The three-dimensional nanostructure fabrication from HSQ by FIB/EB dual-beam lithography

R. Kometani, K. Kuroda, S. Warisawa, S. Ishihara
Graduate School of Engineering, The University of Tokyo
7-3-1 Hongo, Bunkyo, Tokyo 113-8656, Japan
kometani@mech.t.u-tokyo.ac.jp

The three-dimensional (3-D) nanostructures are useful to achieve the various functional devices in the research fields such as nanomechanics, nanooptics and nanobiology. Therefore, we have been researching on the 3-D nanostructure fabrication by dual-beam lithography using focused-ion-beam (FIB) and electron-beam (EB). We can expect to achieve various 3-D nanostructure by combining these beams, because we can use the difference of the penetration depth of FIB and EB, as shown in Fig. 1. Thus far, we reported the nanomechanical resonator fabrication using dual-beam lithography.[1] However, there have not yet been any reports concerning the processing properties of this lithography technique on the 3-D nanostructure fabrication. Therefore, processing properties of FIB/EB dual-beam lithography were examined, and the various 3-D nanostructure fabrications were demonstrated in this study.

Figure 1 show a fundamental process of the 3-D nanostructure fabrication from a hydrogen silsesquioxane (HSQ) resist using FIB/EB dual-beam lithography. EBL was carried out using 50 kV electron beam with a beam current of 100 pA. And processing properties of FIBL on 3-D nanostructure fabrication were examined. As a result, we obtained a suspended nanowire with a width of 23.7 nm, as shown in Fig. 2(a). And also, thickness and shape of nanowire depended on the acceleration voltage and ion-dose, as shown in Figs. 2(b)-2(e). We found that a nanowire with the etched region was formed by exposing with ion dose of over 0.5×10^{15} ion/cm^2. And also, an ultra-thin suspended structure with a thickness of 8.9 nm was achieved. These results indicate that various precisive 3-D nanostructures can be achieved by selecting expose condition of FIBL.

Furthermore, we fabricated the several 3-D structures by using FIB/EB dual-beam lithography technique. Suspended trench structure shown in Fig. 3(a) was fabricated by FIBL and FIB-etching. And also, Fig. 3(b) show a scanning electron microscope (SEM) image of double-tiered crossover structures fabricated by exposing again a second HSQ layer after the expose of first HSQ layer by FIBL. In this way, the 3-D nanostructures can be fabricated by simple process using FIB and EB lithography. This implies that FIB/EB dual-beam lithography is a useful technique for various functional nanodevices with the 3-D nanostructure. The 3-D nanostructure fabrication from HSQ by using FIB/EB dual-beam lithography and their processing properties will be reported in detail.

---

[1] R. Kometani, et. al.: J. Sci. Vac. Technol. B **29**, 06FE06 (2011).

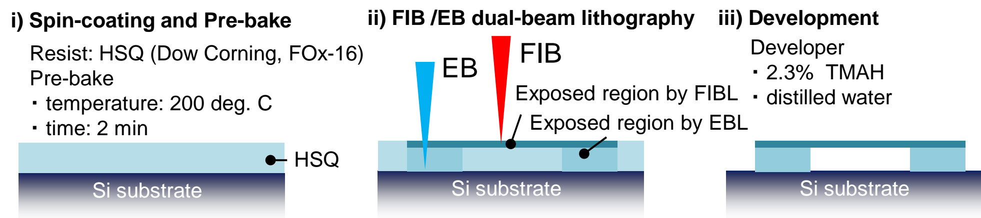

Figure 1: Schematic of a fundamental process of the 3-D nanosturcture fabrication by FIB/EB dual-beam lithography.

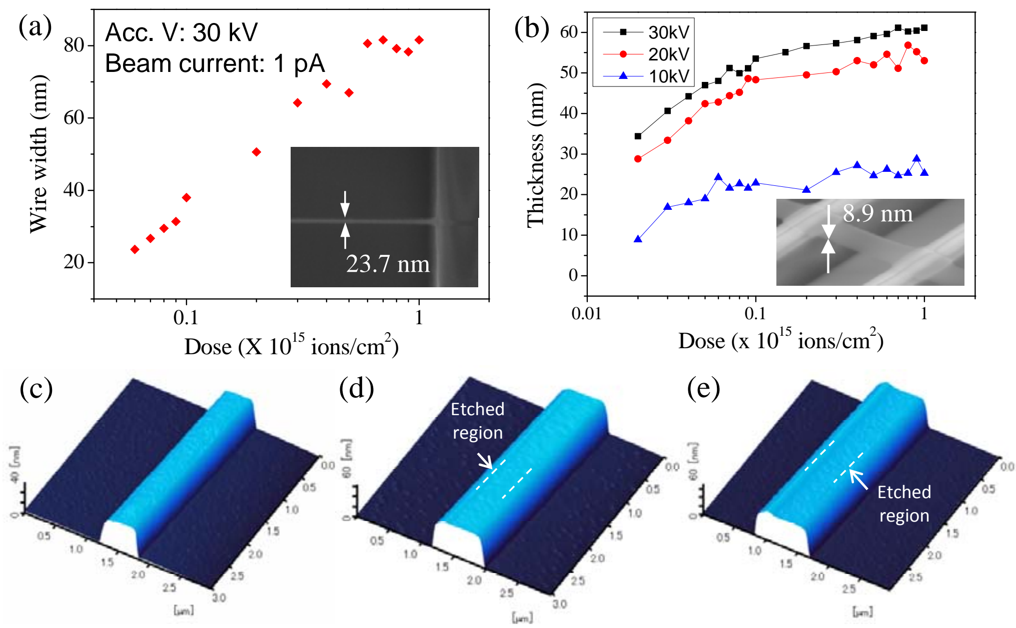

Figure 2: Relationship between the ion dose and structural properties of HSQ structure exposed by Ga^+ FIB: (a) Ion dose dependence of width of a suspended HSQ wire, (b) Acceleration voltage dependence of the developed thickness, Atomic microscope images of HSQ nanowire fabricated with ion dose of (c) 0.1 x 10^{15} ion/cm^2, (d) 0.5 x 10^{15} ion/cm^2 and (e) 1 x 10^{15} ion/cm^2.

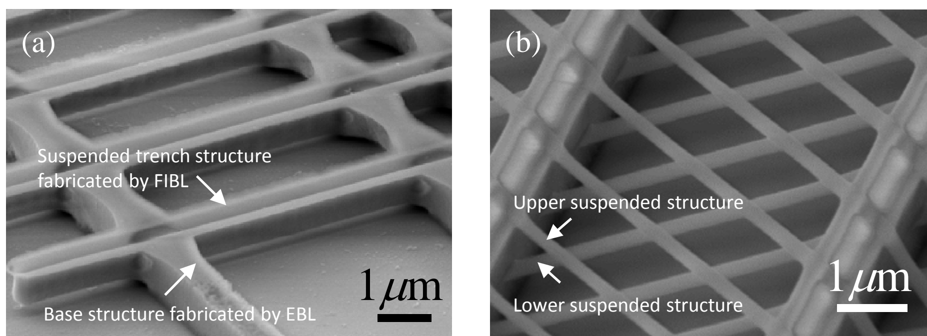

Figure 3: The 3-D nanostructures fabricated by FIB/EB dual-beam lithography. (a) SEM image of a suspended trench structure fabricated by FIBL with a ion dose of 1 x 10^{17} ions/cm^2, (b) SEM image of double-tiered crossover suspended structures fabricated by using a multi-coating technique.