Room-Temperature Nanoimprint using Liquid-Phase Hydrogen Silsesquioxane with PDMS mold

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We have newly developed an imprinting technique using liquid-phase hydrogen silsesquioxane (HSQ) with Poly(dimethyl siloxane) (PDMS) mold. The patterns with various linewidth were demonstrated by imprinting using liquid-phase HSQ. And then, after imprinting, the residual HSQ layer that remained in the compressed area was less than 10 nm thick, because the solvent in HSQ smoothly evaporated through the pores of PDMS mold.

Keywords: poly(dimethyl siloxane) (PDMS), hydrogen silsesquioxane (HSQ), Room-Temperature, nanoimprint, liquid-phase

1. Introduction

Recently, Nanoimprint lithography (NIL)¹⁻³, which has been receiving a lot of attention from many industries, promises a high-throuput production of various nanostructure applications such as optical devices with a simple process and low cost. NIL is a candidate for next generation lithography because of the advantages mentioned above.

In previous experiments on HSQ patterns replication using room-temperature NIL (RT-NIL) with SiO₂/Si mold, we applied a conventional spin-coating to form HSQ resin on a substrate. However, the issue of a higher imprinting pressure than those of thermal NIL and UV NIL still remain to be addressed in NIL using spin-coated HSQ as the replication material. We attribute these disadvantages to evaporation of the solvent contained into HSQ during the spin-coating.

2. Experimental

To overcome the above problem, we reported a nanoimprint technique using liquid-phase HSQ as a replication material alternative to HSQ resin formed by conventional spin-coating.⁴ A low imprinting pressure and HSQ residual layer with less than 10 nm thick were achieved by using liquid-phase HSQ. But the HSQ-coated substrate is required to heat up around 90 °C to evaporate the solvent contained in the HSQ resin while the press pressure was held. And a large area imprinting was difficult because the organic solvent in the HSQ evaporated only through the side-gap between SiO₂/Si mold and HSQ coated Si substrate. To address these problems, we used Poly(dimethyl siloxane) (PDMS)⁵⁻⁶ mold instead of SiO₂/Si mold. Because PDMS is a porous gel, the organic solvent in the HSQ solution can be evaporated through PDMS mold.

3. Results and Discussion

Figure 1 shows a new imprint technique using liquid-phase HSQ with PDMS mold. The process is as follows. (1) First, the PDMS mold was fabricated by spin-coating a 10:1 ratio mixture of base resin and hardener resin (Dow Corning Co. Sylgard 184) on the SiO₂/Si master mold, which is treated by a fluorinated

Fig. 1 Schematic of imprinting process using liquid-phase HSQ with PDMS mold

anti-sticking agent. The rotating speed and time were 500 rpm and 10 sec. (2) Following, PDMS coated substrate was baked at 70 °C for 15 min to cure the PDMS. (3) After curing of the PDMS, the PDMS mold was de-molded from the SiO₂/Si master mold. (4) Next, HSQ solution was dropped onto a Si substrate. (5) Following, the PDMS was pressed onto the Si substrate with 1 MPa pressure. (6) And then, the organic solvent in the HSQ solution was evaporated through the pores of PDMS. The imprinting temperature, pressure and time were RT, 1 MPa, and 10 min, respectively. In this experiment, we used two kinds of HSQ, one is the caged HSQ (Dow Corning Co. FOX-16) and another is the ladder HSQ (Tokyo Ohka Kogyo Co. OCD T-12). (7) Finally, the PDMS mold was removed from the Si substrate, and then HSQ patterns were completely replicated on the substrate.

Figures 2 (a) and 2 (b) show scanning-electron microscopy (SEM) micrographs of imprinted HSQ patterns. Figure 2 (a) shows the imprinted HSQ

Fig. 2 Micrographs of the imprinted HSQ patterns.

- (a) using liquid-phase caged HSQ (FOX-16)
- (b) using liquid-phase ladder HSQ (OCD T-12)
- (c) 4 inch wafer imprinted using liquid-phase caged HSQ.

patterns using liquid-phase caged HSQ resin.

Figure 2 (b) shows the imprinted HSQ patterns using liquid-phase ladder HSQ resin. The residual layer thicknesses for both HSQ patterns were less than 10 nm, which was confirmed by SEM observation.

Figure 2 (c) shows an optical micrograph of a 4 inch Si wafer which imprinted using liquid-phase caged HSQ resin. HSQ pattern was successfully replicated on a 4 inch wafer in full area. This result indicates that the organic solvent in HSQ was evaporated through the pores of PDMS.

In conclusion, we have successfully developed a new RT-NIL using a liquid-phase HSQ resin with PDMS mold.

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