Transport properties of large-area fully & half meshed suspended graphene

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Graphene nanomesh (GNM) has provided new opportunities to investigate both the fundamental physical properties and the applications in phononic crystal engineering to control thermal transport [1-3]. By using the focused helium ion beam milling (HIM), GNM patterning in less than 4 nm nanopore diameter and a sub-10 nm pitch was achieved [4]. In this work, we successfully fabricated a series of suspended graphene nanomesh devices with CVD graphene by HIM technique (Fig. 1) in high yield. This provided a way to investigate the effect of the porosity to the redirection of the energy carrier propagation with different pitches of the nanopores. Moreover, the transport properties of the symmetric ‘fully meshed’ structure (Fig. 2) and the asymmetric ‘half meshed’ structure (Fig. 3) were also investigated.

The suspended GNM devices were based on the CVD graphene transferred to a SiO_2 (285 nm)/Si substrate. The first metal layer was patterned by EBL with PMMA/MMA, which including the heater, sensor and contact pads (Fig. 1). After patterning, 5 nm Cr and 80 nm Au layers were deposited by E-beam evaporation after removing the graphene underneath. The second metal layer (5 nm Cr/ 70 nm Au) was used to form the anchor for the suspended graphene, which was overlapped with the CVD graphene and the first metal layer. Then the Hydrogen silsesquioxane (HSQ) was used to pattern the graphene nanoribbon (GNR) and also be the hard mark for RIE to remove the unpatterned graphene parts. After BHF etching, the GNRs were suspended successfully. 17 devices were successfully suspended in a total of 20 devices, which was confirmed by the helium ion microscope. The periodic nanopores were pattern by HIM in different pitch sizes (15 nm, 20 nm, 25 nm, 30 nm, 50 nm).

The initial electrical measurements were carried in a high vacuum chamber (below 10^{-5} mbar) with the system noise below 1 pA. The temperature range was from 10 K to 300 K. The temperature dependence of the electrical conductance for the GNM devices were extracted. By comparing the devices with different pitches, the effect of the porosity for the electrical conductance could be observed both in ‘fully meshed’ and ‘half meshed’ devices (Fig. 4-5). By increasing the porosity of the GNM, the temperature dependence for the electrical conductance was enhanced (Fig. 4). However, by introducing the non-meshed part (‘half meshed’), the temperature dependence enhancement was suppressed (Fig. 5).

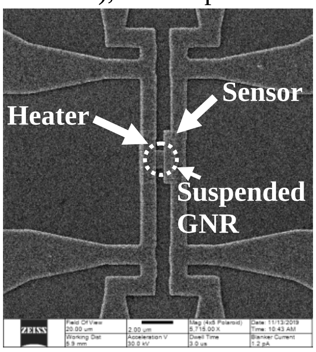

Fig. 1: The structure of the device

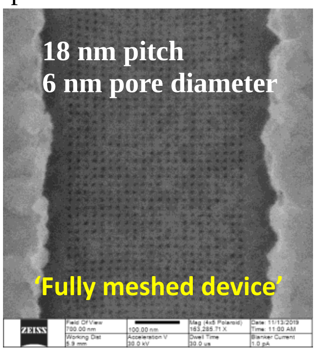

Fig. 2: Nanopores patterned by HIM

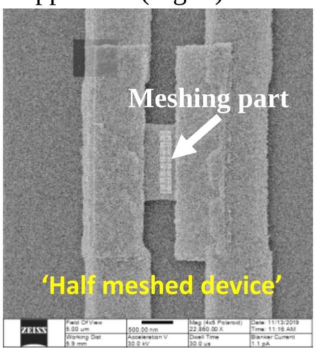

Fig. 3: ‘Half meshed’ device

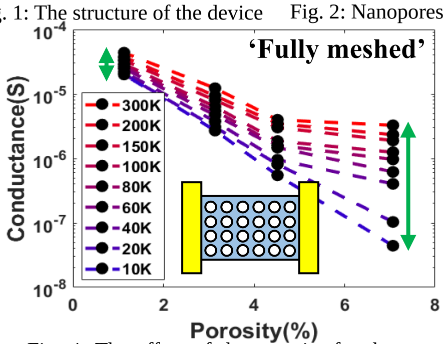

Fig. 4: The effect of the porosity for the ‘Fully meshed’ devices

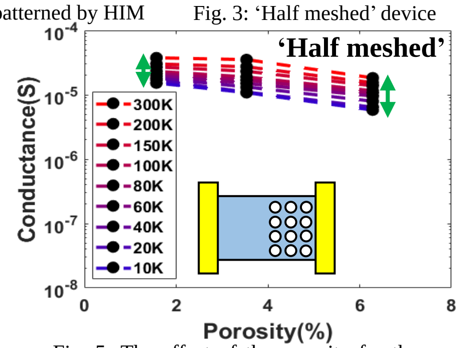

Fig. 5: The effect of the porosity for the ‘Half meshed’ devices

Acknowledgement:
The authors acknowledge T. Iijima and H. Ota for the usage of the HIM at the AIST SCR station for the helium ion irradiations. This work was supported by the Grant-in-Aid for Scientific Research No. 18H03861, 19H05520 from the Japan Society for the Promotion of Science (JSPS).

Reference:

1. T.G. Pedersen et al., *Phys. Rev. Lett.* 2008, 100(13), 136804.
2. L. Yang et al., *Int. J. Heat Mass Transfer*, 2015, 91, 428-432.
3. T. Feng et al., *Carbon*, 2016, 101, 107-113.
4. M. E. Schmidt et al., *Appl. Mater. Interfaces*, 2018, 10.