Relation between field emission properties and material characteristics of DLC fabricated by focused-ion-beam chemical-vapor-deposition

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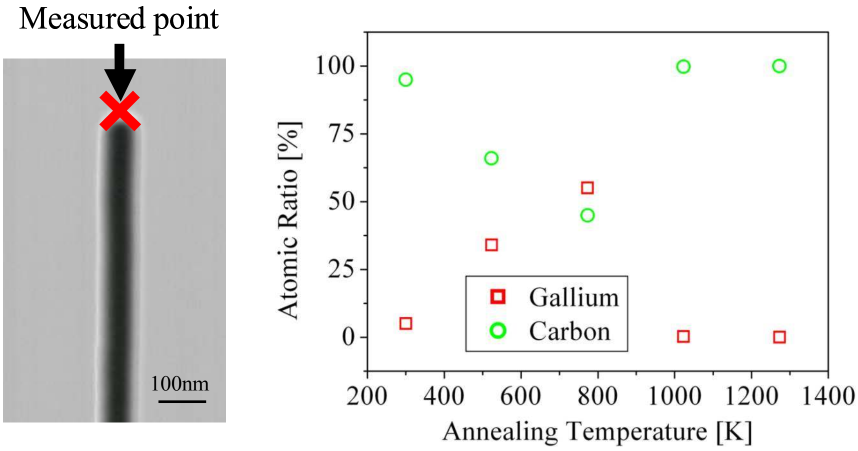
Nano-tools are very important for carrying out the operation and the analysis in the nano-space. Therefore, local electron emitter with diamond-like carbon (DLC) cold cathode on the glass capillary has been researched by using focused-ion-beam chemical-vapor-deposition (FIB-CVD) as a nano-tool to fix nano-parts in the three-dimensinal circuit by spot deposition from various directions. As a result, the field emission from DLC cold cathode was confirmed. And, we found that the DLC deposited by FIB-CVD (FIB-DLC) was useful material for the field emitter fabrication, because the FIB-DLC had a lower work function. However, material characteristic evaluations of FIB-DLC are not enough, because FIB-DLC has specific material characteristics different from typical DLC, because the gallium (Ga) incorporates in FIB-DLC. Ga ion implantation is induced by Ga ion beam used in FIB-CVD.

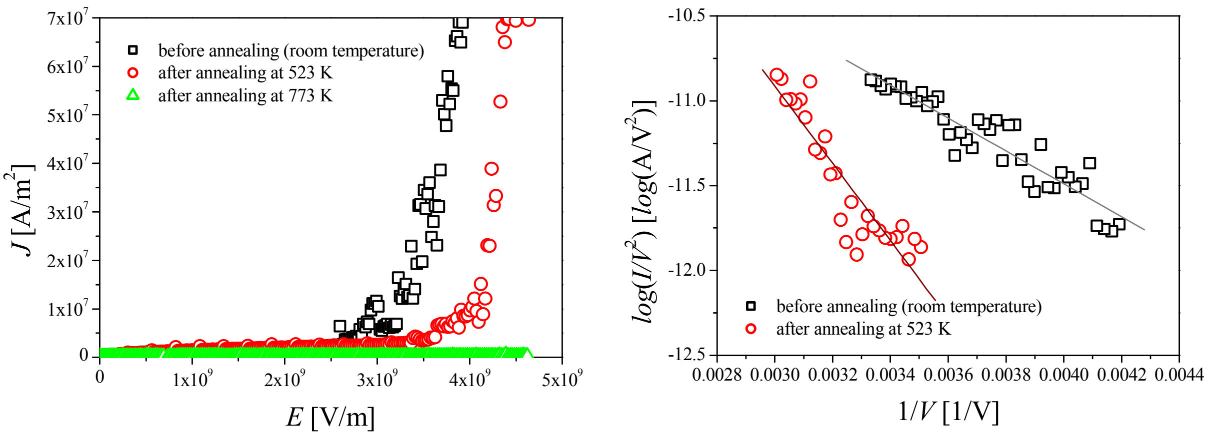
In this study, FIB-DLC's annealing temperature dependencies of field emission properties, work functions and surface conditions were measured to understand material characteristics of FIB-DLC. FIB-DLC pillar as shown in Fig. 1 (a) was annealed at 523 K, 773 K, 1023 K and 1273 K. Figure 1 (b) shows the annealing temperature dependency of atomic ratio at the FIB-DLC pillar's tip. This result indicates that Ga inside FIB-DLC pillar moved gradually to the outside of FIB-DLC pillar by annealing treatment, and Ga lost inside FIB-DLC pillar finally. And field emission property for FIB-DLC pillar was examined as shown in Figs. 2 (a) and (b). Field emission from FIB-DLC pillar after annealing at 773 K or more was not confirmed in the measurement range. In addition to the result, field emission from DLC pillar fabricated by the electron-beam chemical-vapor-deposition (EB-DLC) was not confirmed. EB-DLC was an insulator, because Ga did not exist inside EB-DLC. These results indicate that Ga incorporation was required to obtain an enough electric conductivity for the field emission. Furthermore, the annealing temperature dependency of work function and surface condition of FIB-DLC film were measured using the ultraviolet photoelectron spectroscopy (UPS) and X-ray photoelectron spectroscopy (XPS), respectively. Figures 3 and 4 show the measurement results of work functions and surface conditions, respectively. Work function was changed from 3.5 eV to 5.8 eV by annealing treatment. These results indicate that field emission property from FIB-DLC depended on the Ga distribution because work function changed according to state of Ga distribution.

Relation between field emission properties and material characteristics of FIB-DLC will be reported in detail.



(a) (b)

Fig. 1 SEM-EDX measurements of atomic ratios for FIB-DLC pillar's tip.
(a) TEM image of a DLC pillar without annealing, Allow shows the point measured by SEM-EDX.,
(b) Annealing temperature dependency of atomic ratios for FIB-DLC pillar's tip.



(a) (b)

Fig. 2 Field emission properties of FIB-DLC pillar. (a) Field emission properties, (b) F-N plots

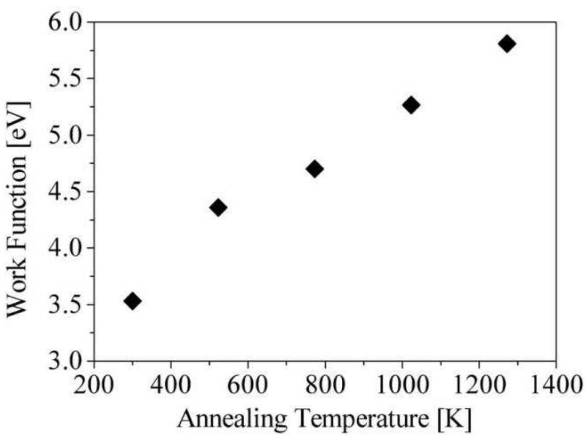


Fig. 3 Annealing temperature dependency of work function measured by UPS.

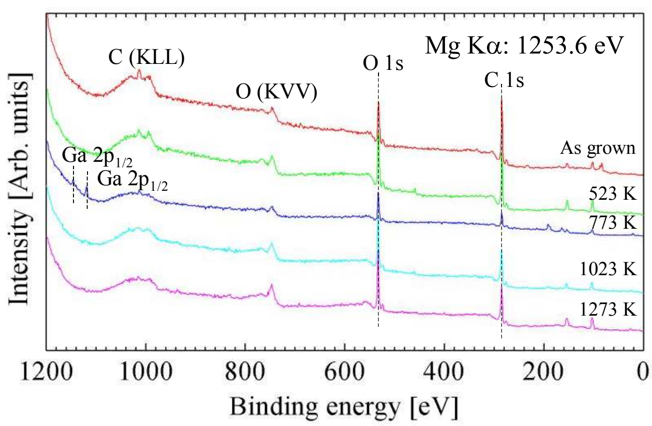


Fig. 4 XPS spectrum of FIB-DLC thin film without and with annealing treatment.