Supporting Information

Interfacial State and Fano-Feshbach Resonance in Graphene-Silicon Vertical Junction

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Hall bar structure for magneto-resistance and Hall measurement

In order to study the possibility of spontaneously magnetization due to interface effect, e.g. hydrogen adsorption, a Hall bar structure was fabricated in following steps. An intrinsic (100) silicon was treated with buffered hydrogen fluoride solution to remove the oxidation layer and form hydrogen passivation. Then a layer of graphene was quickly transferred to the hydrogen-passivated silicon surface and dried under inter gas environment. After that, a layer of Al_2O_3 was deposited onto the graphene top surface for protection followed by photo-lithography and etching processes to generate the Hall bar structure.

The metal electrodes are fabricated through conventional photolithography and metal deposition process. It is worth to mention that there is no Al_2O_3 left between graphene layer and metal electrodes, because a base solution (FM319, MicroChem Inc.) was applied for the pattern developing process, which removes the Al_2O_3 protection layer as well.

The Hall measurement was performed under 1.9K, and the transport signal was dominated by graphene, since the charge carrier excitation in silicon can be ignored and the intrinsic silicon was very insulating.

Device for selected area tunneling spectroscopy study

Figure S2 shows the schematic of the device for selected area tunneling study. There are four groups of electrodes. Two of them are deposited right on top of silicon working area, serving as inner electrode, whereas the other two are deposited on SiO_2 in contact with graphene, serving as outer electrode. All the electrode are connected to wire-bonding pads (not shown in picture) via wires buried in Al_2O_3 layer for insulation purpose, as demonstrated in Figure S2b. ;

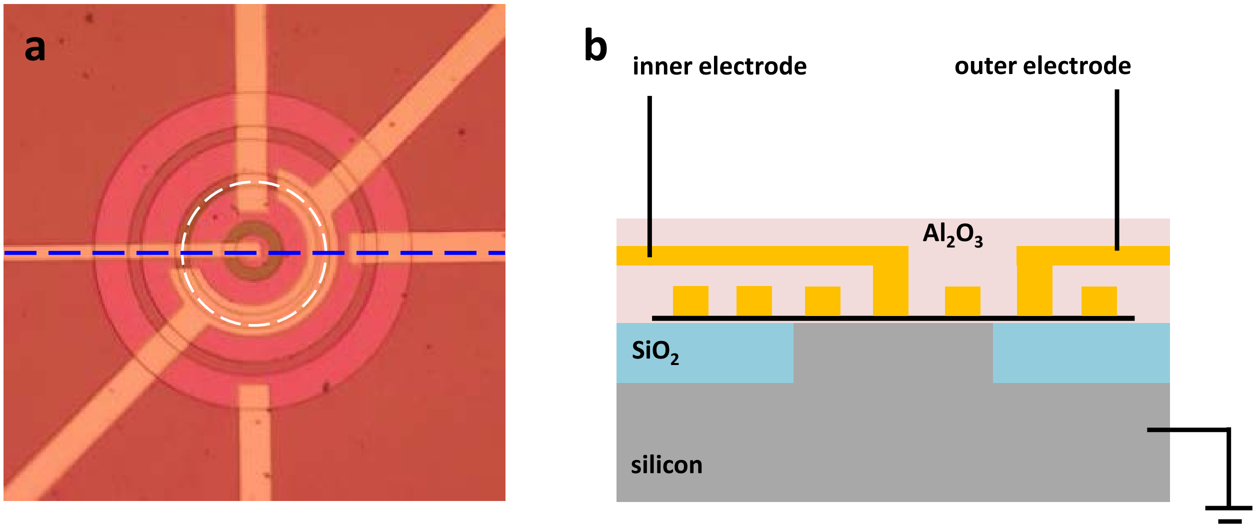

Figure S2. a. The optical image selected area tunneling device, the white dashed line labels the Si/SiO_2 boundary. b. The cross section schematic along the blue dashed line in (a).

Fano-Feshbach resonance simulation

A single Fano-Feshbach resonance peak shape can be described by Equation (4) and Equation (6) mentioned in the main text.

We assume that the tunneling rates to each of the energy levels of the interfacial trap state are the same ($\tau_i = A$), and the tunneling rate to the graphene is proportional to the density-of-states which linear depends on the tunneling bias ($\tau_g = B\varepsilon$), the Equation (6) can be expresses as

$$q \approx \alpha \frac{A}{B\varepsilon} = \frac{\beta}{\varepsilon} \tag{S1}$$

where A is a constant with a unit of time representing the tunneling rate through the discrete interfacial states, B is the coefficient for graphene tunneling rate linear dependence, and $\beta \equiv \frac{\alpha A}{B}$.

Combining Equation S1 and Equation 4, we get Equation (S2)

$$\sigma_n(\varepsilon) = \frac{(\frac{\beta}{\varepsilon}+\frac{\varepsilon-E_n}{\Gamma})^2}{1+(\frac{\varepsilon-E_n}{\Gamma})^2} \tag{S2}$$

Combining all the resonant peaks corresponding to the discrete energy levels of the interfacial states and the linear baseline due to the direct tunneling to graphene, the entire spectrum can be described as

$$\sigma(\varepsilon) = \sum_n \frac{(\frac{\beta}{\varepsilon}+\frac{\varepsilon-E_n}{\Gamma})^2}{1+(\frac{\varepsilon-E_n}{\Gamma})^2} + \gamma\varepsilon \tag{S3}$$

where β, Γ and γ can be determined by fitting the experimental spectrum, and the reciprocal of Γ is proportional to the lifetime of the interfacial state ($\Gamma = \left(\frac{1}{\tau}\right) \cdot \frac{h}{4\pi}$, where h is Plank constant).