Fabrication of tunnel barrier in suspended multi-wall carbon nanotube controlled by Ga focused ion beam irradiation

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This work investigates a reliable technique to fabricate and characterize the tunnel barriers in the suspended multi-wall carbon nanotubes (MWCNTs) by Ga focused ion beam in a systematic way. The two-terminal resistance of each device was measured before formation of tunnel barriers by focused ion beam (FIB). The MWCNTs is then single scanned using FIB as illustrated in Fig 1. A few samples were fabricated with different ion dose and the effect of the resistance change after irradiation will be studied. The resistance before irradiation is ranging from 10kΩ to 20kΩ for all samples. Although there is resistance variation after irradiation, it is shown that the resistance increases with increasing Ga ion dose for both nanotubes on substrate [1] and the suspended nanotubes. Interestingly, for the case of the suspended nanotubes higher dose is necessary to increase the resistance as compared to the nanotubes on substrate. The dependence of nanotube diameter on resistance change after irradiation was investigated as represented in Fig 2. Surprisingly, we found that the resistance change after irradiation is strongly dependent on the nanotube diameter and their relation seems to be linear. This means that under the right condition, we can obtain the desired resistance for the formation of tunnel barrier which is crucial for the demonstration of single electron device. For the case of nanotubes on substrate, the data was scattered probably because of the backscattering ions which could lead to additional damage or healing on the nanotube due to energetic Si atoms ejected from the substrate by Ga^+ ions. Ga FIB seems to be a promising technique for the fabrication of single electron transport based device because it is more reliable and reproducible as compared to other techniques. We estimated the barrier height by temperature dependence of the current (Arrhenius plot) and the current-voltage curves (Fowler-Nordheim plot). There is a tendency that barrier height has a correlation with the resistance increased after irradiation. Single electron transistor with two barriers will be realized with the present technique.

[1] H. Tomizawa, K. Suzuki, T. Yamaguchi, S. Akita, K. Ishibashi, Nanotech. **28**, 1 (2017).

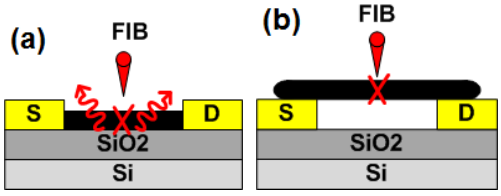

Fig. 1 Schematic of (a) nanotube on substrate (b) suspended nanotube

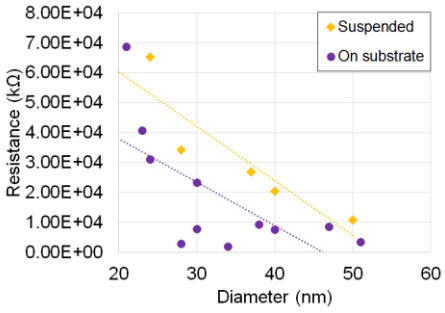

Fig. 2 Diameter dependence of resistance after irradiation at a fixed dose of $6.0X10^{16}$ions/cm^2