Quantum Hall Effect in Hybrid Heterostructures Based on Graphene

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The quantum Hall effect (QHE) in graphene and graphene-based heterostructures is significantly distinct in comparison to conventional two-dimensional (2D) systems, such as Si/SiO_2 MOSFETs or III-V quantum wells, due to the relativistic nature of its charge carriers. Just a few years after the first isolation of graphene, the QHE was reported at room temperature in a high mobility exfoliated flake of graphene [1]. Nearly a decade later, a robust "giant" QHE plateau (over 50 T long) was observed in a graphene film grown on SiC at T < 120 K [2], attributed to charge transfer from the SiC substrate. Similar giant QHE plateaus have been reported in graphene/metal chalcogenide heterostructures where charge transfer at the van der Waals interface and subsequent pinning of the chemical potential in the energy gap between Landau levels can elongate the plateau and stabilise the QHE to high temperature (T < 200 K) [3].

In this presentation, I will expand upon the techniques for modifying the QHE in graphene through interaction with other low-dimensional materials by engineering hybrid heterostructures. I will discuss our most recent work on different material systems including the giant QHE plateau and room temperature QHE both observed in a graphene/In_2Se_3 heterostructure (up to 60 T), where charge transfer between the In2Se3 and graphene can be controlled by introducing a separating hBN layer. Another structure of interest is graphene coupled to a ferroelectric insulator, $CuInP_2S_6$, where we observe room temperature QHE in fields as low as 15 T [4]. I will also discuss the effects of slow charge transfer between graphene and inorganic perovskite nanocrystals and the use of pulsed magnetic fields to probe charge carrier dynamics in these systems [5]. Finally, I will look at a 'new' type of graphene in the form of 3D printed graphene flake networks whereby the material properties are governed by a combination of both classical and quantum phenomena, revealed in high (up to 60 T) magnetic field experiments [6].

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