# Observation of Fluorescence Inclination Moiré Fringes for Imprint Alignment

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**Introduction**: In UV nanoimprint lithography (UV-NIL), highly accurate alignment between the mold and substrate is important to form resist patterns at a predetermined position on the substrate. Optical multiplicative-type moiré fringes are generally used for imprint alignment due to magnification of little deviation of overlaid patterns [Fig. 1 (a)]. Our group proposed an advanced method of "fluorescence moiré alignment" using a fluorescent liquid and demonstrated that fluorescence moiré fringes belong to additive-type moiré fringes [1] [Fig.1 (b)]. Fluorescence moiré alignment has a unique advantage of no need of an optically functional additional layer deposited on a silica mold. In this study, we practically observed fluorescence inclination moiré fringes in our UV nanoimprinting system and investigated whether the angles of additive-type moiré fringes were identical to the theory of the multiplicative type.

**Experimental**: Line (L)-and-space (S) gratings of L:S = 1:1 with pitches of $P_1$ = 10.73 μm and $P_2$ = 10.70 μm for 7× fluorescence microscope observation were fabricated on a silica mold and Si substrate by maskless lithography involving laser drawing. The experimental procedure is shown in Fig. 2. Fluorescent liquid droplets were screen-printed on the substrate surface using a polyimide laser-drilled mask[2]. The recesses of grating patterns were filled with fluorescent liquid. Fluorescence images of overlaid patterns were obtained by fluorescence microscopy with the substrate rotated in a clockwise direction. The angles of fluorescence inclination moiré fringes were measured from the captured images.

**Results and Discussion**: It is known that angles of multiplicative-type moiré fringes are calculated by the following equation[3]. The grating pitches of 10.73 and 10.70 μm used in this study were designed according to the equation.

$$\varphi = \tan^{-1}\frac{P_1 \sin\theta}{P_1 \cos\theta - P_2} \qquad \begin{pmatrix} \theta: \text{angle of deviation of substrate to mold [rad]} \\ \varphi: \text{angle of moiré fringes to mold grating [rad]} \end{pmatrix}$$

Fluorescence inclination moiré fringes could be observed from the mold and substrate grating patterns filled with fluorescent liquid (Fig. 3). The gratings of the mold and substrate were also discernible by fluorescence microscope observation. To discern the gratings is essential for observation of additive-type moiré fringes. As the substrate was rotated in a clockwise direction, the fluorescence moiré fringe was inclined to a counterclockwise direction. The angle of the fluorescence inclination moiré fringe of 68.5 ± 0.4 degree was measured from the captured image. According to the equation, the measured angle corresponded to 0.39 degree of the substrate-mold deviation. In this conference, the author will discuss the relationship of angle between the additive-type fluorescence inclination moiré fringe and the theoretical multiplicative-type inclination moiré fringe.

**Reference**: [1] E. Kikuchi, et al., *J. Vac. Sci. Technol. B* **35**, 06G303 (2017). [2] T. Nakamura, et al., *J. Vac. Sci. Technol. B* **35**, 06G301 (2017). [3] J. Shao, et al., *Opt. Eng.* **47**, 113604 (2008).

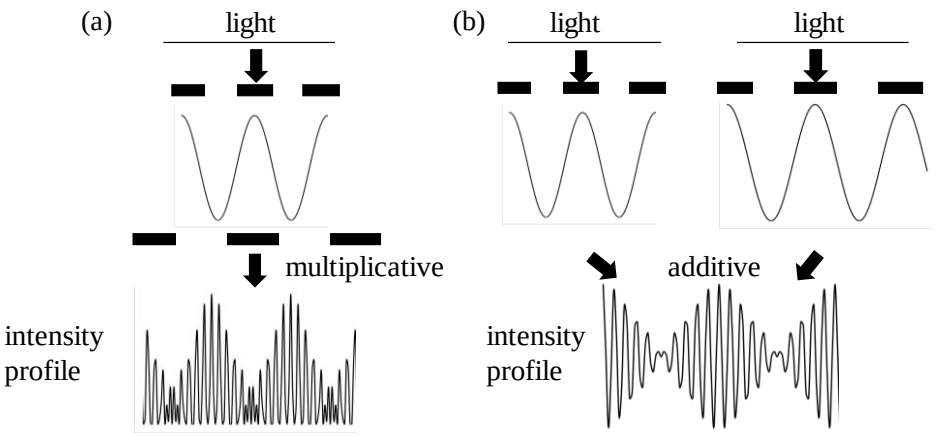


**Figure 1.** Schematic illustration of light intensity of (a) multiplicative-type and (b) additive-type moiré fringes.

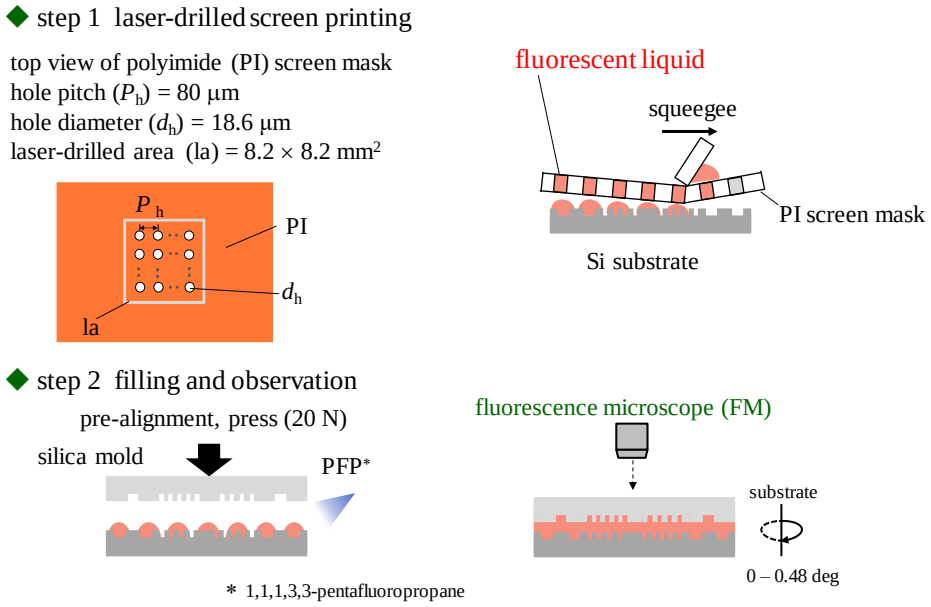


**Figure 2.** Schematic illustration of fluorescence alignment experiments consisting of laser-drilled screen printing (step 1) and fluorescence microscope observation for fluorescence inclination moiré fringes (step 2).

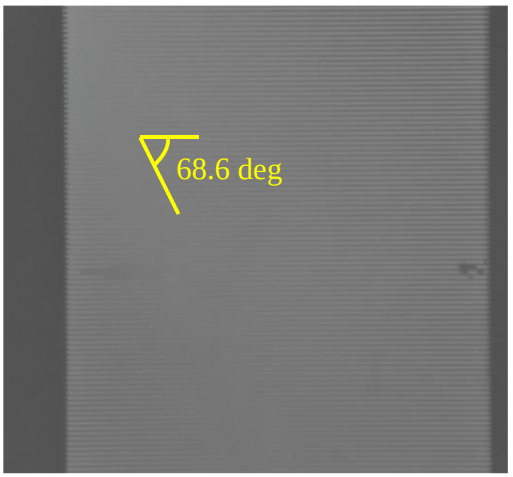


**Figure 3.** Fluorescence microscope image of fluorescence inclination moiré fringe corresponding to a substrate-mold deviation of 0.39 degree. Color and brightness are modified to discern the image.