Full-field Substrate conformal imprint lithography (SCIL) on mask aligners

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Nowadays, the development of nanotechnologies relies more and more on the nanofabrication techniques. Optical lithography and electron beam lithography are limited by resolution and throughput, respectively. Nanoimprint Lithography [1] (NIL), which allows cost-effectively fabrication of nanostructures, receives therefore considerable attentions in the last decades. As a candidate of the next generation lithography (NGL) technique, its capabilities of several nanometers resolution and full field patterning over large-area have been demonstrated in many scientific publications. In addition, its potentials in many applications, such like IC industry, patterned media storage, HB LED……, have been discussed and introduced. However, some major process and engineering problems hinder the NIL technique from real applications in high volume manufacturing (HVM).

Rigid quartz stamps used in UV-enhanced nanoimprint (UV-NIL) techniques provide high structure fidelity. However, they can not compensate the waviness of the substrates in range of several microns over large-area and the throughput of step and repeat concept can not meet the requirements of HVM. The high fabrication costs of those stamps and their fragility also indicate that they are not suitable to be used in the real productions with this direct contact patterning technique. Soft stamps, e.g. PDMS stamps, are employed to make full-field imprints over large-areas and to lower the costs of stamps by replicating the expensive master molds. However, on the other hand the flexibility of the soft stamp also has disadvantages: The imprint pressure can lead to lateral stamp distortion and structure deformation, which will limit the overlay accuracy and imprint resolution, respectively. In addition, on most of the imprint machines with soft stamp concept the PDMS stamps are fixed on thick glass carriers for handling. During imprint process the deformation degree of the PDMS stamp is not uniformly distributed due to the topography of the substrate. This could result collapses or deformations of the imprint structures at highly deformed positions and proper imprint at less deformed positions.

In this paper, we introduce a novel NIL technique developed by Philips Research and Süss MicroTec, Substrate Conformal Imprint Lithography (SCIL) [2], which bridges the gap between UV-NIL using rigid stamps for high structure fidelity and soft stamps for large-area patterning. Based on a cost-effective upgrade on Süss mask aligners, the capability of the aligners can be enhanced to nanoimprint with sub-50 nm resolution up to 6 inch diameter area without affecting any established conventional lithographic processes on the machine. This revolutionary technology employs unconventional consequential contact process and composite working stamp with thin glass carrier to actualize repeatable conformal imprints over large-area substrates. Instead of imprint pressure, capillary forces of the resist surface major the structure filling on the stamp. A low force "peal-off-like" separation concept guarantees that the imprinted structures and the stamp are not damaged. Benefit from the above mentioned advantages, the SCIL technology shows great potential in the future HVM of nanostructures.

[1] S. Y. Chou, P. R. Krauss. P. J. Renstrom, *J. Appl. Phys. Lett.* 1996, 67, 3114;
[2] R. Ji, *et. al.*, *Microelectron. Eng.,* 2009, doi:10.1016/j.mee.2009.11.134.

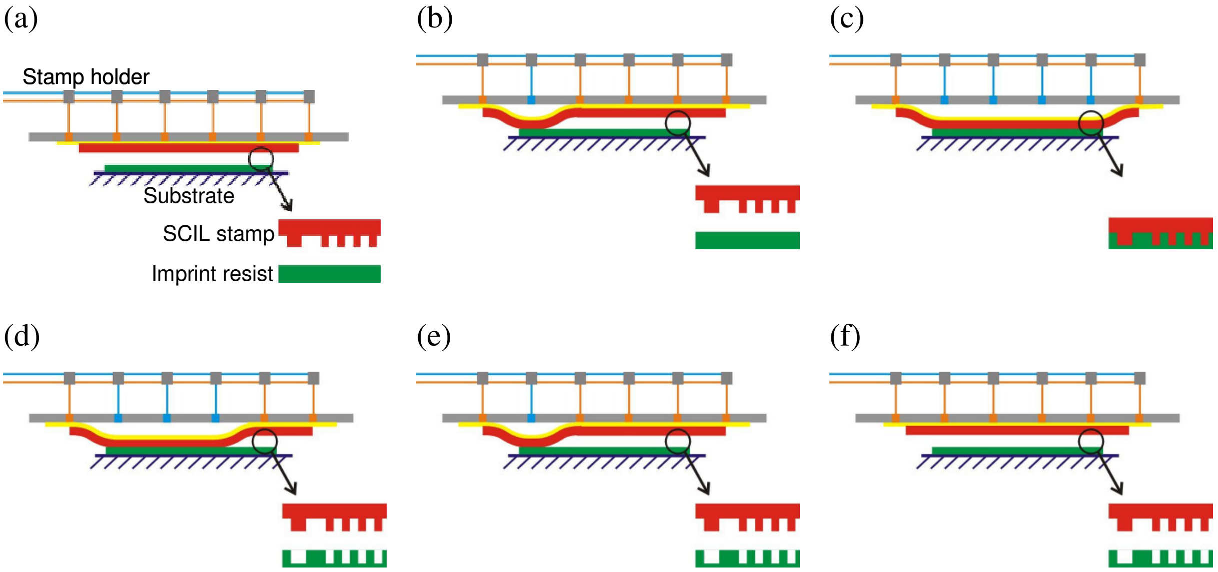

Figure 1: Schematic illustration of the SCIL imprint and separation sequences. (a) The SCIL stamp is fixed on the stamp holder by vacuum; (b) the imprint process starts from one side of the stamp; (c) the imprint is completed by releasing the stamp holder vacuum grooves one by one; (d) after curing of the resist, the separation process starts from the other side of the stamp; (e) and (f) the separation process is completed by switching on the vacuum in the grooves one by one.

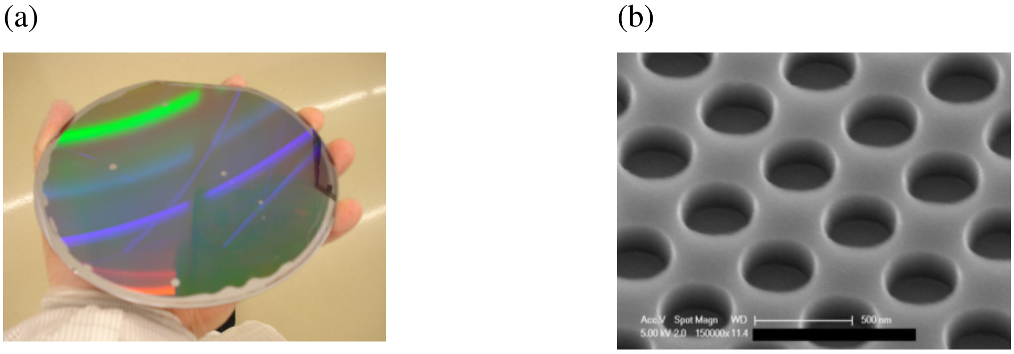

Figure 2: (a) Photograph and (b) SEM image of the imprinted 6 inch wafer with holes array after structure transfer and stripping of the imprint resist. The diameter of the holes is around 290 nm and the pitch is 513 nm.

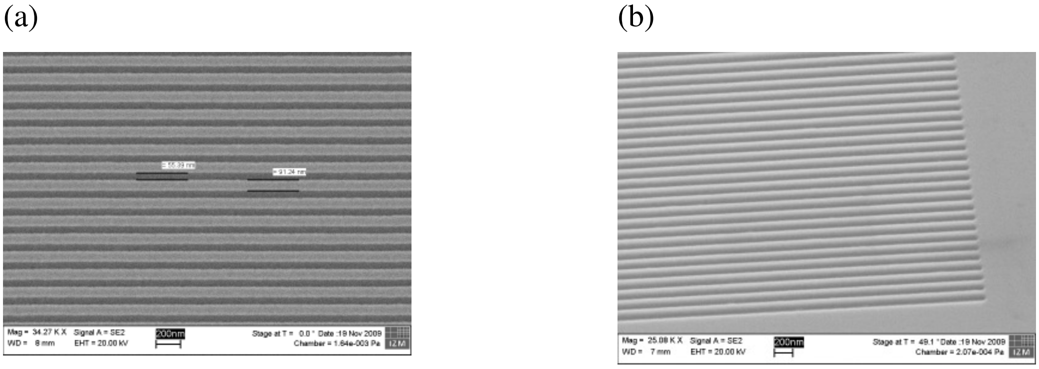

Figure 3: SEM images of imprinted grating structures by SCIL with a lines width of 55 nm and a pitch of 147 nm from (a) top-view and (b) bird-view.