Rapid Patterning of Spin-On-Glass using Ultrasonic Nanoimprint

H. Mekaru, M. Takahashi
National Institute of Advanced Industrial Science and Technology (AIST),
1-2-1, Namiki, Tsukuba, Ibaraki 305-8564, Japan

We succeeded in room-temperature patterning on a spin-on-glass (SOG) coated Si substrate by an ultrasonic nanoimprinting in one minute. Typically, at room-temperature it takes ten minutes of contact time with a press pressure of 2.5 MPa to nanoimprint [1]. In our ultrasonic nanoimprinting, plastic deformation and thermal deformation caused by initial pressure and frictional heat generated by ultrasonic vibration are combined to achieve precise structures.

The ultrasonic nanoimprinting is a simple process. Here, mold patterns are pressed against a SOG coated Si substrate, followed by a longitudinal ultrasonic vibration impressed during the contact process. After a pre-set time the ultrasonic vibration is stopped and mold patterns are separated from the imprinted SOG substrate that completes the patterning process (Fig. 1). In our experiment, for SOG we spin-coated a 480-nm-thick film of Accuglass 512B (Honeywell Co.,Ltd) on a Si substrate at 5000 rpm for 30s. We used an electroformed-Ni mold NIM-RESO-S(Ni) (NTT-AT Nanofabrication Corp.). The mold size was $30\times30\times0.3$ mm^3, and it contained 550 nm high convex square dotted patterns in widths of 200, 300, 500, 800, 1000 and 3000 nm. The width-to-space pattern ratios on the mold were designed as 1:1, 1:2, and 1:3.

Figure 2 shows optical micrographs of a SOG surface after nanoimprinting. Figure 2(a) is the result of ultrasonic nanoimprinting at 10 kHz with 3 μm amplitude for one minute using 28 MPa of pressure. Each dot array of 200, 300, and 500 nm was faithfully transferred onto the SOG. When the pressure was reduced to 5.6 MPa (1/5 of 28), while keeping other conditions unchanged, a discoloration in the imprinted patterns appeared in part of the Fig. 2(b). Figure 2(c) shows the result of applying a press pressure of 28 MPa for one minute without the use of ultrasonic. No noticeable imprinted pattern was seen in Fig. 2(c). It became clear that ultrasonic vibration is effective for patterning on non-baked SOG, and that a trade-off between the press pressure and the amplitude of ultrasonic vibration is important.

Figure 3 shows field-emission (FE) SEM images of SOG patterns from Fig. 2(a) sputter-deposited with15-nm-thick Au film. Here each concave pattern in widths of 200, 300, 500, 800 nm are well fabricated in SOG. The contrast difference between Figs. 3(c) and 3(d) depended on the imprinted depths of the SOG patterns. The depths of the patterns with low and high contrasts were measured by a five-line confocal microscope Optekics S130 (Lasertec Corp.) using 405 nm wavelength, and were found to be 210 and 420 nm, respectively.

1 S Matsui *et al*., J. Vac. Sci. Technol. B 19, 2801 (2001).

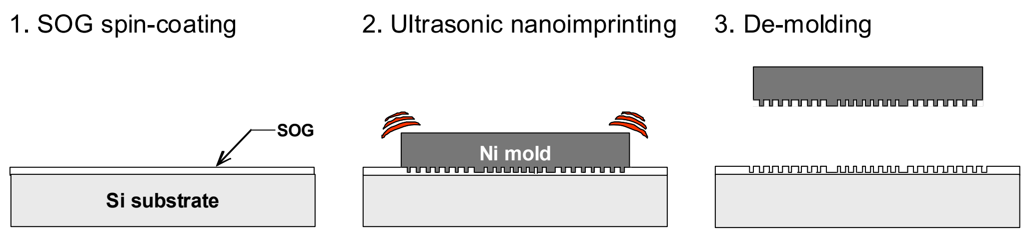

Fig. 1: Process flow of ultrasonic nanoimprint on SOG.

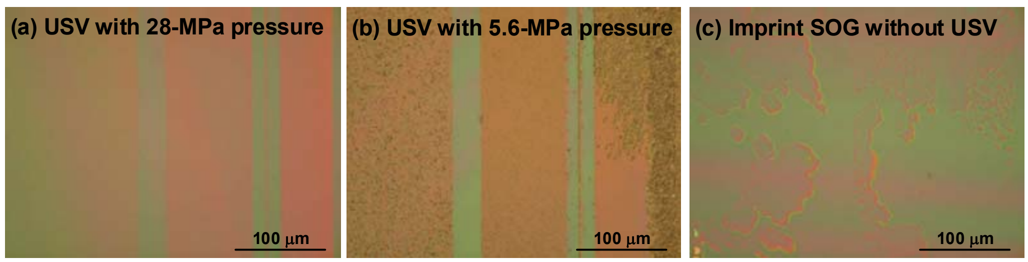

Fig. 2: Optical microphotographs of imprinted patterns on SOG coated substrates. “USV” means ultrasonic vibration.

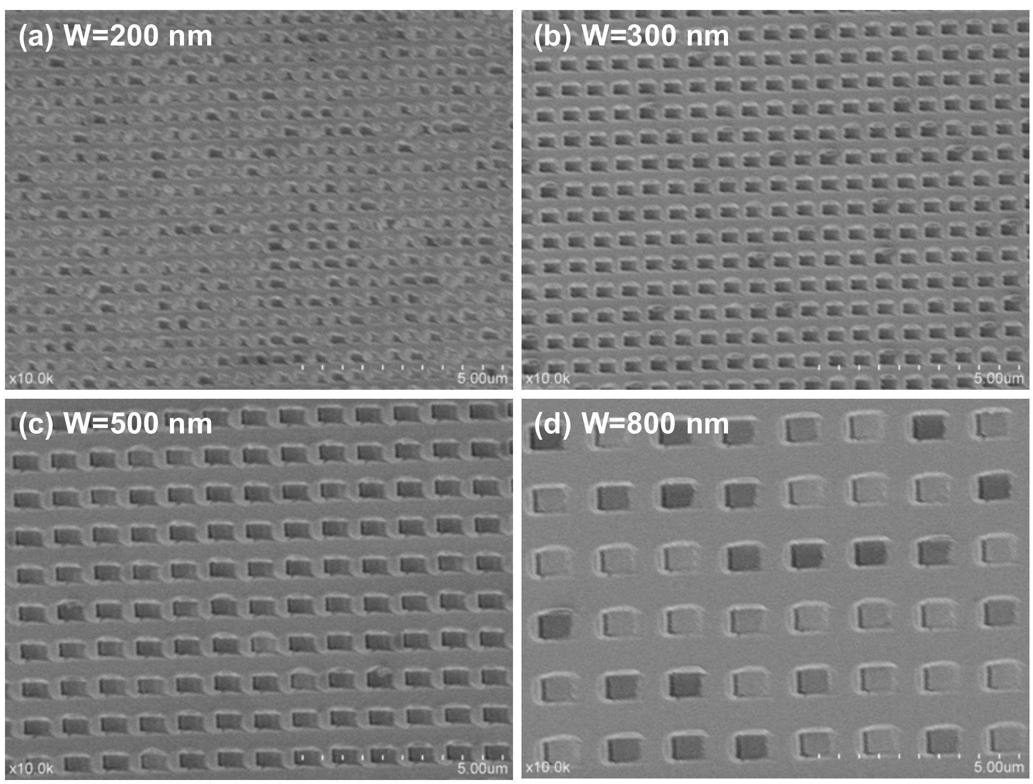

Fig. 3: FE-SEM images of ultrasonic-nanoimprints on SOG coated substrates after depositing a 15-nm-thick Au film. “W” means pattern width.