Resisitivity change of the diamond-like carbon, deposited by focused-ion-beam chemical-vapor-deposition, induced by the annealing treatment

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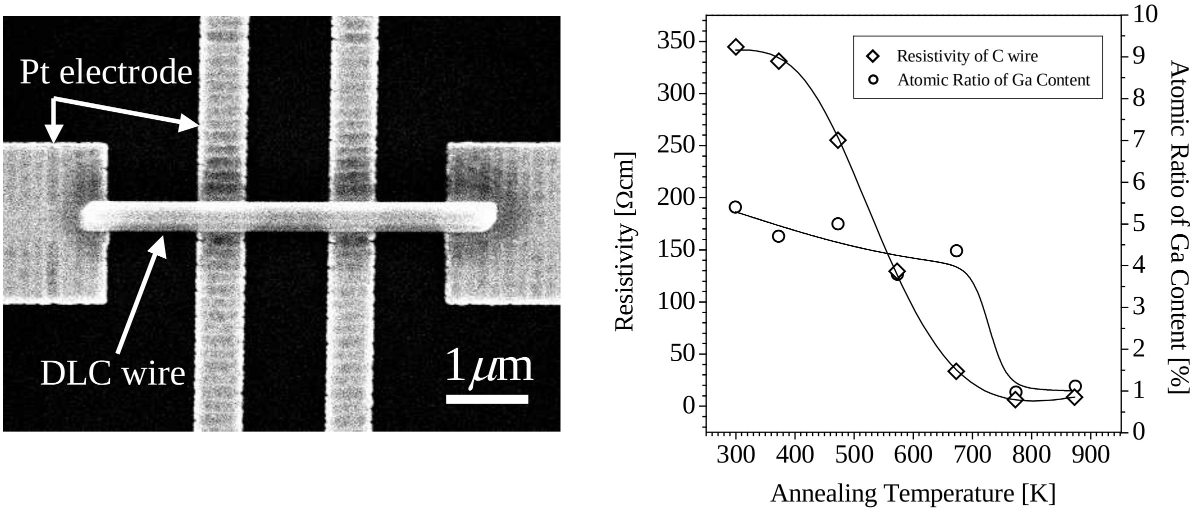
Focused-ion-beam chemical-vapor-deposition (FIB-CVD) is a useful technology to fabricate the three-dimensional (3-D) nanostructure. Therefore, FIB-CVD is a key technology to achieve the novel nano-devices in the field of the nano electromechanics. Thus far, we demonstrated that the 3-D free space wiring, and a local electron emitter could be fabricated by FIB-CVD. Their nanostructure devices were made of diamond-like carbon (DLC) because *phananthrene* ($C_{14}H_{10}$) was used as the gas source. However, the relation between the electrical property and the other material characteristics is less certain, because DLC deposited by FIB-CVD has the specific material characteristics compared with the typical DLC because DLC deposited using the gallium (Ga) FIB are contained Ga.

For the above reason, the annealing temperature dependency of the resistivity of DLC wire was examined by using 4-terminal measurement method, as shown in Fig. 1(a). Before this measurement, we guessed that the resistivity of DLC would increase by Ga elimination induced by the annealing treatment. However, the resistivity of DLC wire was decreased from 3.5×10^2 Ωcm to 6.3 Ωcm though Ga content in DLC decreased from 5 % to 1 % by the annealing treatment, as shown in Fig. 1(b).

To understand the cause of this resistivity decreasing, the fine structural characteristic change of the DLC deposited by FIB-CVD were examined using transmission electron microscope electron energy-loss spectroscopy (TEM-EELS). In TEM-EELS measurement, DLC pillar structure fabricated by FIB-CVD was used. Then, EELS C *K*-edge spectra of the three measurement points (INNER, TOP and OUTER) on the DLC pillar, as shown in Fig. 2(a), were measured in the energy range 270 eV – 330 eV. The sp^2 fraction of the two measurement points (TOP and OUTER) was increased by the annealing treatment except as to a measurement point (INNER), as shown in Fig. 2(b). This result indicated the graphite component was increased on the DLC surface by the annealing treatments. Furthermore, the composition change of DLC by the annealing treatment was examined in detail by using RBS/ERDA measurements as shown in Fig. 3, because the cause of the graphite components the increasing on DLC surface was Ga elimination or the hydrogen (H) elimination. After annealing at 1023 K, the incorporated Ga in DLC was lost. And the atomic ratio of H content continued to shrink. These results indicated that the resistivity decreasing of DLC wire by the annealing treatment was caused by the increasing of the graphite component induced by H elimination in the DLC surface.

Relation between the electrical property and the other material characteristics and other material characteristics of FIB-DLC will be reported in detail.

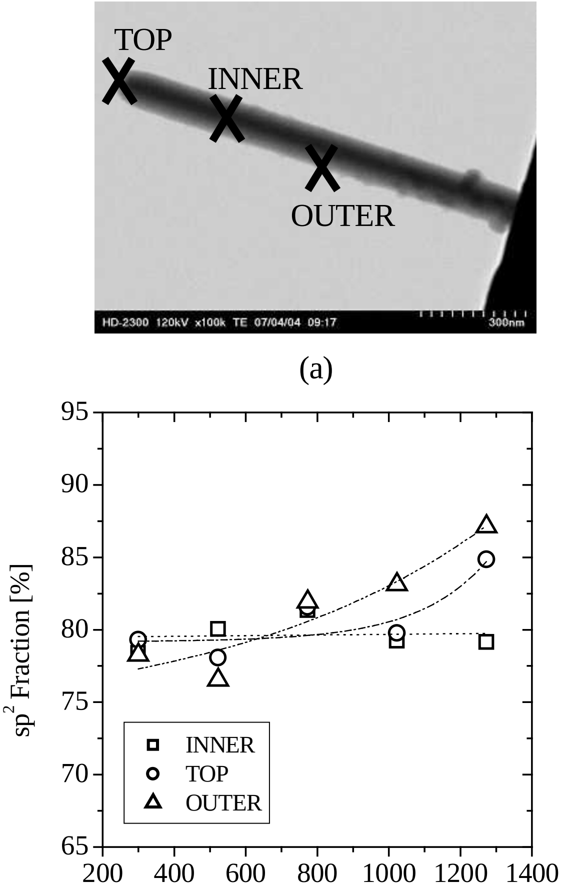


(a) (b)

Fig. 1 Resistivity change of DLC wire by the annealing treatment

(a) SEM image of DLC wire fabricated by FIB-CVD on the 4-terimanal Pt electrode

(b) Annealing temperature dependency of the resistivity and Ga content in DLC wire



(a)

(b)

Fig. 2 Fine structural characteristics change by the annealing temperature

(a) STEM image of the DLC pillar fabricated by FIB-CVD

(b) Annealing temperature dependency of the C sp^2 fraction at the measurement points

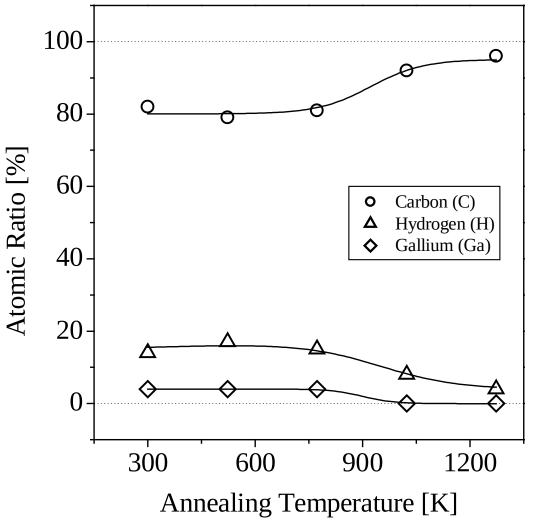


Fig. 3 Atomic ratio changes of DLC by annealing treatment; Atomic ratios were measured by Rutherford backscattering spectroscopy / elastic recoil detection analysis (RBS/ERDA) measurement.