Anomalous sequence of quantum Hall liquids revealing tunable Lifshitz transition in bilayer graphene

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Fermi surface topology plays an important role in determining the electronic properties of metals [1]. In bulk metals, the Fermi energy is not easily tunable at the energy scale needed for reaching conditions for the Lifshitz transition - a singular point in the band structure where the connectivity of the Fermi surface changes. Bilayer graphene [2,3] is a unique system where both Fermi energy and the low-energy electron dispersion can be tuned using the interplay between trigonal warping and a band gap opened by a transverse electric field. Here, we show that once can drive the Lifshitz transition to experimentally controllable carrier densities by applying large transverse electric fields through a h-BN-encapsulated bilayer graphene structure, and detect it by measuring the degeneracies of Landau levels [4]. These degeneracies are revealed by filling factor -3 and -6 quantum Hall effect states of holes at low magnetic fields reflecting the existence of three maxima on the top of the valence band dispersion. At high magnetic fields all integer quantum Hall states are observed, indicating that deeper in the valence band the constant energy contours are singly-connected. The observation of ferromagnetic quantum Hall states at odd-integer filling factors in the highquality samples enables one to identify several phase transitions between correlated quantum Hall states at intermediate magnetic fields, in agreement with the calculated evolution of the Landau level spectrum.

References

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