In-liquid alignment detection by fluorescence moiré fringes for print and imprint method

E. Kikuchi[1], Y. Ishito[1], S. Matsubara[2], T. Nakamura[1], M. Abe[2], M. Nakagawa[1]
[1]*IMRAM, Tohoku University, Sendai, Miyagi 980-8577, Japan*
[2]*Asahi Kasei Corp., Fuji, Shizuoka 416-8501, Japan*
nakagawa@tagen.tohoku.ac.jp

Introduction: In ultraviolet (UV) nanoimprinting, alignment marks are difficult to detect with an optical microscope, because of little difference in refractive index between a silica mold and a UV-curable resin. Alignment marks partially depositing a light-shielding metal layer or a high-refractive-index SiN_x layer are usually used to increase optical contrast during microscope observation.[1,2] The purpose of this study is to demonstrate the principle to detect in-liquid alignment marks by fluorescence microscopy with fluorescent liquid and to confirm the generation of fluorescence moiré interference fringes by overlaying line and space patterns with a different pitch for fine alignment.

Experimental: Silica molds and substrates with line and space patterns were fabricated by electron beam lithography. Droplets of fluorescent liquid containing a fluorescent dye (0.5 wt%) was deposited onto a silica patterned substrate by screen printing.[3] The substrate was contacted with a silica mold, and the position of the substrate was operated on manual using X, Y, Z, and θ optical stages. Fluorescence microscope (FM) images and reflective optical microscope (ROM) images of liquid between mold and substrate surfaces were captured by a CCD camera from a mold side.

Result and Discussion: Fluorescent liquid droplets deposited on a silica patterned substrate (Fig. 1a) were contacted with a patterned silica mold to fill concave patterns with liquid. Bright alignment marks of bar array were observed under filling the concave bar patterns with the liquid by fluorescence microscopy as shown in Fig. 1c, while bar-array alignment marks disappeared by optical microscopy as shown in Fig. 1b. When a cross bar on a substrate was overlaid with one on a mold, two bar arrays with different pitches of P_1 = 4.0 μm and P_2 = 4.4 μm on a substrate were overlaid with ones with P_2 = 4.4 μm and P_1 = 4.0 μm, respectively, on a mold. As a result, other bright fluorescence regions with a long periodicity were generated at positions of triangle marks in indicated in Fig. 2b. Figure 3 showed a fluorescence intensity profile along with the bight bar arrays. The value of the long fluorescence periodicity was 43.8 μm, which was consistent with a period of moiré interference fringes calculated by $P_1/(P_2 - P_1)$. This suggested that the accuracy of course alignment with cross bars could be detected by fluorescence moiré fringes and fluoresce moiré fringes will be available for further fine alignment.

[1]N. Li, et al., *Nano Lett.*, **2006**, *6*, 2626. [2]N. Suehira, et al., *J. Vac. Sci. Technol.* B, **2007**, *25*, 853.[3]A. Tanabe, et al., *Jpn. J. Appl. Phys.* **2016**, *55*, 06GM01.

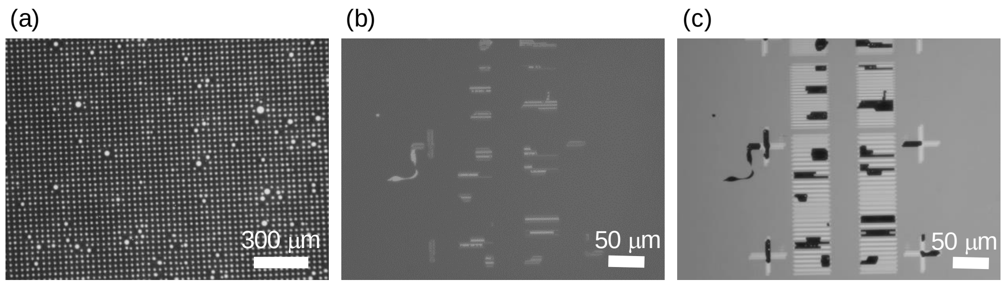

Figure 1: (a) Fluorescence microscope image of droplets deposited onto a silica patterned substrate by screen printing. (b) Optical and (c) fluorescence microscope images of dye-containing liquid inserted between silica substrate and mold surfaces.

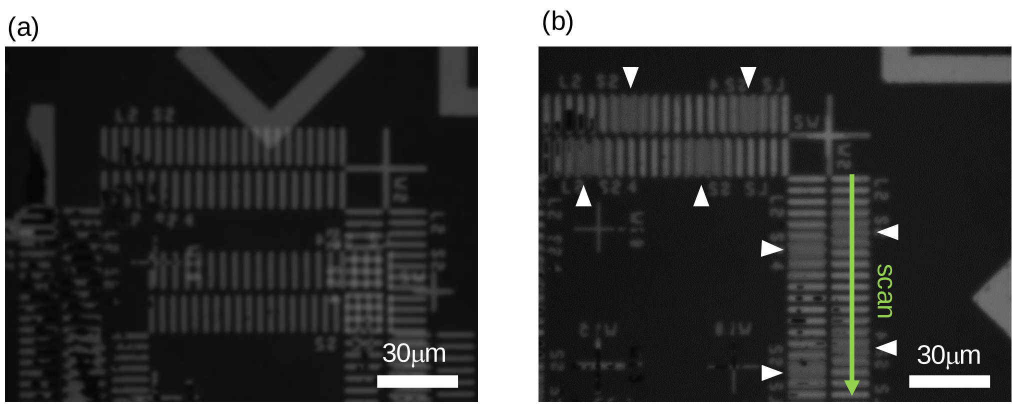

Figure 2: Fluorescence microscope images of dye-containing liquid inserted between silica patterned substrate and mold surfaces (a) before and (b) after course alignment with cross bars.

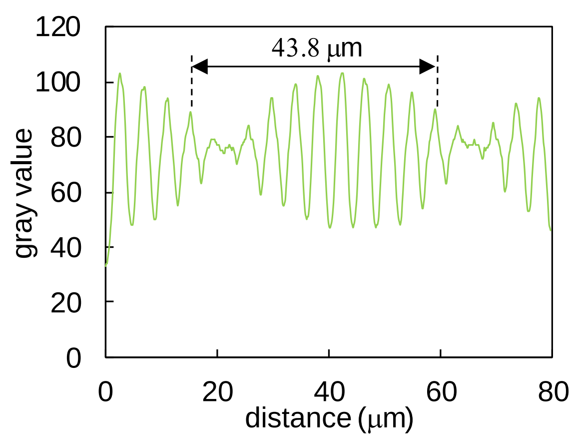

Figure 3: A line-scanned profile of fluorescence intensity of the region where bar arrays with a pitch of P_1 on a substrate were overlaid with ones with P_2 on a mold.