UV-nanoimprint with the assistance of gas condensation at atmospheric environmental pressure

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Two types of UV-nanoimprint system have been proposed as viable UV-nanoimprint technique. One is using reduced environmental pressure [1], and the other is using droplets at atmospheric environmental pressure [2]. They can be escape from bubble defects [3] unavoidable for UV-nanoimprint in air. We propose the third system of UV-nanoimprint with the assistance of gas condensation to solve the bubble defect problem. It is aimed at complete filling with very simple way using spin-coated UV-curable resin even at atmospheric environmental pressure.

Figure 1 shows the mold table equipped with gas lines of UV-nanoimprinter [4]. A 10 x 10 mm mold is positioned at the center of the mold table and branched gas lines are connected to the mold table. Pentafluoropropane of which the vapor pressure at room temperature is 0.15 MPa was supplied to the nanoimprint space between the mold and wafer through the gas lines as shown in Fig. 2. The trapped gas in the mold recesses starts condensation when the gas pressure exceeds 0.15 MPa during nanoimprint.

To prove the effectiveness of the gas, severe nanoimprint conditions [1] were adapted, i.e., large pattern feature, thin initial resin film and short process time. A mold having 300-μm-wide 150-nm-deep checker pattern was used. UV-curable resin (PAK-01) was spun on a Si wafer with the initial resin film thicknesses ranging from 80 to 320 nm. The nanoimprint pressure was 0.5 MPa and the waiting time before UV exposure was 60 s. We confirmed that severe bubble defect problem arises when UV-nanoimprint is carried out without pentafluoropropane.

Figure 3 shows nanoimpirnt pattern fabricated using pentafluoropropane for initial resin thickness of 80 nm. Uniform patterning seems to be realized except for peripheral regions i.e., vicinity of corners and edges. Optical microscope inspection revealed that no bubbles exist in the central region and around 10 μm wide bubbles were generated in the vicinity of an edge. The percentage of complete filled structure [1] was 95% in this case and the percentage became 100 % for initial resin thickness larger than 100 nm.

Figure 4 shows the map of residual layer thickness, measured with reflective film thickness monitor, of 15 x 15 points in 9 x 9 mm square for the sample shown in Fig.3. We can see that residual layer is thin and uniform in the central region. The average value of residual film thickness was 26.8 nm and the standard deviation was 4.6 nm.

We expect that the minimum initial resin thickness where no bubbles are generated will be reduced when the SOFT stage [4] (shown in Fig.2) the conformable pressing mechanism of the UV-nanoimprinter is retrofitted.

References
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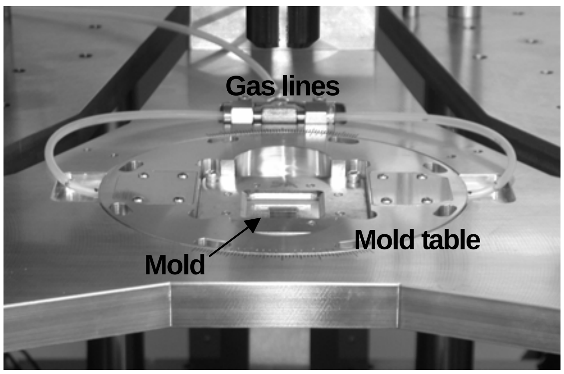

Fig. 1. Mold table equipped with gas lines. A 10 x 10 mm quartz mold is attached at the center of the mold table.

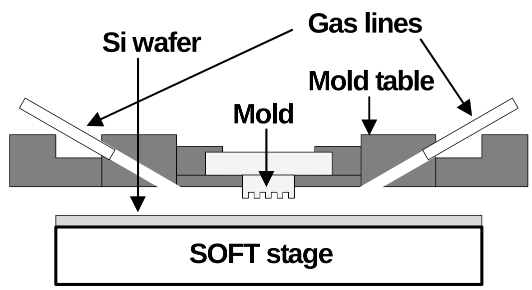

Fig. 2. Schematic cross section of mold table and sample stage. Gas is supplied to the nanoimprint space between the mold and wafer through the gas lines

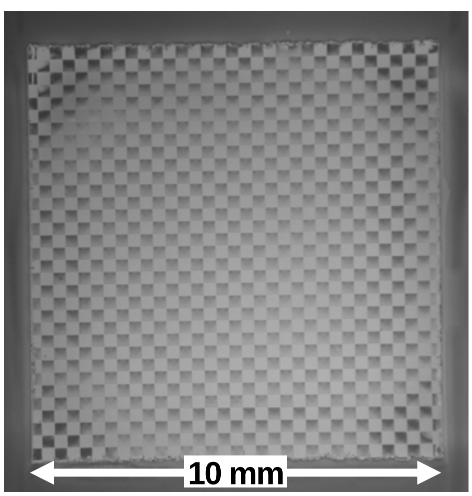

Fig. 3. Checker pattern fabricated by UV-nanoimprint for initial resin thickness of 80 nm.

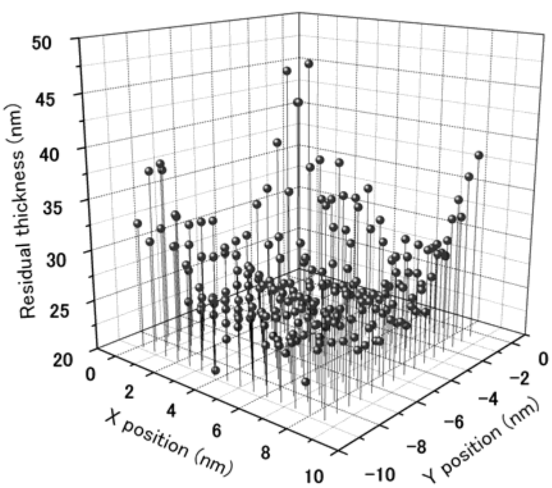

Fig. 4. Map of residual layer thickness.