CROSSED ANDREEV REFLECTION OF QUANTUM HALL EDGE STATE IN GRAPHENE

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Understanding the interplay between superconductivity (SC) and quantum Hall effect (QHE) has been a long-sought theoretical and experimental challenge. SC contacts to QHE systems allow us to study fruitful physics, such as Cooper pair injection into ballistic 2D channels, Andreev QH edge states, and emergent excitations of non-Abelian anyons. We developed an in-situ etching technique for highly transparent SC contacts (niobium nitride, NbN) to hBN encapsulated graphene channels. The high critical field (B_{c2} > 30 T) and high critical temperature (T_c = 12 K) of NbN and the high mobility of graphene system enable us to experimentally access a wide range of magnetic field where SC, QHE, as well as fractional QHE coexist.

In a conventional Andreev reflection measurement scheme, differential conductance (dI/dV) across the SC/normal metal interface has been studied. However, we found that dI/dV at the graphene/NbN interface is affected mostly by the density of state of graphene in the QH regime, but not by SC. In order to probe Andreev reflection of QH edge states, we individually measure the chemical potential of normal electrodes located on the upstream (V_U) and the downstream QH edge states (V_L) relative to a narrow grounded superconducting electrode (Fig. 1a). We observed that V_L has sign opposite to V_U, suggesting crossed Andreev reflection (CAR) of incident electrons to outgoing holes across the narrow superconducting contact (Fig. 1b). We systematically investigated this phenomena as a function of temperature (T), magnetic field (B), bias voltage as well as the width (W) and the length of the superconducting electrode. We find out CAR happens only when $T < T_c$, $B < B_{c2}$ and $W < \xi_s$ (superconducting coherence length of NbN).

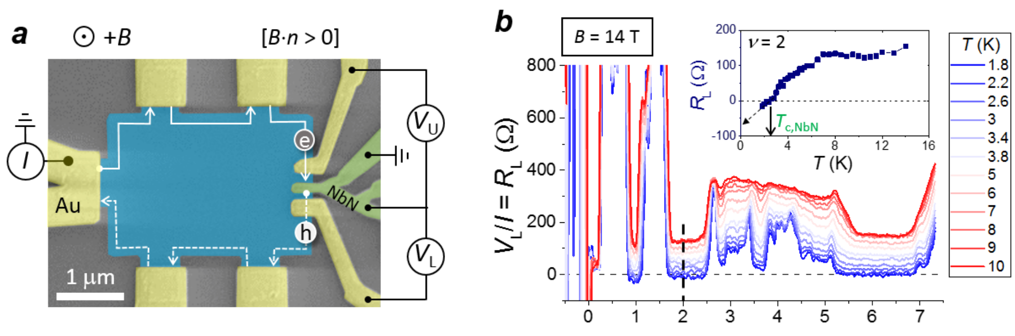

Figure 1. **a**, False color SEM image of graphene Hall bar (blue) contacted with a narrow superconducting drain electrode (green) and the normal electrodes (yellow). **b**, Filling factor (ν) dependence of downstream resistance (R_L) at different temperature (T) at B = 14 T. Inset, Temperature dependence of R_L at ν = 2. Green vertical dotted line represents superconducting critical temperature of NbN electrode ($T_{c,NbN}$).

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