Full area real time monitoring of filling process by dark field illumination in UV nanoimprint lithography

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Resist filling process in nanoimprint lithography plays an important role for the integrity of pattern transfer. To optimize the nanoimprint process, and obtain defect-free patterns, it becomes necessary to monitor the filling process in-situ at real-time. Prof. Chou's group proposed a powerful in-situ real-time monitoring system using time-resolved diffractive scatterometry. [1-3] It can continuously monitor the filling process from the change of surface relief diffraction during a nanoimprint process. However, the method was limited to localized areas (laser spot) only, whereas any information regarding other areas could remain uncertain until a post-process verification could be carried out. In this work, we proposed a full area in-situ real-time monitoring system that has a high sensitivity to defect detection during the nanoimprint process.

A dark field illumination system was used in the proposed system for real-time monitoring of a full area of a mold to verify the integrity of resist-filling in UV nanoimprint lithography (Fig. 1). Figure 2 shows a schematic of the dark field illumination system used for the monitoring the filling process of nanoimprint. The angle of the illuminating light is adjusted to allow only the diffusion light scattered by the edges of the entrapped bubbles in the pattern cavities reaching the camera. Fig.2a shows the case of an incomplete filling of resist. The diffusion light is scattered by the edges of bubbles entrapped at pattern cavities. In Fig. 2b, the bubbles disappear with the disappearance of the diffusion light scattered from the mold, which signals the completion of filling.

A 10mm x 10mm quartz mold with 300nm deep micro-patterns of squares ranging in the sizes of 2 to 100μm was used in the nanoimprint experiment. For this size of the mold, we fulfilled successfully a full area monitoring of the filling process. Consecutive images taken using the dark field illumination monitoring (DFIM) system show the full process of resist filling into the pattern cavities from the start of imprinting to complete filling (Fig. 3). Before the contact of the mold with the substrate, the all patterns on the mold were visible (Fig. 3a). With the contact of the mold with the substrate, the patterns in the area of complete filling disappeared gradually (Fig. 3b-g). At last, we obtained a full dark image (Fig. 3h) that means a complete filling. Figure 4 shows a filling process deliberately stopped before the complete filling. We can found the areas of complete filling and incomplete filling at the same image taken from DFIM system. The optical microscopic images of three squared areas (a, b, and c in Fig. 4) are shown in Fig. 5. We noticed that the patterns in the full dark area (c in Fig. 4) were filled completely. The filling defects in the microscopic images in Fig. 5a-b are corresponding to the patterns visible in the areas a and b in Fig.4. These results verified the accuracy of complete filling as judged by the dark field illumination system.

Our studies demonstrate that our proposed real-time monitoring system provide a reliable way to monitor the resist filling in full area of a mold, and is a convenient way for in-situ quality control of defects, which is crucial to the success of employing nanoimprint lithography in mass production of devices.

References

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3) Z. Yu, H. Gao, and S. Y. Chou: Nanotechnology 18 (2007) 065304.

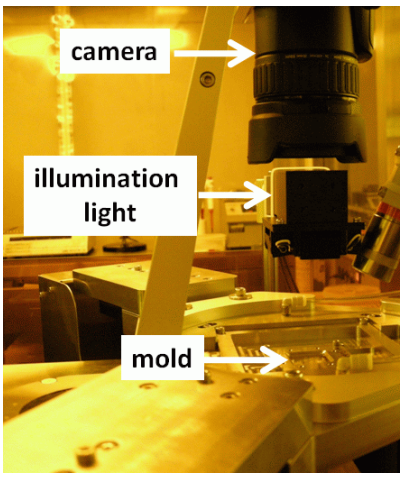


Fig. 1. Picture of the dark field illumination system installed on a nanoimprint

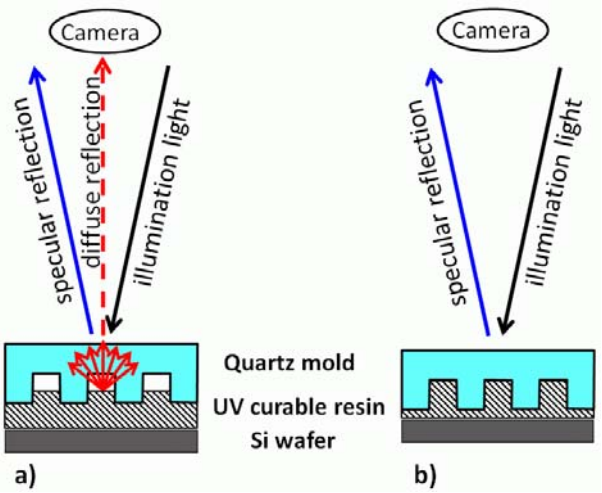
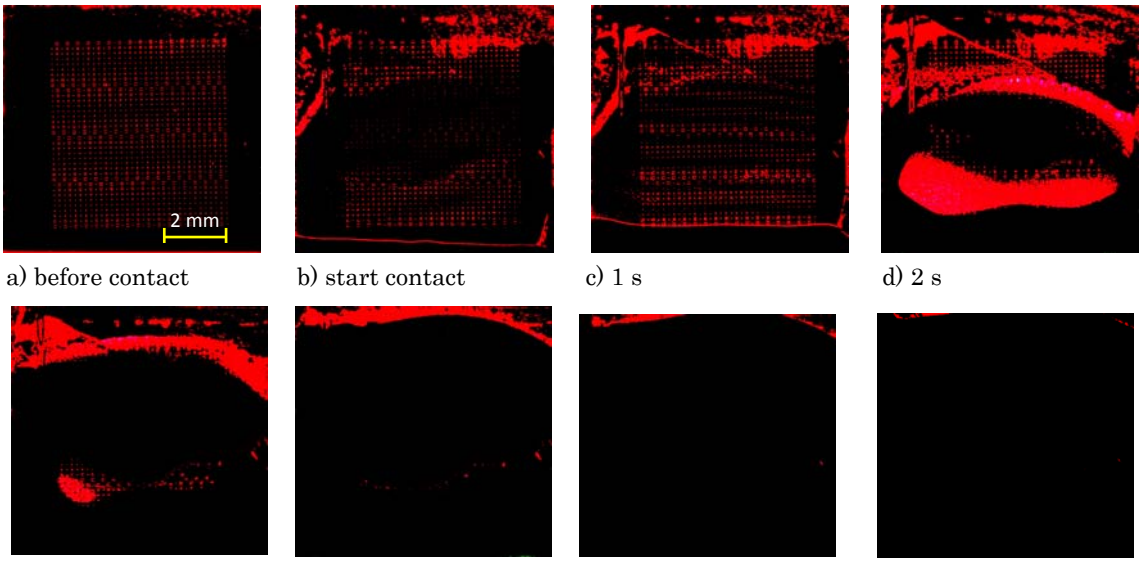


Fig. 2. Schematic of a dark field illumination system used for monitoring the bubble shrinking during the filling process..



a) before contact b) start contact c) 1 s d) 2 s

e) 3 s f) 4 s g) 5 s h) 6 s (complete filling)

Fig. 3. Consecutive images of dark field illumination monitoring system for a filling process. No light scattered from the sample means complete filling in DFIM system.

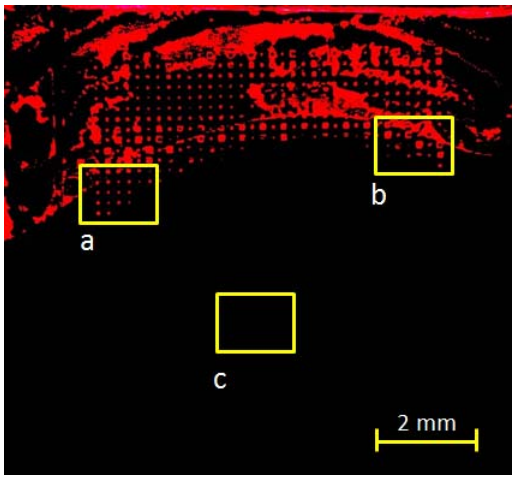
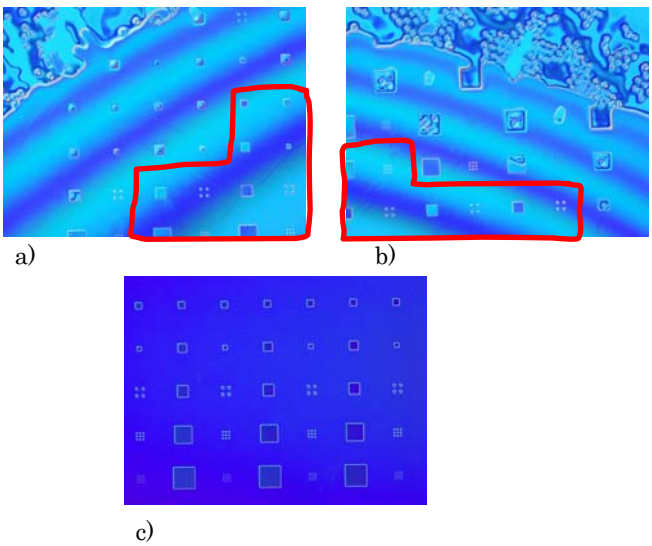


Fig. 4. An image of dark field illumination monitoring system for a filling process stopped before complete filling.



a) b)

c)

Fig. 5. Optical microscopic pictures of areas a, b and c in Fig. 4 Encircled areas in a and b are patterns of complete filling.