Fluorescence-intensity histogram characterizing uniformity of imprint resist patterns with different pattern-density distributions

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In UV nanoimprint lithography (UV-NIL), the presence or absence of pattern-density distribution of molds determines the difficulty in the formation of uniform resist patterns. Therefore, inkjet[1]and screen-printing[2,3] are useful for the quantitative placement of droplets of UV-curable liquid. We have demonstrated the microprint-and-imprint method combining laser-drilled screen-printing and nanoimprint lithography.[2,3] In this sturdy, fluorescent imprint patterns with pattern-density distributions were fabricated via the microprint and nanoimprint method. The height distributions of the imprint patterns were visualized by fluorescence imaging. The fluorescence-intensity histograms allowed the characterization of differences in height uniformity of the imprint patterns.

By UV nanoimprinting, we fabricated imprint patterns with three regions of a flat-film region and two convex pattern regions consisting of micro-bar (MB) arrays for alignment and a nano-disk (ND) array in center. For adjusting to the differences in pattern density, two polyimide screen-printing masks with different divided-unit areas were prepared based on calculating the number of droplets per divided unit, under the condition of a residual layer thickness of 100 nm, a convex pattern height of 150 nm, and a droplet volume of 0.34 pL. Fluorescent UV-curable droplets were placed on modified Si substrates separately using the two screen-printing masks. Transformed resist patterns and Si patterns transferred after dry etching were characterized using fluorescence and reflection microscopes at a magnification of 1.25×.

Figure 1a shows the design of a screen-printing mask divided into sections of 0.5×0.5 mm^2. The through-hole pitches were determined to be 50 µm for the red sections, 55 µm for the yellow and green sections, and 62 µm for the blue sections. The fluorescence image of the imprinted resist pattern (Fig. 1b) and its fluorescence-intensity color map (Fig. 1c) indicates that the MB and ND regions showed high fluorescence intensities compared to the flat-film region. The fluorescence-intensity histogram (Fig. 1d) confirms that the ND array region exhibited a normal distribution which suggests the uniform pattern heights. The design of a screen-printing mask divided into sections of 1×1 mm^2 is shown in Fig. 1e. The screen-printing mask was designed, in which the through-hole pitches were averaged near the boundaries between flat-film and ND-array regions. The fluorescence image of the resist pattern (Fig. 1f) and its fluorescence-intensity color map (Fig. 1g) suggested that the fluorescence intensities of the ND-array region became non-uniform. The histogram (Fig. 1h) indicated that the ND-array region showed a broad fluorescence-intensity distribution. These results demonstrated that the selection of section deviation was important for the design of screen-printing masks. The transferred Si patterns after dry etching showed a histogram of reflection light similar to the fluorescence-intensity histogram of the resist patterns.

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[1] S. V. Sreenivasan, *Microsyst. Nanoeng.* 3, 17075 (2017)
[2] M. Nakagawa, *Jpn. J. Appl. Phys.* 61, SD0805 (2022)
[3] M. Nakagawa, K. Kawasaki, A. Onuma, and H. Niinomi, *Jpn. J. Appl. Phys.* 62, SG1010 (2023)

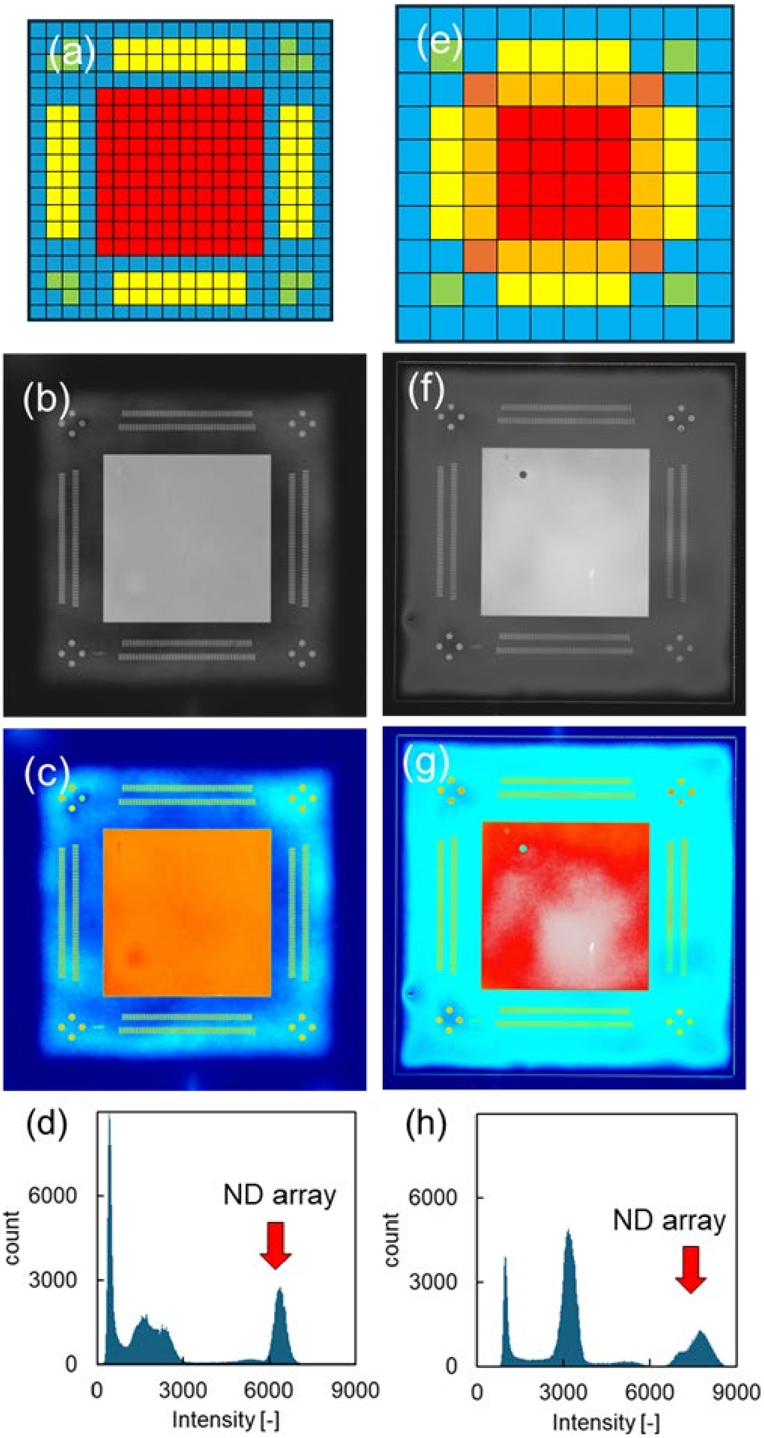

Figure 1. Design of screen-printing masks divided into sections of (a) 0.5 × 0.5 mm^2 and (e) 1 × 1 mm^2. (b, f) Fluorescence images (c, g) and colored fluorescence-intensity images of resist patterns fabricated by UV nanoimprinting using the mask (a) and (e), respectively. (d, h) Fluorescence-intensity histogram of the resist patterns fabricated using the mask (a) and (e), respectively.