Surface confined equilibration for super-smooth surfaces

N. Chidambaram, R. Kirchner, H. Schift
Paul Scherrer Institute, Laboratory for Micro- and Nanotechnology,
5232 Villigen PSI, Switzerland
nachiappan.chidambaram@psi.ch

M. Altana
Heptagon Oy, Moosstrasse 2, 8803 Rüschlikon, Switzerland

S. Neuhaus, M. Kristiansen
University of Applied Sciences and Arts Northwestern Switzerland,
5210 Windisch, Switzerland

Refractive micro-optical elements are finding applications in high volume consumer electronic devices ranging from mobile gadgets to flat panel displays. The most convenient mastering technique for fabricating complex 3D pattern required for this application seems to be direct laser writing (DLW) with variable doses which results in different heights upon development. Using this grayscale approach, tall aspheric micro-lenses with deep sag are difficult to write as the resolution in lateral and vertical direction provided by single photon absorption is not high enough. A truly 3D capable approach boasting higher resolutions in lateral and vertical direction is 'two photon polymerization' (2PP)[1]. Even with higher resolutions, 2PP is not considered for mastering due to high inherent roughness and the inability to smoothen them out with post processing: Reflow is not possible in 2PP structures as it is primarily in negative cross linking resists.

Here we have established a mastering technique for micro-optical applications using a 2PP process and still get a smooth surface finish that is demanded. It is derived from the TASTE[2] process established for grayscale electron beam lithography but has now been advanced for surface selective modification of PMMA resists. For this purpose, master structures were replicated from the 2PP resist into PMMA through PDMS intermediate copy. UV-casted PDMS preserves the fine features present in the original and provides low energy surface for easy demolding after hot embossing into PMMA. To have surface selective reflow, while preserving the structural fidelity of a 3D pattern, one has to use high energy exposure (electrons, ions or photons) that modifies the polymer at a defined depth of the surface by chain scission followed by molecular weight dependent reflow at elevated temperatures. We have considered various high energy radiations and narrowed down to 172 nm UV exposure to be the ideal fit for this application. This provided high enough 'damage' in a 200 nm thick surface skin layer and negligible etching, which allowed smoothening out up to 100 nm roughness down to final roughness.

---

[1] NanoScribe GmbH. http://www.nanoscribe.de/en/

[2] A. Schleunitz, et al., *Nano Convergence* **1**, 7 (2014), p. 1-8

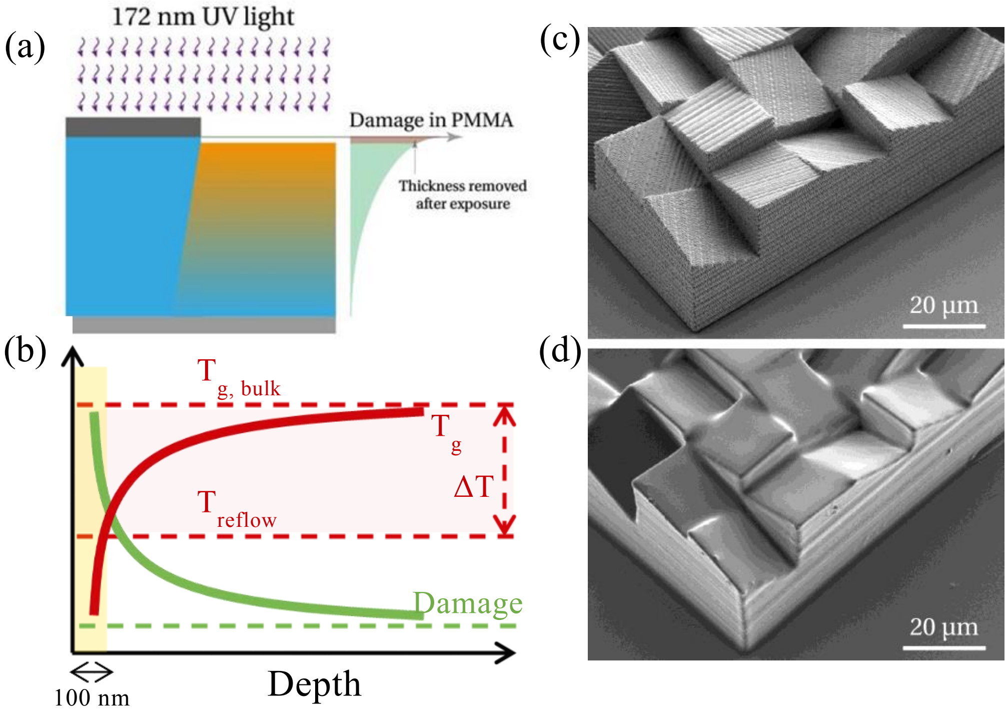

Figure 1: (a) Schematic illustration of 172 nm UV exposure in PMMA film. (b) Expected depth profile of the damage in PMMA (green) and corresponding glass transition temperature dependence (red) for one specific exposure dose. The ideal reflow temperature for smoothening out 100 nm roughness is has to be chosen in a way that only the top 100 nm will be flowing (ΔT is the process latitude) (c) As written microprism array with 2PP. (d) After transfer into PMMA with surface sensitive exposure and reflow for 15 mins at 115°C.

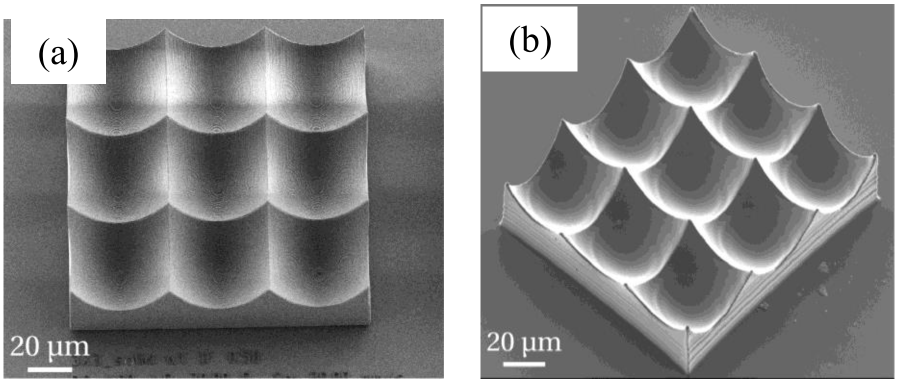

Figure 2: (a) As written micro-lens array (b) after transfer into PMMA with surface sensitive exposure and reflow for 15 mins at 115°C.