In-situ current annealing of suspended graphene nanoribbon devices

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Graphene is one of attractive candidates for next-generation nano-switches, gas sensors and single molecules detectors. However, the excellent optical and electrical conductance properties have been reported to be degraded due to surface contaminants, mainly consisting of polymethyl methacrylate [1-2]. Unfortunately, such residues are inevitable during the fabrication of graphene nanoribbon (GNR) devices. Although many efforts have been made to reduce and remove contamination from the surfaces [3-5], the issue is far from resolved, especially for suspended GNRs.

For obtaining atomic clean graphene surface, here we report in-situ current induced-annealing on a fabricated substrate-free GNR device in transmission electron microscopy (TEM), as shown in Fig.1. During the annealing process, a controllable source-drain bias voltage (1.0 - 3.0 V) is applied to induce a large current flow through the suspended GNR, and in-situ TEM observation is used to identify the cleaning effectiveness.

During the current annealing process, the contaminant-free region was observed to start from the left side of GNR, then to expand to right side as shown in Fig.2a-c, when increasing the current density or power. The desorption of contaminations on GNR started when the current density was 1.95×10^{12} A/m^2, then finished at 4.5×10^{12} A/m^2. The temperature distribution on the GNR device was simulated by Finite Element Method (FEM). It showed that the cleaning direction was related with the shift of the temperature distribution during the annealing process. It suggests that the high local temperature is the most important factor for the removal of contaminations. We found that the necessary temperature for cleaning suspended GNR is about 900 K. This in-situ current annealing experiment clarifies the cleaning process of the contaminated graphene nanoribbon.

References:

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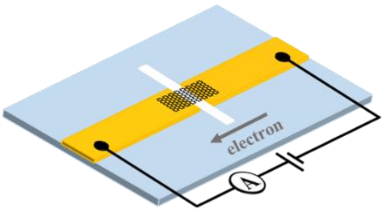

Fig 1. The schematic of current annealing procedure, which shows the application of a source-drain bias voltage.

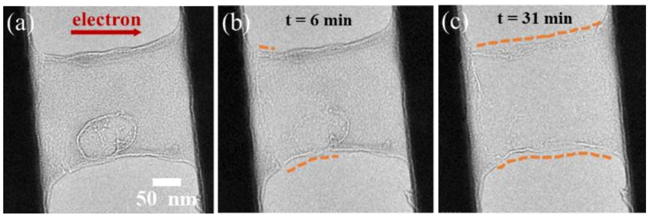

Fig 2. (a)-(c) A series of TEM images for GNR during current annealing which captured at different time intervals. The clean area expand with the time as indicated by orange dashed lines near GNR