Ion beam lithography of quartz

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Mask less and rapid patterning of quartz surface is useful for various applications such as rapid prototyping of optical elements and UV nanoimprint mold. To fabricate these quartz applications, ion beam lithography (IBL) of quartz is effective because of high sensitivity. Therefore, IBL of quartz and pattern controllability of IBL were examined.

Mechanical polished quartz substrates were used as specimens. Quartz is an electrical insulator, so charge-up occurs during ion beam irradiation. To prevent charge-up, ESPACER (SHOWA DENKO K.K.), a conductive polymer, was spin-coated over quartz surface. Quartz samples with or without ESPACER coating were irradiated using focused ion beam (FIB) equipment (JEOL JFIB-2300) at an acceleration voltage of 30 kV, an ion beam current of 0.35 pA and an ion species of Ga^+. The ESPACER coating was removed by water rinse before development. The irradiated samples were developed in buffered hydrofluoric acid, and then irradiated area was etched away because dissolution rate was enhanced by ion beam irradiation. Fabricated patterns were observed with atomic force microscope (SII SPA-400).

The etched depth and etched line width of fine patterned quartz surface are shown in Fig 1 and 2, respectively. The developing time was 60 s. The etched depths and line widths saturate with increasing ion dose. Line width of bare quartz was larger than that of quartz with ESPACER. The reason is that ion beam is wobbled by surface charge-up, so scanning line width will be widened. Therefore, the prevention of surface charge-up is important to fabricate nano-order structures. A 34 nm depth and 487 nm width line pattern was obtained at the dose of 53 $\mu C/cm^2$ using 330 nm diameter FIB irradiation.

To obtain deeper etched pattern, high acceleration IBL was carried out with electron cyclotron resonance type ion beam equipment (PANTECHNIK Co., 10 GHz-NANOGAN). This is the Ar^+ shower type ion beam, so ion beam irradiation was shut out by Cu stencil mask. The acceleration voltage dependences of developed depths are shown in Fig 3. The developed depth increases with increasing acceleration voltage. Thus, the developed depth corresponds to ion beam projected range and depth control is possible using acceleration voltage change. If the removal volume of quartz was the same, etching rate of IBL is 1818 times as fast as that of sputtering etching.

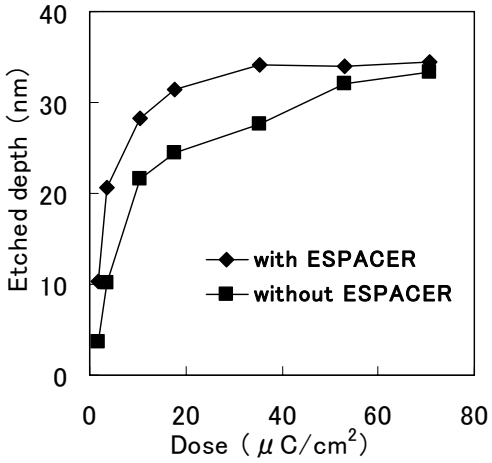

Fig 1: The ion dose dependence of the etched depth of quartz surface.

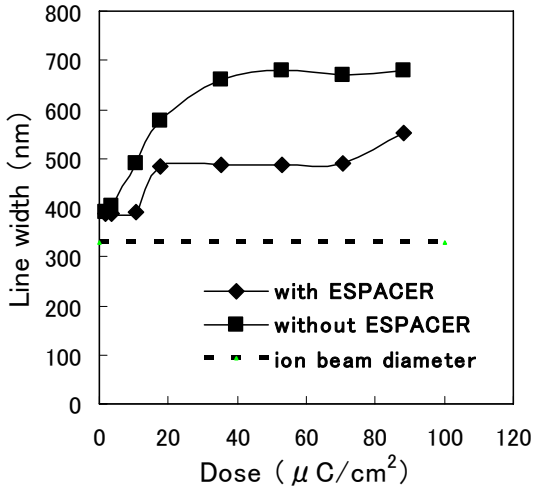

Fig 2: The ion dose dependence of the etched line width of quartz surface.

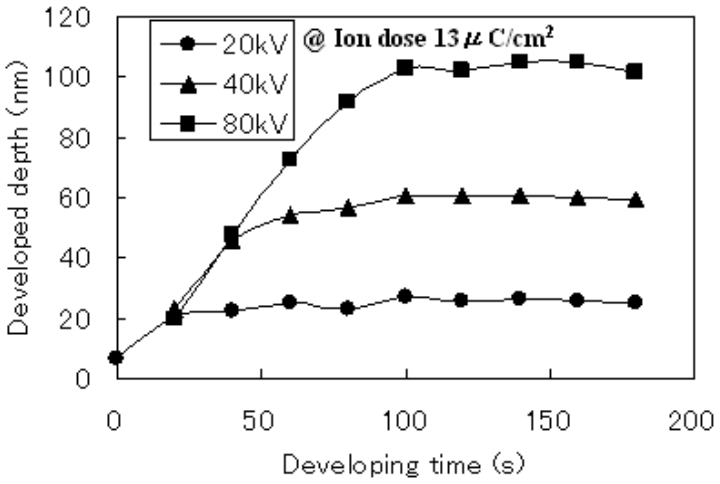

Fig 3: The developed depth vs. acceleration voltage and developing time.