Room-Temperature Nanoimprinting Using Organic Spin-on-Glass

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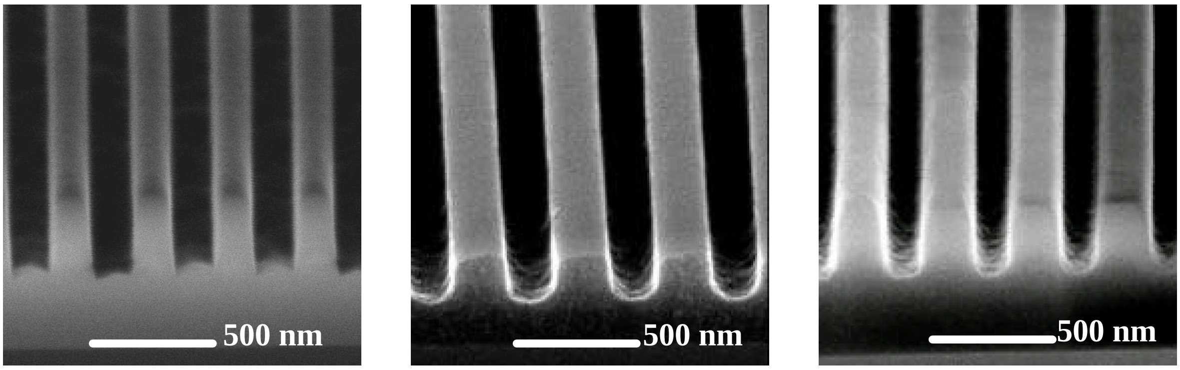
Room-temperature nanoimprint lithography (RT-NIL) is capable of achieving a precise nanopattern replication with a simple process and a low cost, because the technique can eliminate resist-thermal cycle and UV exposure, prone to causing reduction in pattern accuracy and a throughput. As the replication material in RT-NIL, we proposed the use of spin-on-glass (SOG) [1]. SOG is an inorganic material, and particularly beneficial for optical applications because of its good optical characteristics such as a high transparency and a low-k property. SOG is also suitable for a dry etching mask owing its high dry etching durability. Whereas SOG allowed imprinting at RT, there is a problem that the imprinted depth was very shallow even the application of pressures above 20 MPa. This was attributed to immediate surface hardening caused by solvent evaporation, and hydrolysis reaction after spin-coating. To address the above problem, a new material, organic SOG, which contains organofunctional groups in the polymer structure, has been proposed as an alternative to the inorganic SOG currently used.

Imprinted-patterns replicated using two kinds of SOG are compared here. A mold shown in Fig. 1(a) was used for the investigation. Figure 1(b) shows an inorganic SOG pattern imprinted with 40 MPa pressure. Whereas the linewidth of the pattern was the same as the mold linewidth, the depth was only 260 nm, approximately 190 nm shallower than the height of the mold, even the application of the high pressure. Figure 1(c) shows an organic SOG pattern imprinted with 20 MPa. Thus, organic SOG newly proposed allowed RT imprinting as well. The depth of the pattern was almost 100 nm deeper than the depth of the inorganic SOG pattern replicated with 40 MPa. The results indicate that the organic SOG offers the efficient property of enabling low-pressure imprint replication compared to the inorganic SOG.

RT-NIL using organic SOG as the replication material also produced nanoscale pattern of 30-nm line-and-spacing grating, as shown in Fig. 2. In addition, we successfully fabricated lens structures by polymer reflow method, as shown in Fig. 3(b). Organic SOG patterns with a circular cylinder shown in Fig. 3(a), which had 1-μm-diameter and 600-nm-height, produced the lens structures of 1.3-μm-diameter and 330-nm-high after baked on a hot plate at 170^{o}C for 2 min. The lens structures will be used directly as microlens because the organic SOG has the good optical properties including high transparency exceeding 98% and high reflective index of 1.56.

[1] S. Matsui and Y. Igaku et al, J. Vac. Sci. Technol. **B**19 2801 (2001).



(a) (b) (c)

Figure 1. (a) SiO_2/Si mold with 200-nm line-and-spacing grating and 450 nm high. (b) inorganic SOG pattern with 200-nm line-and-spacing grating and 260 nm high, imprinted at RT with 40 MPa pressure, and (c) organic SOG pattern with 200-nm line-and-spacing grating and 360 nm high, imprinted at RT with 20 MPa pressure

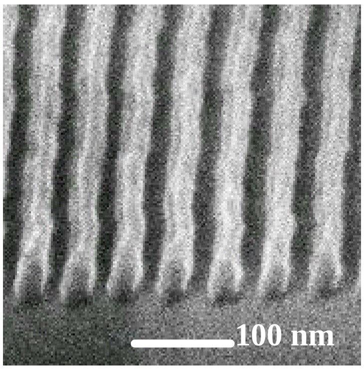
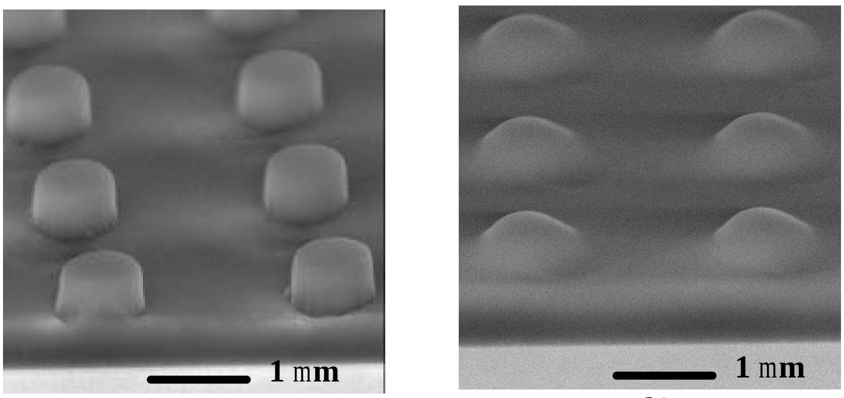


Figure 2. Organic SOG pattern with 30-nm line-and-spacing grating.



(a) (b)

Figure 3. (a) Organic SOG pattern with 1-µm-diameter and 600-nm-height, and (b) lens structures fabricated by polymer reflow using the organic SOG pattern of Fig. 3(a). This pattern has 1.3-µm-diameter and 330-nm-high.