Helium Ion Beam Milling Patterned Suspended Graphene Double Quantum Dots

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Coupling single charge transport to mechanical motion is useful for ground state cooling,[1] sensitive charge sensing,[2] and atomic scale mass detection.[3] This coupling can be realized by embedding a single electron transistor (SET) in a nanoelectromechanical resonator. In this field, carbon based materials, *i.e.*, suspended carbon nanotubes (CNTs) and graphene nanoribbons (GNRs), are appealing due to their stiffness, widely tunable resonance frequency and exceptional transport properties.[2-5] To gain an insight view of the coupling mechanism, it is necessary to develop the single dot SET to double dots. Double quantum dots can be realized by nanopatterning graphene. However, these channels easily deform during the supporting substrate etching process. To guarantee such a fragile structure, it is better to define the dots after suspending the channel. Helium ion beam milling (HIBM) has been demonstrated as an efficient technique for shaping suspended graphene into sub-10 nm scale structures with small deformation owing to its small beam diameter, fine spatial resolution and suitable energy.[6] Therefore, well-shaped suspended graphene double quantum dot can be expected using HIBM. However, practical fabrication processes for such a complex suspended structure has been rarely reported.

In this work, we present a fabrication process for suspended graphene double quantum dots. A relatively large GNR (width w=500 nm, length l=1000 nm) with seven stiff metal electrodes on its edges was pre-fabricated through conventional e-beam lithography fabrication process (Fig 1 (a)). Among the seven electrodes, two larger electrodes with a width of ~1000 nm were defined as source and drain. The other smaller electrodes with widths of ~50 nm were later defined as side gates. Afterward, the substrate was etched out by using BHF. These strong electrodes pulled the GNR and kept its shape from deformation during etching (Fig 1 (b)). Then HIBM was carried out to pattern the GNR into double dots as the helium ion microscopy image shown in Fig 1 (c, d). Impressively, two islands with a diameter smaller than 100 nm connecting to source and drain through constrictions with a width of sub-10 nm are obtained. More details regarding fabrication conditions will be presented at the conference.

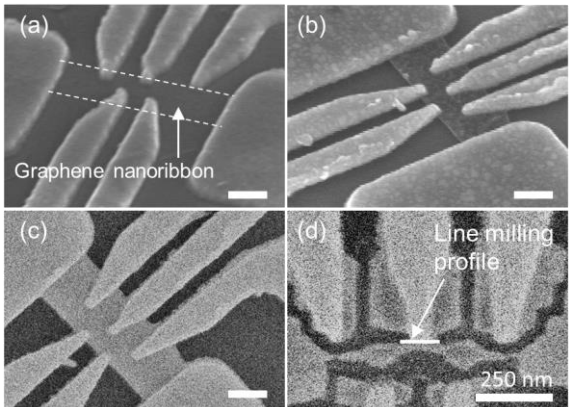

Fig 1. (a), (b) SEM images of GNR before and after BHF etching. (c), (d) helium ion microscopic images of suspended GNR before and after HIBM.

Acknowledgement:

Authors acknowledge T. Iijima for the usage of AIST SCR helium ion microscope for the helium ion beam milling. This research is supported by the Grant-in-Aid for Scientific Research Nos: 18H03861 and 18K04260 from Japan Society for the Promotion of Science (JSPS).

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