45 nm hp line/space patterning into a thin spin coat film by UV nanoimprint based on condensation

Hiroshi Hiroshima[1, 2], Qing Wang[1, 2] and Sung-Won Youn[1, 2]
[1]National Institute of Advanced Industrial Science and Technology (AIST),
AIST East, 1-2-1 Namiki, Tsukuba, Ibaraki, 305-8564 Japan
[2]JST-CREST, 5 Sanbancho, Chiyoda-ku, Tokyo, 102-0075 Japan
E-mail: hiroshim@ni.aist.go.jp

UV nanoimprint lithography is a promising candidate of next generation ULSI patterning technologies. Droplet dispensing of UV curable resin is popular for UV nanoimprint lithography.[1] However, we dare to choose spin coating of UV curable resin for high throughput process with the assistance of pentafluoropropane (PFP) as a bubble elimination gas.[2] Bubble elimination in the UV nanoimprint based on condensation has been demonstrated for several μm wide isolated square patterns, but has not been proved for tens of nm sized line/space patterns frequently appeared in ULSI circuits. Such fine grooves of a mold produce extremely high capillary force[3] and may have anisotropic filling behaviors along or transverse the grooves. In this study, UV nanoimprint of such fine line/space patterns using spin coating UV curable resin films are investigated in air and in PFP.

Vertical and horizontal line/space patterns with half pitches of 90, 65 and 45 nm were etched to a depth of 90 nm in a 10 mm × 10 mm quartz mold. Each area of the six different patterns is 80 μm × 80 μm and is fringed with 1 μm wide line/space patterns. The 80 μm × 80 μm patterns are distributed with intervals of 200 μm in 5 mm × 5 mm at the center of the mold. UV nanoimprint was carried out using UV nanoimprint stepper at an imprint force of 10 N for 10 s in air and in PFP. Patterns fabricated into 110 nm thick UV curable resin (PAK-01, Toyogosei) in air are shown in Fig. 1 and the magnified image of the vertical line/space patterns are shown in Fig. 2. In air, complete resin filling cannot be realized despite the extremely high capillary force and created bubbles tend to be coalesced at the middle of lines. This implies that resin filling starts from both end of lines and spreads to the middle of lines. Such anisotropic filling behavior was not observed in the 1 μm wide line/space fringes. Patterns not at the bubbly area look uniform for 90 and 65 nm half pitches but show uneven appearance for 45 nm half pitch. Figure 3 shows patterns with half pitches of 90, 65 and 45 nm fabricated by UV nanoimprint in PFP. There are no traces of bubbles in the middle of lines and quite even colored patterns were obtained. We think that the patterns were successfully fabricated judging from the appearance and this is the first successful demonstration of tens of nm patterning by UV nanoimprint based on condensation.

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[2]H. Hiroshima and M. Komuro, J. Vac. Sci. Technol. B, **25** (2007) 2333.
[3]G. Kumar, H. Tang and J. Schroers, Nature **457** (2009) 868.

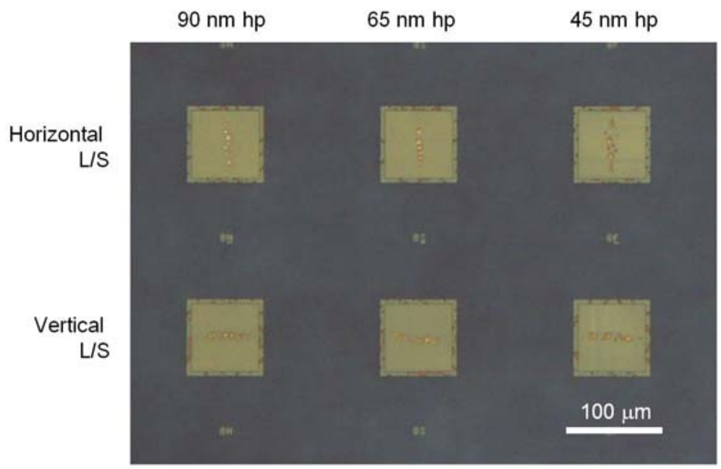

Fig. 1. Line/space patterns with half pitches of 90, 65 and 45 nm. Those patterns were fabricated by UV nanoimprint in air. Bubbles were coalesced in the middle of lines.

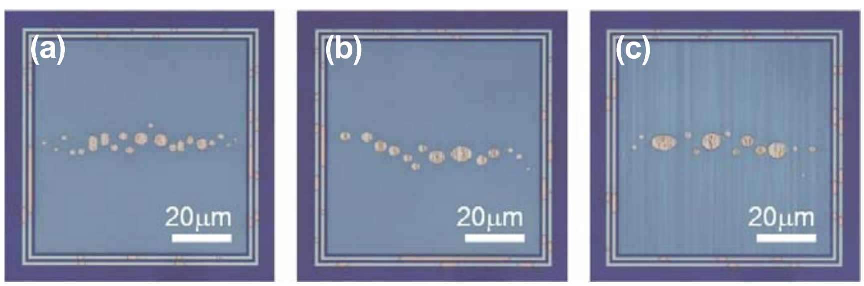

Fig. 2. Magnified images of the vertical line/space patterns with half pitches of (a) 90, (b) 65 and (c) 45 nm shown in Fig. 1.

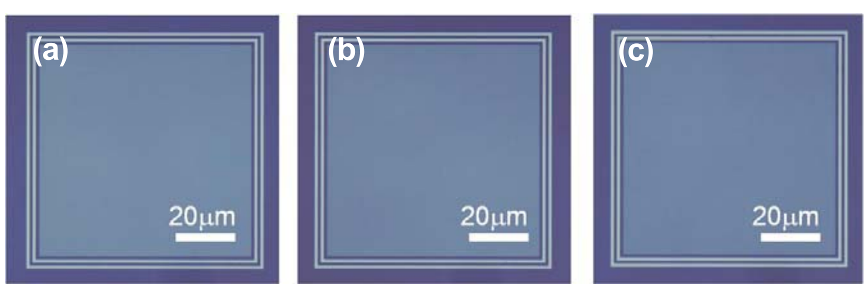

Fig. 3. Vertical line/space patterns with half pitches of (a) 90, (b) 65 and (c) 45 nm fabricated by UV nanoimprint in pentafluoropropane. The patterns were fabricated by the same portions of a mold producing patterns shown in Fig. 2.