Gate Control of Nonlinear Characteristics in Chemically Doped Graphene Three-Branch Junction Device

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Graphene is regarded as a promising channel material for switching device due to its ultra high carrier mobility. Furthermore, its unique properties such as ambipolar transport open up new possibility for novel device applications. Three-branch junction (TBJ) device, a nanodevice having a simple structure, exhibits unique nonlinear voltage transfer characteristics even at room temperature [1]. This nonlinear behaviour could also be observed in graphene TBJ device [2,3]. For graphene TBJ device, the polarity of the nonlinear characteristics depends on the conduction type of graphene channel, which could be controlled by gate voltage [2]. By changing gate bias condition and measurement configuration, graphene TBJ is expected to operate as an AND and OR logic gate. In this paper, we investigate the gate control of the nonlinear characteristics in chemically doped graphene TBJ.

Figure 1 shows a schematic illustration and scanning electron microscope (SEM) image of the fabricated graphene TBJ. A single graphene flake was prepared by mechanical exfoliation of kish graphite and was placed on a 300-nm thick SiO_2/p-Si substrate. Then, Ohmic electrodes were formed using sputtering of 35nm-thick PtPd alloy. Finally, the T-shaped TBJ structure was fabricated by means of electron beam lithography and oxygen plasma etching. The width of each TBJ branch, W, and the total length of right and left branches, L, were 200 nm and 1 µm, respectively. The fabricated device was immersed into Polyethyleneimine (PEI), an n-type dopant of graphene, to control the Dirac point (V_{Dirac}) and improve the mobility of graphene channel.

For the typical operation of the TBJ device, input voltages, V_R and V_L, were applied at right and left branches, respectively, and voltage at center branch was measured as output voltage, V_{out}. In order to control the nonlinear characteristic of TBJ, gate voltage, V_{BG}, was applied at the Si substrate. Figure 2(a) shows the measurement results when input voltages were applied in push-pull (V_R=-V_L) fashion. In general, the measured voltage transfer characteristics showed two shapes, namely, V-shape and bell-shape. When the conduction type changed from n-type to p-type, the curve changed from the bell-shape to the V-shape. The curvature of the observed nonlinear curve increased when V_{BG} approached V_{Dirac}. We also measured voltage transfer characteristics when the input voltage was applied in push-fixed fashion, where left branch is grounded. Figure 2(b) shows the measured voltage transfer characteristics. A V_{BG}-controlled nonlinear behaviour of the TBJ device was also observed in this measurement configuration. This nonlinear behaviour could be explained by the difference of number of carrier induced by V_{BG} in right and left branches of TBJ. Based on a simple lumped equivalent circuit consists of two capacitances connected in series, the relationship between the curvature of nonlinear characteristics, α, in Fig. 2(a) and V_{BG} was given by the following equation.

$$\alpha \approx -\frac{1}{V_{BG} - V_{Dirac}}$$

This equation shows that the polarity and the curvature of the nonlinear characteristics could be controlled by applying V_{BG}.

References

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Figures

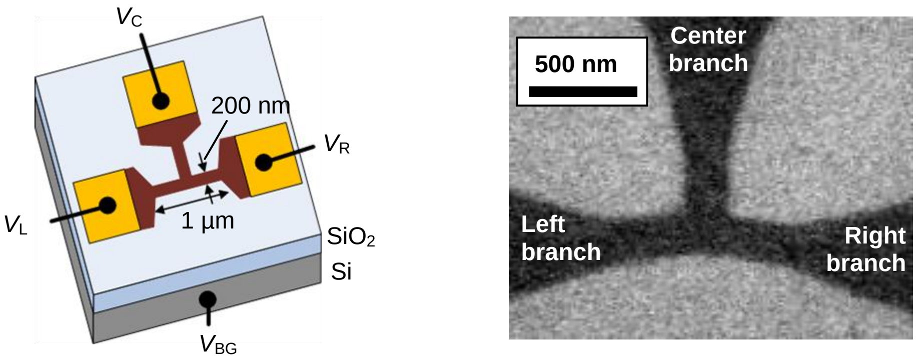

Figure 1. Schematic illustration and scanning electron microscope image of fabricated graphene TBJ device

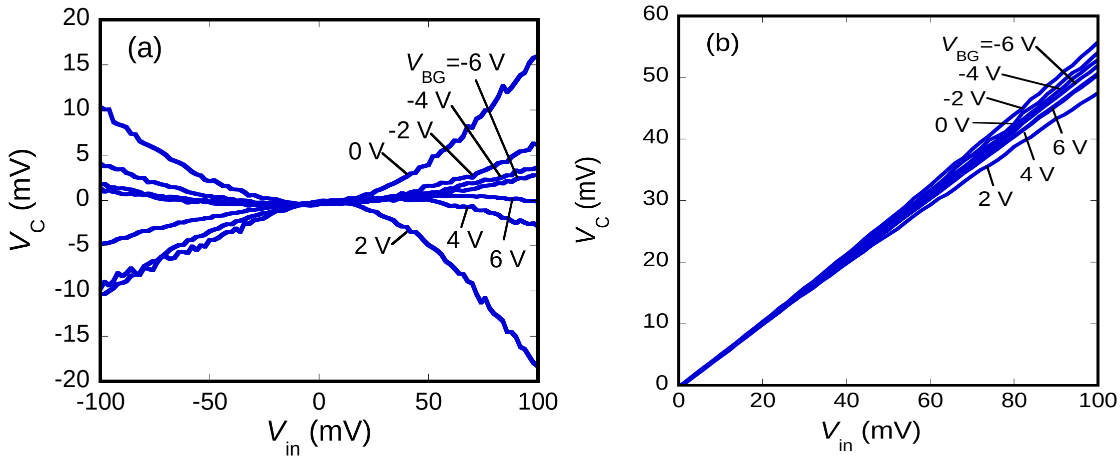

Figure 2. (a) Measured voltage transfer characteristics of graphene TBJ when input voltages were applied in push-pull fashion and (b) voltage transfer characteristics for measurement in push-fixed fashion.