Fabrication of Ordered Nanospheres using a Combination of Nanoimprint Lithography and Controlled Dewetting

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Reflow of resist structures by melting is a powerful post-processing method for the generation of 3D structures with defined spherical and cylindrical shapes [1]. It has also been used for the fabrication of nanoscale gratings with reduced line edge roughness, gap narrowing and aspect ration enhancement [2]. Thus it becomes an attractive post-processing method which enhances the scope and flexibility of current nanofabrication.

In this contribution, we enlarge the portfolio of reflow even further by forming new structures by controlled dewetting and agglomeration. In contrast to binary photolithography, we use nanoimprint lithography (NIL) for the formation of polymer structures prior to reflow. This is because of its range of shapes and materials along with high resolution capability [3]. The main difference to photolithography is the fact that it needs an additional etching step to remove the residual layer and to open windows on the substrate. The plasma treatment changes the surface properties of the substrate surface significantly. After window opening it becomes hydrophilic which enhances the ability of the resist to wet and spread into areas previously not covered. This spreading can be inhibited by an additional hydrophobic surfactant coating by CVD before heating the sample [4]. However, for ridges with line widths below 200nm, we then observe a dewetting of resist during reflow. The resist, which normally (feature size > 200 nm) tends to spread laterally to some extent over the areas covered by the surfactant, splits locally and collects material along the ridges to form larger dots. Since the material is not able to flow large distances, local depletion happens and dots are formed along the lines which are almost randomly distributed (see Fig. 1). Since this needed to be more controlled, we fabricated stamps with defined nodes (Fig. 2), which serve as nucleation points for these dots during the reflow step. If these nodes were set in a distances smaller than the average distance of dots without nodes, we obtained a regular dot matrix (Figs. 3 and 4) with almost totally dewetted lines.

We now have made a survey of different line widths and node distances to investigate the limitations of the method. The lens-like structures were transferred into the silicon substrate using anisotropic RIE to fabricate stamps with 3D shapes (see Fig. 5). The method shows that reflow is not only able to form spherical structures, but can also be used for future designs were more complex structures are formed from much simpler imprinted pre-forms. This can be used either as a post-processing step in production or for the fabrication of stamp copies with the desired shapes. A possible application is the fabrication of arrays of nanospheres with defined shape and low edge roughness as and can be used for magnetic nanodots with perpendicular anisotropy [5].

[1] D. Daly et al., J. Meas. Sci. Technol. **1**, 759-766 (1990).
[2] S.Y. Chou and Q. Xia, nature nanotechnology **3,** 295-300 (2008).
[3] H. Schift, J. Vac. Sci. Technol. B **26**(2) 458-480 (2008).
[4] H. Schift et al., Microelectron. Eng. **61**-**62**, 423-428 (2002).
[5] D. Makarov et al., Appl. Phys. Lett. **90** (9), 093117 (2007).

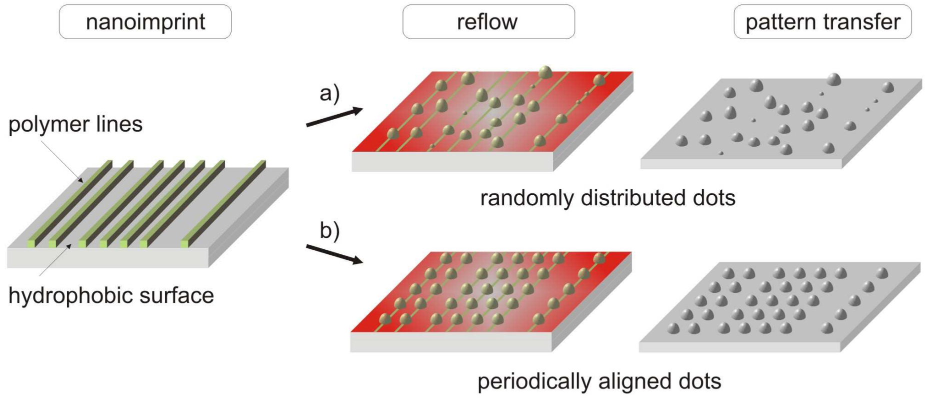

Figure 1 Process scheme: Polymer line structures are generated by nanoimprint lithography and window opening before a hydrophobic surfactant coating is applied. Depending on minor modification of the stamp design, randomly distributed dots (a) or a regular pattern (b) are formed during a subsequent reflow step.

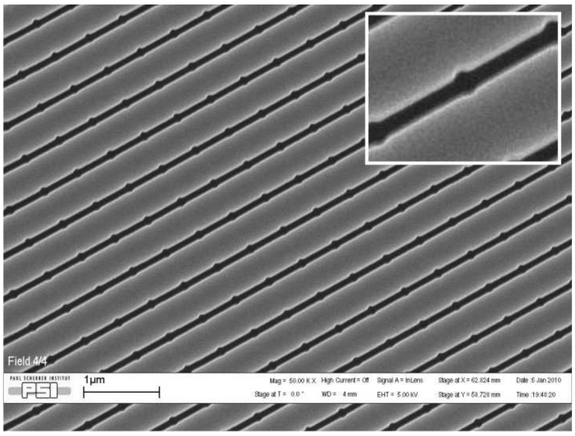

Figure 2 Stamp detail showing nodes (nucleation points) along 100 nm wide lines.

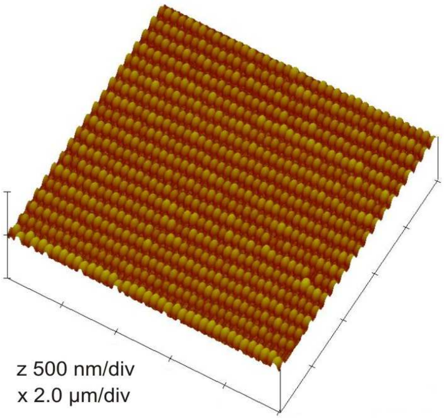

Figure 3 AFM micrograph illustrating an orthogonal matrix of regularly sized dots.

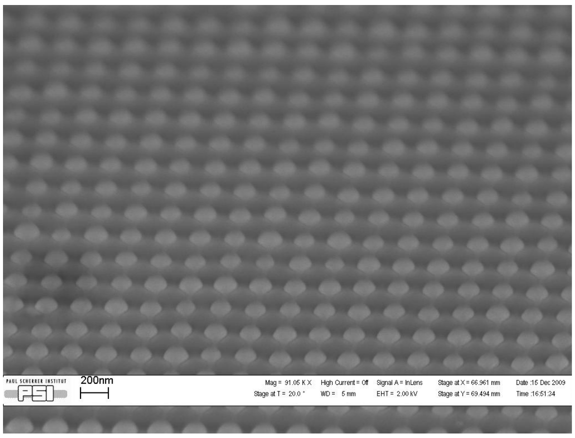

Figure 4 SEM micrograph showing matrix of 250 nm wide hemispherical dots with a pitch of 500 nm.

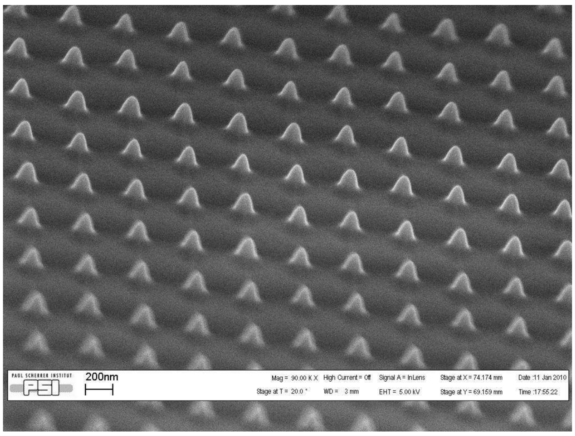

Figure 5 SEM micrograph of silicon substrate with hemispherical dots after pattern transfer using anisotropic RIE.