2D to 3D Imprinting on Surface of Teflon PFA Inlet Tube

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We successfully demonstrated the imprinting of patterns from a plate electroformed-Ni mold onto the surface of a Teflon perfluoroalkoxy (PFA) inlet tube to develop three-dimensional (3D) micro valves and micro pumps.

Figure 1(a) shows our method of pattern transfer. A cylindrical plastic fiber is sandwiched between a plate mold on a bottom loading stage and a buffer sheet fixed on an upper loading stage. The cylinder plastic fiber rotates when the mold slides on the bottom loading stage. Figure 1(b) shows a photograph of the experimental setup assembled on a desktop thermal nanoimprint system NI-273 (Nano Craft Technologies Co.). An electroformed-Ni mold was mounted on the bottom stage of a stepping motor (Sigma Koki Co.,Ltd.) where it could be moved in horizontal direction. A Si rubber was fixed on the upper loading stage, and a Teflon PFA inlet tube (1/16 inch o.d., 0.02 inch i.d., Upchurch Scientific Inc.) was set perpendicularly to the slide direction on the surface of the Ni mold.

Figure 2(a) shows a SEM image of a convex mold pattern processed by MEMS fabrication technologies. The mold pattern replicates a microcoil and an electrostatic actuator with the line-width of 5 μm (or more) and a depth of 2 μm. In the imprint process, the upper loading stage was kept at the room temperature, and the bottom loading stage was heated up to 180 °C. The moving speed of the stepping motor was fixed to 0.5 mm/s. Figure 2(b) shows an example of the Teflon-PFA tube after imprinting. With this technique the mold patterns were clearly transcribed on the surface of a Teflon-PFA tube.

In Fig. 3, the contact force, the rotation speed, and the depth of imprinted patterns are plotted as functions of press depths. The position of the initial contact of Si rubber with the Teflon-PFA tube is defined as press depth = 0 μm. The contact force increased proportionally with increasing press depths. However, the rotation speed of the Teflon-PFA tube decreased dramatically when the press depth reached 500 μm or more. At 600 μm press depth the Teflon-PFA tube became unable to rotate. The imprinted depth measured with a 3D optical profiler was found to be 1.75 μm at a press depth of 300 μm. Thus, it became necessary to imprint under an optimized condition that does not obstruct the rotation to be able to transfer precise patterns on the surface of a cylinder fiber.

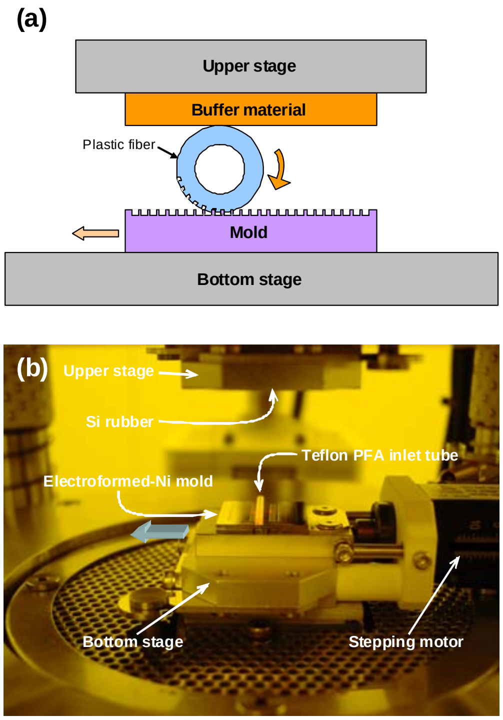

Fig. 1: (a) Illustration of 2D to 3D imprint method. (b) Photograph of experimental arrangement in NI-273 nanoimprint system.

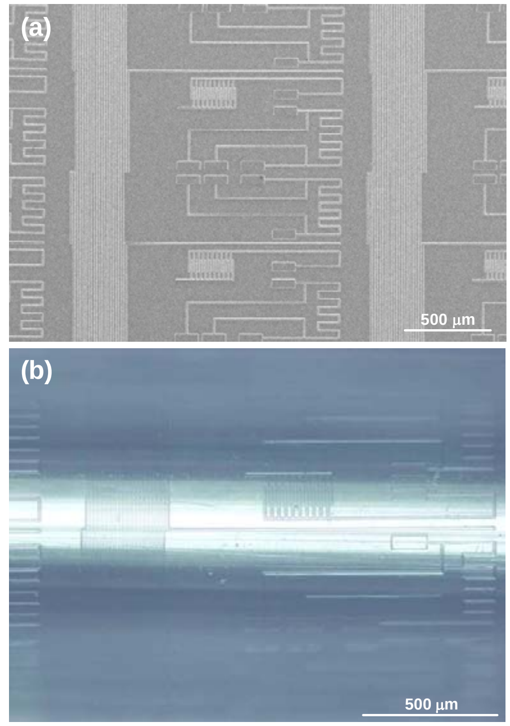

Fig. 2: (a) SEM images of mold patterns in an electroformed-Ni mold. (b) Optical micrograph of imprinted patterns on a Teflon PFA inlet tube.

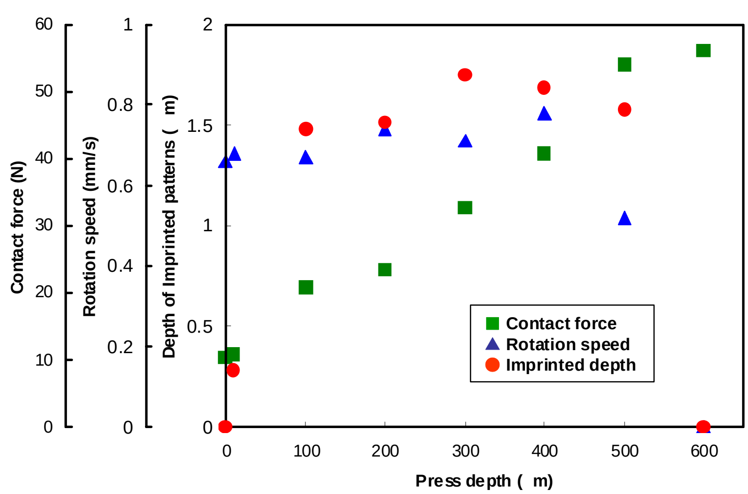

Fig. 3: Contact force, rotation speed, and depth of imprinted patterns shown as functions of press depth.