Fabrication of High Aspect Si Pillars by Deep Reactive Ion Etching Using Nanoimprinted HSQ Masks

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Nanoimprint lithography (NIL) is attracting considerable attention from many industries. There are many polymers that can be used as the replication materials used in imprinting. In particular, hydrogen silsesquioxane (HSQ) has a useful property that enables imprinting at room temperature (RT). Therefore, HSQ allows a precise nanopattern replication in a simpler and lower cost processes than conventional thermal NIL and UV NIL. Furthermore, HSQ is very suitable for dry-etching masks thanks to its high dry-etching durability.

In this report, we introduce a fabrication of high-aspect Si pillars by deep reactive-ion etching (D-RIE) using HSQ masks replicated by RT nanoimprinting. We used caged-HSQ (FOX-16, Dow Corning Co.) as the replication material. The fabrication process is as follows. (1) HSQ was spin coated on a Si substrate. (2) A SiO_2/Si mold was pressed into the HSQ resin at RT. (3) After removing the mold from the HSQ resin, HSQ residue in compressed areas was etched by CHF_3 RIE. (4) Si was deeply etched by SF_6 and C_4H_8 gases-combined D-RIE using the HSQ patterns as the etching mask.

Table I shows a summary of dry-etching rates of HSQ. As the table shows, a dry-etching rate of HSQ resins annealed at 750^oC and 1000^oC are approximately twice as much as that of HSQ resin without annealing. Figure 1 shows an annealing temperature dependence of Fourier transform infrared spectroscopy (FT-IR) spectra of HSQ resins. Peaks of Si-O at 1130 cm^{-1} and Si-H at 3300cm^{-1} appeared in the spectra of HSQ resin without annealing. However, the peak of Si-H decreased as annealing temperature increased. Moreover, in the spectra of HSQ resin annealed at 1000^oC, we can observe only an intensive-sharp peak of Si-O. This means that the HSQ was transformed into SiOx structure by 1000^oC annealing. This is attributed to the enhancement of the etching durability of the 1000^oC-annealed-HSQ resin. We therefore used the 1000^oC-annealed-HSQ patterns as the etching mask to fabricate the high-aspect Si pillars.

Figure 2 shows 250-nm-wide and 170-nm-high HSQ patterns fabricated by RT nanoimprinting after 1000^oC annealing. Figure 3 shows 3300-nm-high and 250-nm-wide Si pillars fabricated by D-RIE using HSQ masks of Fig.2. As the result indicates, the high-aspect Si pillars with an aspect ratio of 13.2 were successfully fabricated with HSQ mask replicated by RT nanoimprinting.

These results indicate the adequacy of using HSQ patterns as the dry-etching mask for fabricating high-aspect Si structures.

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Sample	etch time (min)	etched HSQ (nm)	etching rate (nm/min)
1000°C-annealed HSQ	5.25	60	11.4
750°C-annealed HSQ	5.25	60	11.4
HSQ no treated	5.25	105	20

Table I. Dry etching rates of HSQ resins.

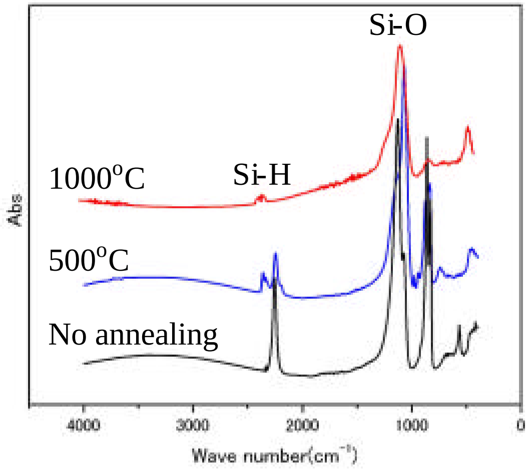

Figure 1. Annealing temperature dependence of FT-IR spectra of HSQ resins.

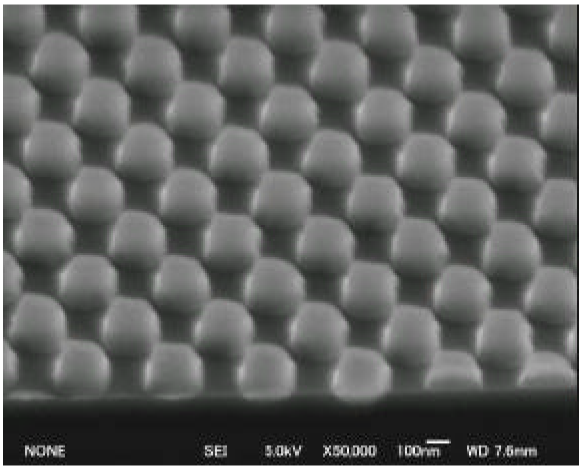

Figure 2. HSQ patterns fabricated by RT nanoimprinting after 1000°C annealing.

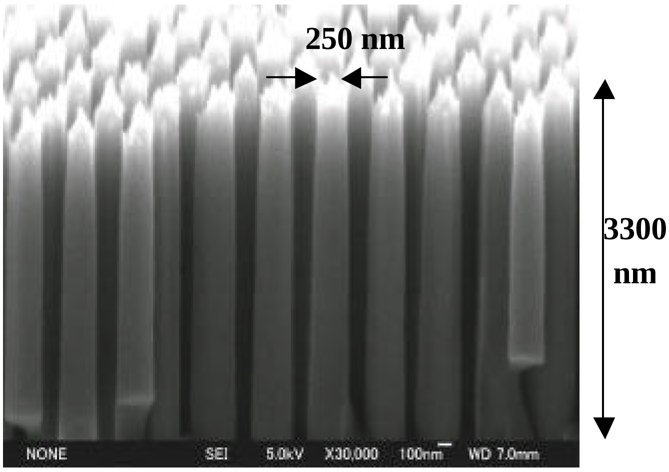

Figure 3. High-aspect Si pillars fabricated by DRIE using nanoimprinted-HSQ mask.