Fabrication of 3D-photonic crystals via UV-Nanoimprint Lithography

T. Glinsner[1,3], P. Lindner[1], M.Mühlberger [2], I. Bergmair[2,3], R. Schöftner[2], K.Hingerl[3]
[1]EVGroup, DI Erich Thallner Strasse 1, 4782 St. Florian, Austria
[2]Profactor GmbH, Steyr, 4407 Austria
[3]CD Laboratory of Surface Optics, Linz, 4040 Austria

UV-based Nanoimprint Lithography (UV-NIL) offers several decisive technical advantages concerning overlay alignment accuracy, simultaneous imprinting of micro- and nanostructures and tool design. Thereby this technique provides low-cost solutions for R&D institutes and small businesses to compete in emerging patterning technologies. A variety of potential applications has been demonstrated by using Nanoimprint Lithography (e.g. SAW devices, vias and contact layers with dual damascene imprinting process, Bragg structures, patterned media) [1,2].

3D-photonic crystals have been fabricated by using e-beam lithography [3] with high precision piezoelectric alignment stages for achieving sub-100 nm overlay alignment needed to exhibit full photonic bandgap structures for woodpile rod line width ranging from 200 nm to 400 nm. In e-beam lithography the area to be patterned is clearly restricted; furthermore it is a sequential and slow process. In order to increase this area to 25x25 mm² UV-NIL has been selected for this application. Quartz glass templates were designed in such a way that the first layer as well as subsequent layers can be imprinted with the same stamp by rotating the stamp by 90° following optical alignment and imprinting. The alignment is performed in 3 stages using Vernier and Moiré pattern resulting in overlay alignment accuracies better than 100 nm [4,5]. Alignment marks are defined in the 0^{th} layer by photolithography or nanoimprint lithography and lift-off which are used as reference for all layers to be stacked. The template contains 16 squares (each 3x3 mm²) with elevated structures with a height of nominally 200 nm or 400 nm and periods ranging from 800 nm to 2400 nm (lines are ranging from 200 nm to 600 nm). After imprinting in UV-NIL resists [Figure1] the structures are transferred into SiO_2 by dry etching techniques. Subsequently poly-Si is deposited on the sample. Finally, a planarization process is carried out by chemical mechanical polishing, defining a planar surface for building up the next, 90° rotated, layer [Figure 2].

Our contribution will demonstrate a concept for the fabrication of the woodpile structure as an example for 3D-structuring. Recently achieved results of imprinted lines and space structures and 3D-sructures as shown in figure 1 and 2 will be presented and discussed in detail.

References:

[1] MD Stewart et. al., "Direct Imprinting of Dielectric Materials for Dual Damascene Processing" Proc. SPIE 5751 p. 210-218 (2005).
[2] P.Dorsey et. al., Discrete Track Recording (DTR) Media Fabricated using Nanoimprint Lithography, NNT, December 1-3, (2004).
[3] Minghao Qi, et.al, A three-dimensional optical photonic crystal with designed point defects, Nature, 429, p. 538, (2004).
[4] M.Mühlberger, et.al, High precision alignment in multilayer nanoimprint lithography, to be published in conference proceedings ICPS, (2006).
[5] M.Mühlberger, et.al, High precision alignment in multilayer nanoimprint lithography, Conference Proceedings 6th international conference of precision engineering and nanotechnology, Volume 1, 309-312, (2006).

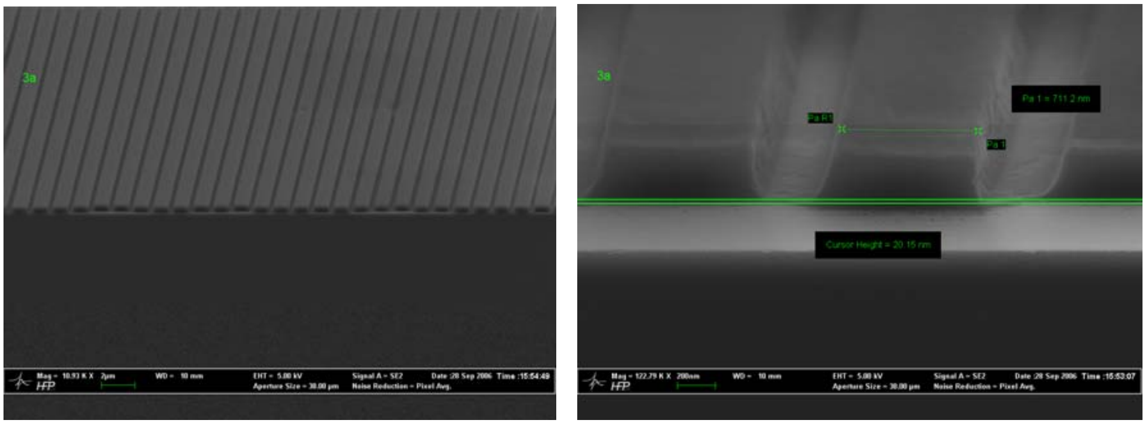

Figure 1: SEM picture of imprinted lines; left: lines and space structures; right: close-up of a feature with a residual layer of 20 nm.

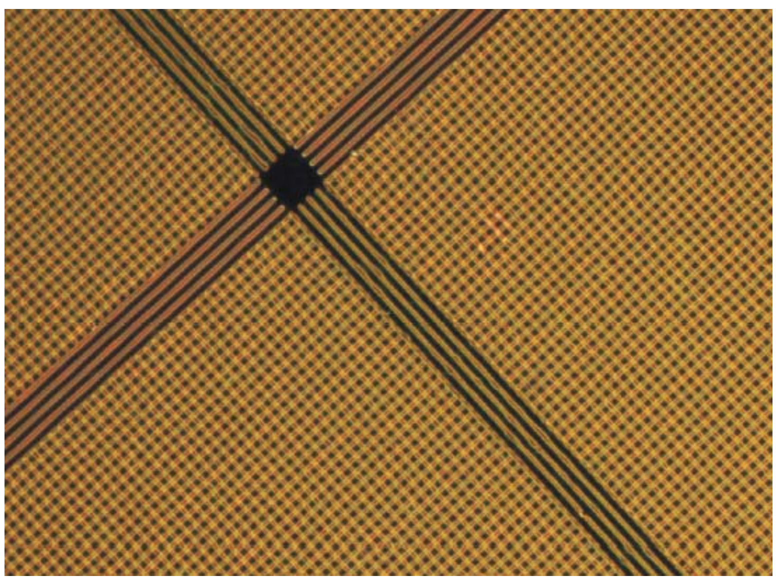

Figure 2: Micrograph of 2 layers of a photonic crystal perpendicularly imprinted on top of each other in UV-NIL resist.