Source gas distribution measurement in focused-ion-beam chemical vapor deposition using graphene sensing device

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In this paper, we fabricated a graphene sensing device to measure local gas distribution around a gas nozzle in 200 μm square in FIB-CVD. Phenanthrene ($C_{14}H_{10}$) which is used as a source gas to deposit carbon was a measurement object. A single-layer graphene exfoliated with 2 μm size was synthesized on a SiO_2 substrate to realize high sensitivity in gas concentration change and sufficient spatial resolution. We also measured a carbon deposition ratio distribution to investigate a relationship between the gas concentration and deposition rate.

Figure 1 (a) shows a detection part of the gas sensing device with 2 μm size using a single-layer graphene which is surrounded by a dotted line. A sensitivity of the graphene sensing device was investigated. Phenanthrene poweder was heated in a gas reservoir in the range from 70 ℃ to 95 ℃ to produce different concentration gas from a gas nozzle on the sensing device in FIB-CVD chamber. Relationship between the heating temperature and resistance was obtained as shown in Fig. 1 (b). It was found that the sensing device had a linear relation between its resistance and heating temperature, i.e., a gas concentration.

To measure a gas concentration distribution, the sensing device was moved around the gas nozzle in FIB-CVD chamber. The result is shown in Fig. 2. The origin represents the location of the gas nozzle. It reveals that there existed a gas concentration distribution around the gas nozzle, which showed higher values beneath the gas nozzle and decrease with the distance from the gas nozzle.

To measure a deposition ratio distribution, carbon nano pillars were fabricated in a reticular pattern with 10 μm-spaced in 200 μm square by FIB-CVD. The deposition ratio is defined here as a deposition volume per unit time and unit area. Figure 3 explains the measurement result which shows a higher deposition ratio just beneath the gas nozzle and decrease with the distance from the gas nozzle.

The measurement results suggest a possibility that the source gas distribution may cause the carbon deposition rate distribution which affects nano structure fabrication accuracy. The carbon deposition rate distribution, however, should be investigated further considering other experimental parameters such as beam conditions with the gas concentration distribution results obtained in this paper.

(a) (b)

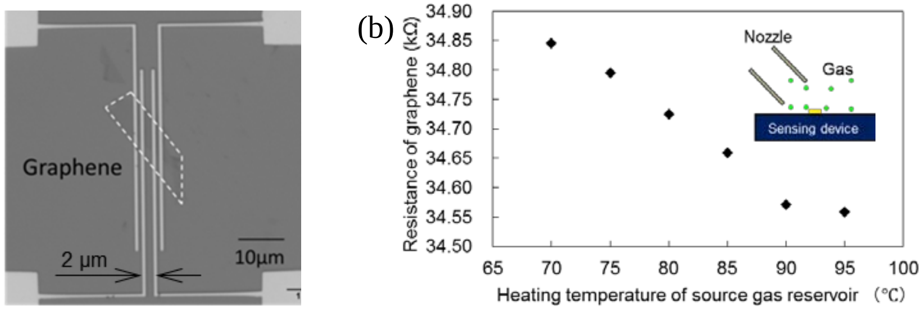

Figure 1: Graphene gas sensing device: (a) A single-layer graphene was exfoliated on a SiO_2 substrate with electrodes patterned by using electron-beam lithography. (b) Relationship between heating temperature of source gas reservoir and resistance of graphene was measured. Powder phenanthrene was heated in a gas reservoir from 70 ℃ to 95 ℃ to produce different concentration gas which was exposed to the sensing device from a nozzle.

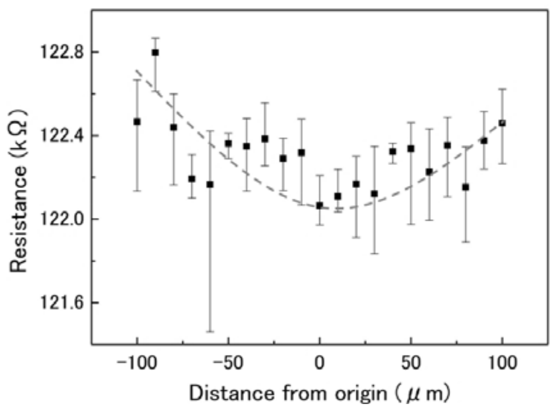

Figure 2: Gas concentration distribution around a gas nozzle in FIB-CVD chamber: The graphene gas sensing device was moved around the gass nozzle and measured its resistance in FIB-CVD chamber. The resistance change suggests that there exists a gas concentration distribution.

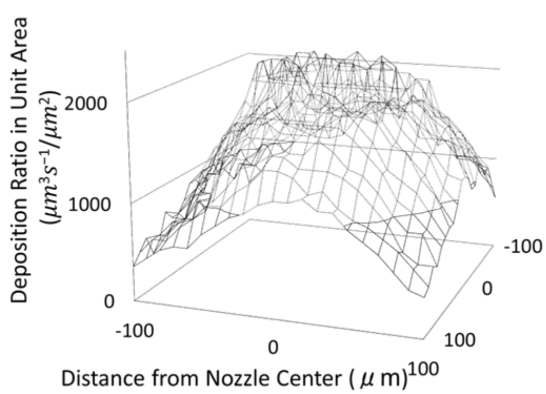

Figure 3: Carbon deposition rate distribution around a gas nozzle: Carbon nano pillars were fabricated in a reticular pattern with 10 μm-spaced in 200 μm square by FIB-CVD. Carbon deposition rate was calculated by measuring height and width of carbon nano pillars.