Graphene PN junction formation by asymmetric work function of metal contacts

JAIST [1], Minia Univ. [2], Hitachi Cambridge Laboratory[3]

°Ahmed Hammam[1,2], Manoharan Muruganathan[1], Hiroshi Mizuta[1, 3]

E-mail: a-hammam@jaist.ac.jp

Graphene is a zero band gap two dimensional (2D) material with superior electronic properties. Since conventional chemical doping techniques of carbon-based nanostructures are challenging due to the strong C-C bonds in GNRs. Electrostatic doping is the main technique to realize graphene PN junction. However, electrostatic doping enhance carrier scattering in the area underneath the controlling gate. Furthermore, electrostatic gating increases the number of required electrodes to control the device characteristics, which leads to more fabrication complications. Here we propose a PN junction engineering by utilizing work function difference between graphene (~ 4.5 eV) and metal contacts. Both simulation and experimental work showed that work function difference introduce doping to graphene sheet underneath the metal [1,2]. Additionally, the charge doping effect can extend to the channel as well. Therefore, Graphene PN junction can be realized by introducing asymmetric work function metal-contacts.

In this work, we used Nickel (work function of 5.01 eV) and Aluminum (work function of 3.9 eV) as a metal contacts for source and drain electrodes. Due to its high work function, Nickel (Ni) known to introducec P-type doping and form chemical bond with Graphene [2], However, Aluminum (Al) with lower work function, expected to introduce N-type doping. Three groups of devices are fabricated (Al-Al, Ni-Ni, and Al-Ni) using Electron beam lithography (EBL) - Lift-off technique. Figure 1a, shows back-gate characteritics at room temperature of the three groups. As depicted in the figure below, (Ni-Ni) devices shows P-type doping. However, Al contacted devices show two local minima, which indicates the formation of PN junction. In contrast, asymmetric contatcted devices (Al-Ni), show more clear PN junction formation (two clear local minima). Figure 1b, shows the effect of vacuum annealing at 200 °C for three hours on Ni-Al contacts compared with room temperature measurements. The difference between the two local minima (ΔVg) increased by annealing; which can explained by the pinning of the graphene fermi level underneath the metal contacts. More investigation is still needed to clarify the effect of temperature on the PN junction formation, which will be dicussed in the presentation.

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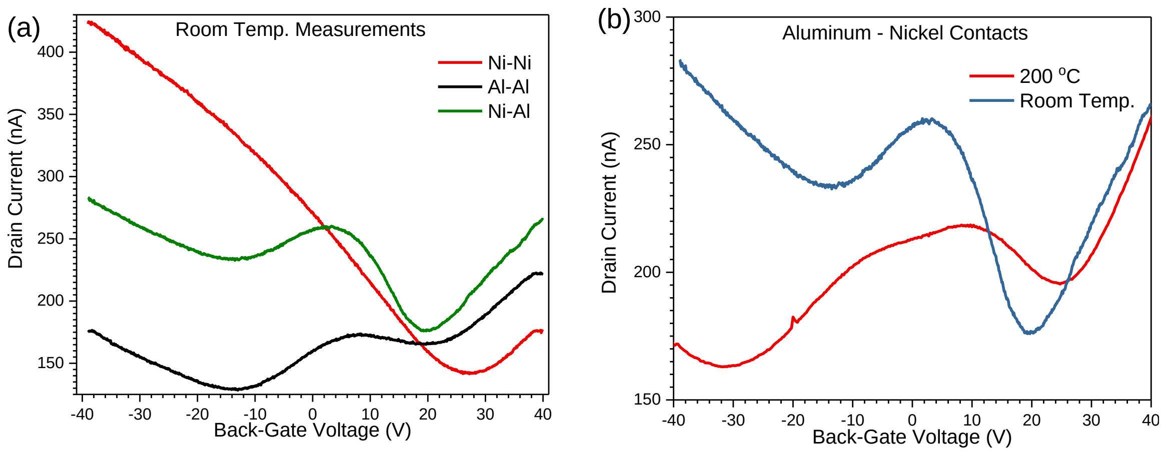

Figure 1: (a) Back-gate characteristics of Ni-Ni, Al-Al and Al-Ni metal-contacted graphene devices at room temperature. (b) Effect of vacuum annealing at 200 °C on asymmetric work function contacted (Al-Ni) devices.