exist[8]. We also discuss tunneling and stochastic phenomena arising in these systems[9,10].



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