Viscosity range of UV-curable resins usable in screen printing with polyimide through-hole membrane masks for sub-100 nm-wide imprint patterns

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Introduction: Unleveled residual layer thickness formed at concave parts of imprint resin patterns on a substrate surface is one of critical issues that needs to be resolved in UV nanoimprint lithography. We demonstrated the Printing & Imprint method for discharging a high-viscosity UV-curable resin as droplets on solid substrates by screen printing.[1)] Resin droplets of 12,800 mPa s were placed using polyimide through-hole membranes (PI masks) with a hole diameter of *ca.* 10 μm at the ratio of hole pitch (P) to hole diameter (d) of $\geq$ 2.5. Compared with a spincoated UV-curable resin film, use of UV-curable resin droplets was effective in leveling residual layer thickness due to suppression of edge effect in the molding process. In this study, we investigated the viscosity range of usable UV-curable resins in screen printing using PI masks. Distribution of diameter and height of cured resin droplets were measured to determine the volume of individual resin droplets. We investigated how to level residual layer thickness of sub-100 nm-wide imprint resin patterns.

Experimental: Fluorescent UV-curable resins in the viscosity range of 1,000 - 400,000 mPa s were prepared. Fluid resins were discharged on a 2-in. Si wafer using a PI mask with d = 10 μm and P = 45 μm. The diameters and heights of resin droplets were determined using a fluorescence microscope and surface profiler, respectively. UV nanoimprinting was carried out using a NL-SK1F resin (η = 12,800 mPa s) after screen printing as illustrated in Fig. 1. Residual layer thicknesses were measured using cross-sectional FE-SEM images of imprint resin patterns.

Results and Discussion: Figure 2 shows the fluorescence microscope images of discharged droplets with different viscosities. Resin droplets with a low viscosity of 1,909 mPa s were merged with adjacent droplets (Fig. 2a), while uniform dotted resin patterns were formed with UV-curable resins of 6,256 (Fig. 2b), 12,800 (Fig. 2c), and 265,500 mPa s (Fig. 2d). The diameter and height of NL-SK1F droplets were approximately 15 μm and 0.7 μm, respectively. Figure 3 shows the cross-sectional FE-SEM images of NL-SK1F imprint patterns with 45-nm-wide and 100-nm-wide concave line and space patterns on a Si substrate. The residual layer thicknesses were 0.18 μm for 45-nm-width and 0.19 μm for 100-nm-width. Placement of high-viscous resin droplets by screen printing was effective in leveling residual layers for sub-100 nm-width UV nanoimprinting.

Reference: 1) A. Tanabe, T. Uehara, *et al*., The 28th International Microprocesses and Nanotechnology Conference (MNC2015, Toyama, Japan), .P12P-7-85.

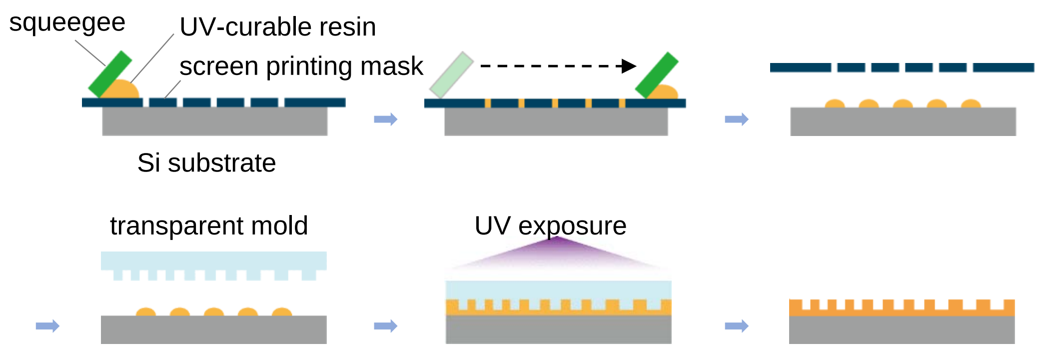

Figure 1: Schematic illustration of screen printing of high-viscous UV-curable resin droplets for leveling residual layer thickness in UV nanoimprinting.

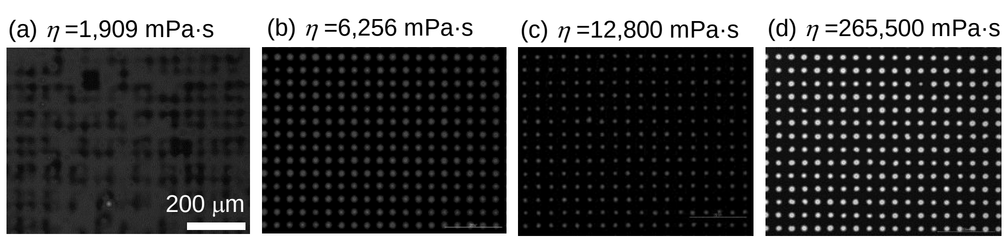

Figure 2: Fluorescence microscope images of UV-curable resin droplets with different viscosities of (a) 1,909, (b) 6,256, (c) 12,800, and (d) 265,500 mPa s discharged on a 2-in. silicon wafer by screen printing using a PI mask (d = 10 μm and P = 45 μm).

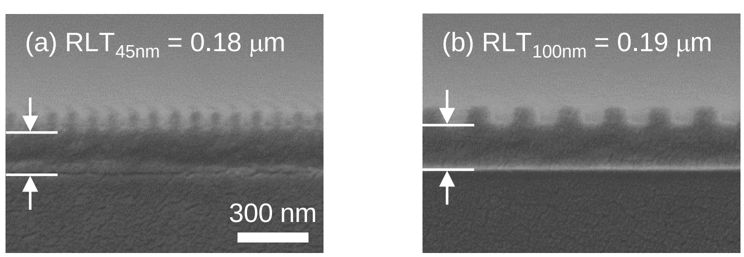

Figure 3: Cross-sectional FE-SEM images of NL-SK1F imprint patterns of (a) 45-nm-width and (b) 100-nm-width concave line patterns on a silicon substrate prepared using resin droplets discharged with a PI mask (d = 10 μm and P = 30 μm).