Replacement of Trapped Air by Fluoride Liquid in Thermal Nanoimprint

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In order to minimize the amount of trapped air in concave pattern of a mold, that makes the mold defective, we have developed an immersion nanoimprint technique of spraying an optimum amount of fluoride liquid between the mold and a molding material. In a previous work with thermal-nanoimprinting on bulk plastic substrate at a low imprint pressure, molding defects were minimized by dropping of a fluoride liquid. In bulk material, some sections of pattern did not get transferred and appeared as macroscopic defects.[1] On the other hand, in case of spin-coated plastic-film on Si wafer, the quantity of the melted plastic that flows in thermal deformation is lower than in bulk plastics. Around each concave pattern the compressed air, that is caused by the imprint pressure, explodes by decompression, and generates viscous fingering pattern (Fig, 1(a)); and the trapped air remaining inside the convex pattern gives rise to bubble defects (Fig. 1(b)). These micro-size defects are caused by volume change of the gaseous material according to their compression. Then, in order to remove such defects, we proposed an immersion nanoimprint method where by replacing the compressible gaseous material by an incompressible liquid material.

A concave quartz mold NIM-PH350 (NTT-AT) was set on the bottom stage of a desktop thermal nanoimprint system NI-273 (Nano Craft Technologies). A 2-inch Si wafer with a 460-nm-thick PMMA (OEBR-1000, Tokyo Ohka Kogyo) spin-coated film was mounted on the upper stage with its coated surface facing down. Next, perfluorotributylamine (Fluorinert FC-43, 3M) with its boiling point of 174 ºC being higher than that of the imprint temperature was sprayed on the surface of the mold. Figure 3 shows 5- and 10-μm-width patterns fabricated by our immersion nanoimprint method. The quartz mold, and the PMMA coated Si wafer were heated to 145 ºC and brought close to each other, leaving a separation of 500 μm between the two, and then followed by spraying 100-μl FC-43 into the space between the two. After applying an imprint pressure of 5 MPa for 10 s, the mold and the PMMA coated Si wafer were cooled to 95 ºC, followed by a de-molding process. From both patterns, the defective moldings with fingering patterns and bubbles were removed. However, after the spray, a superfluous amount of FC-43 still remained in the surrounding area of the convex patterns. This problem will be resolved by curtailing the amount of FC-43 sprayed. In our next insertion device, to be introduced into the desktop thermal nanoimprint system, the amount of the fluid liquid will be precisely controllable.

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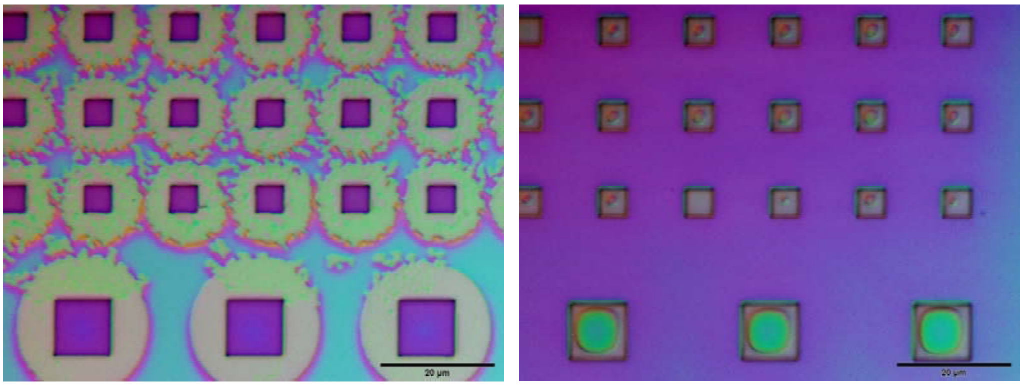
[1] H. Mekaru and H. Hiroshima, Jpn. J. Appl. Phys., 50, 06GK05 (2011).



(a) Concave imprinted patterns (b) Convex imprinted patterns

Figure 1: Optical micrographs of imprinted patterns on PMMA film coated on Si wafer without using FC-43.

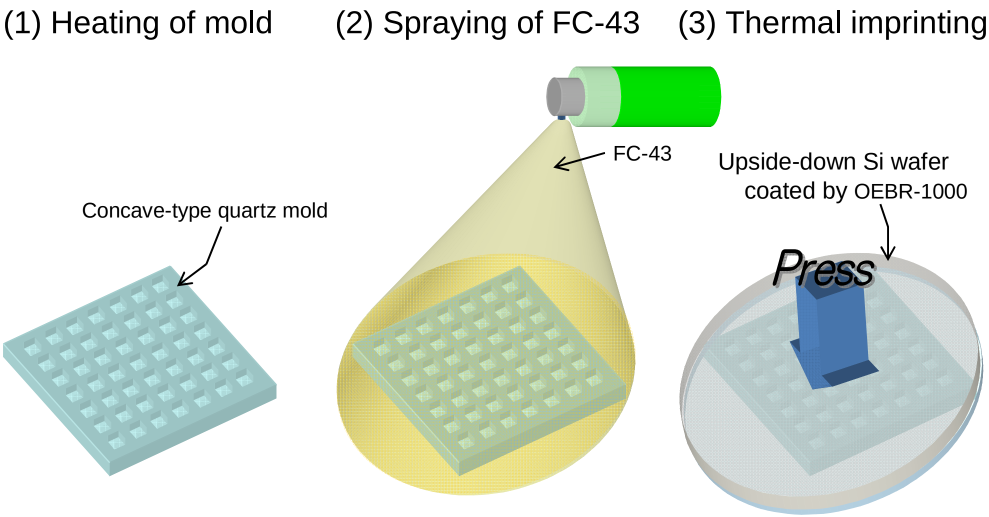
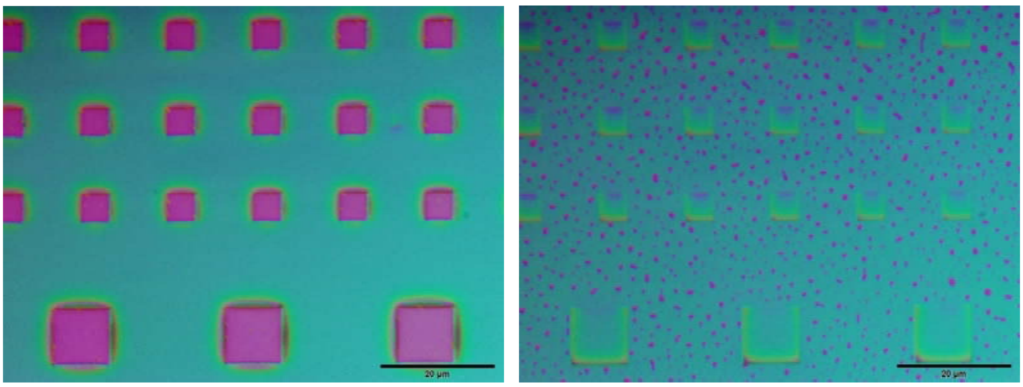


Figure 2: Experimental procedure in thermal nanoimprint inserted a spraying step of a fluoride liquid.



(a) Concave imprinted patterns (b) Convex imprinted patterns

Figure 3: Optical micrographs of imprinted patterns on PMMA film coated on Si wafer after the spraying of FC-43.