Enhancement of rectifying behavior for hetero-structured graphene tunneling diodes by chemical doping

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Abstract

In this study, a tunneling rectifier prepared from vertically stacked two-dimensional (2D) materials composed of chemically doped graphene and h-BN is demonstrated. [1] **Figure 1(a)** shows the fabricated p-doped top graphene (p-Gr_T)/ h-BN/ n-doped bottom graphene (n-Gr_B) tunneling diode (TD). [2] The changes in the properties of the CVD graphene before and after doping were characterized by fabricating a back-gate graphene FET (GFET) on a 90 nm SiO_2 wafer. As shown in **Figure 1(b)**, the applied drain voltage (V_D) was 20 mV and the Dirac point of the n-doped graphene, obtained using BV, was shifted by about 80 V toward more negative V_G values, enhancing the flow of electrons. In contrast, the Dirac point of p-doped graphene, obtained using $AuCl_3$, was shifted by more than 100 V toward positive V_G values, suppressing the flow of electrons whereas enhancing the flow of holes,. [3], [4] The tunneling current induced by the change in the Fermi level due to the chemical doping was estimated by simulations and was found to agree well with the experimental results. Figure 2(b) shows the calculated current as a function of bias voltage. The tunneling probability was calculated using the equation $T(E) = \exp\left[-\int_0^d \sqrt{\frac{2m}{\hbar^2}|E - V(z)|}dz\right]$, where d is the width of the potential barrier, m is the effective mass of tunneling electrons (0.5 m_0, where m_0 is the free electron mass), $\hbar$ is Planck's constant, E is the energy of the electrons, and $V(z) = [\Phi_h(d - z) + (\Phi_e - eV)z]/d$, where e is the electron charge, V is the applied voltage, and Φ_h and Φ_e are the work-functions of the p- and n-doped graphene, respectively. The calculated current was normalized by $J_{(7V)}$ as the current at V = – 7V. In this calculation, the thickness of the potential barrier (h-BN) was 6 nm and the barrier height was 3.5 eV. [5] By applying high bias, the asymmetric current can increase relative to the change in the interfacial potential barrier depending on the direction of bias. Under a forward bias, the n-Gr is at a lower potential, and the interfacial insulating barrier width becomes narrower than that obtained in the unbiased case. This effect gives rise to a higher current because the electrons tunnel through lower barrier or across shorter tunneling distance, obeying the F-N tunneling mechanism. In contrast, under a reverse bias, the current will be much smaller because the width of the interfacial potential barrier does not change. This current is described by the direct tunneling mechanism. The asymmetric 2D tunneling diode is expected to be a key building block for the preparation of future flexible and transparent electronic devices, as it enables electronic devices to operate through a functioning p-n junction.

References

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Figures

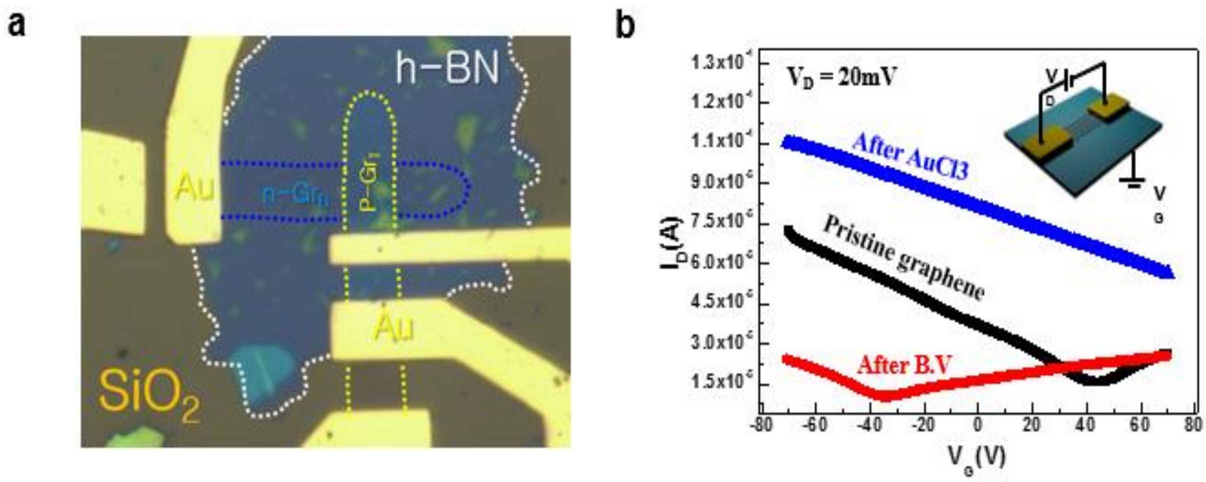

Figure 1: (a) A scanning electron microscopic picture of the fabricated p-type doped top graphene (p-Gr_T)/ h-BN/ n-type doped bottom graphene (n-Gr_B) hetero-structure. (b) Transfer curves (I_D-V_G) of a graphene field effect transistor (GFET) before and after doping.

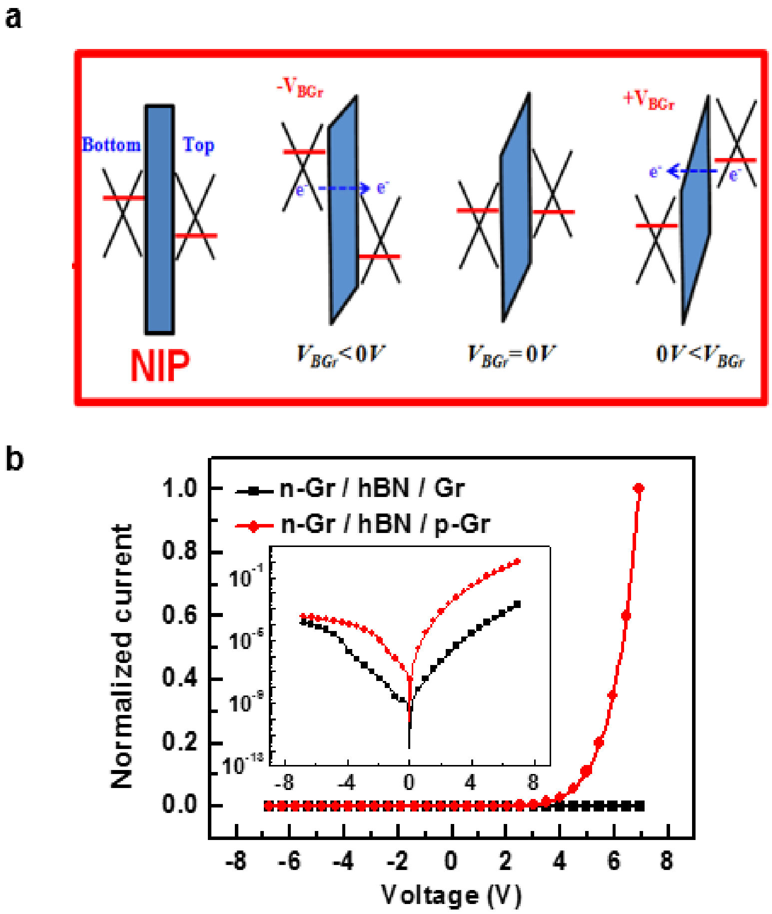

Figure 2: (a) Energy band diagrams under zero, reverse, and forward bias conditions. (b) Simulation results of the GBG-TDs before and after p-doping of the top graphene layer.