Combined nanoimprint and photolithography of integrated polymer optics

Christiansen, Mads Brøkner; Schøler, Mikkel; Gersborg-Hansen, Morten; Kristensen, Anders

Published in:
Digest of the IEEE LEOS Summer Topical Meetings, 2007

Link to article, DOI:
[10.1109/LEOSST.2007.4288352](https://doi.org/10.1109/LEOSST.2007.4288352)

Publication date:
2007

Document Version
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

Citation (APA):
Christiansen, M. B., Schøler, M., Gersborg-Hansen, M., & Kristensen, A. (2007). Combined nanoimprint and photolithography of integrated polymer optics. In *Digest of the IEEE LEOS Summer Topical Meetings, 2007* (pp. 101-102). [4288352] IEEE. <https://doi.org/10.1109/LEOSST.2007.4288352>

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Combined nanoimprint and photolithography of integrated polymer optics

Mads Brøkner-Christiansen, Mikkel Schøler, Morten Gersborg-Hansen, and Anders Kristensen*

*MIC – Department of Micro and Nanotechnology, Nano•DTU, Technical University of Denmark,
DTU building 345east, DK-2800 Kongens Lyngby, Denmark*

**e-mail: ak@mic.dtu.dk www.mic.dtu.dk/NIL*

We demonstrate wafer-scale fabrication by combined nanoimprint and photolithography (CNP) [1] of integrated polymer optics, combining active and passive polymer components with nm to mm features. Distributed feed-back (DFB) polymer dye lasers [2] are integrated with polymer waveguides [3]. The laser devices are defined in SU-8 resist, doped with Rhodamine 6G laser dye, shaped as planar slab waveguides on a Fused Silica buffer substrate, and with a 1st-order DFB surface corrugation forming the laser resonator, see Fig. 1. When optically pumped at 532 nm, lasing is obtained in the wavelength range 560 nm – 600 nm, determined by the grating period, see Fig. 3. Our results, where 20 laser devices are defined across a 10 cm diameter wafer substrate, demonstrate the feasibility of CNP for wafer-scale fabrication of advanced nano-structured active and passive polymer optical components

Fig. 1 (a): Outline of the distributed feed-back (DFB) polymer dye laser device, formed as a slab waveguide on a borofloat glass substrate. Feedback is provided by Bragg grating surface corrugations of period $\Lambda \sim 200$ nm. (c) The chip layout. The laser is positioned 10 μm from a curved waveguide made of 4.2 μm thick undoped SU-8 polymer. 20 chips are defined across the 10 cm diameter wafer substrate.

In the CNP process, a combined UV mask and nanoimprint stamp, Fig 2 (a)-(b), is embossed into the resist, which is softened by heating, and UV exposed, Fig 2 (c)-(d). Hereby the mm to μm sized features are defined by the UV exposure through the metal mask, while nm-scale features are formed by mechanical deformation (nanoimprinting). The UV exposed (and imprinted) SU-8 is crosslinked by a post-exposure bake, before the stamp and substrate are separated, and the un-exposed resist is dissolved, Fig 2 (e). Polymer waveguides are added [3] by an additional UV lithography step in a film of un-doped SU-8, which is spincoated on top of the lasers and substrate, Fig. 2 (f)-(g).

The combined UV mask and nanoimprint stamp is fabricated from a 10 cm diameter, 500 μm thick Quartz wafer. To define the sub-micron features ($\Lambda \sim 200$ nm period Bragg gratings), the Quartz wafer is spin-coated with a 50 nm thick film of TEBN-1 electron beam lithography (EBL) resist, and a 20 nm aluminium film is deposited to avoid charging effects during the EBL exposure. Following the 100 kV EBL exposure, the charge compensating layer is removed in MF-322 and the TEBN-1 resist is developed in methyl isobutyl ketone (MIBK). A RIE process transfers the gratings 40 nm into the substrate. The UVL mask - 200 nm Cr

and 20 nm aluminium - is defined by UV lithography and lift-off. Before metal deposition, the un-masked areas are recess-etched by RIE (250 nm). Finally, an anti-stiction coating is deposited on the stamp. The Rhodamine 6G perchlorate doped SU-8 resist (13 wt% solid content SU-8 in cyclopentanone) is prepared as described in [3]. The final Rhodamine concentration is 3.2 μmol per g solid SU-8. The SU-8 is spincoated onto a borofloat glass substrate to a thickness of 450 nm. The combined UV mask and stamp is embossed into the unexposed SU-8 at 90°C and 2.5 bar before UV (i-line) exposure, and post-bake (2 min. 90°C). After separation the SU-8 is developed in PGMEA.

Fig. 2 Outline of the CNP fabrication process. (a)-(b): Combined UV mask and imprint stamp is used. (c)-(e): Embossing and UV exposure of dye doped resist to form DFB lasers. (f)-(g) Additional UV lithography step in undoped SU-8 film to define polymer waveguides.

Fig. 3 (a) AFM image of a fabricated DFB surface corrugation. The period is $\Lambda = 188$ nm, and the corrugation depth is $a = 60$ nm. (b) Emission spectra from four laser devices of different DFB grating pitch.

Fig. 3a shows an AFM image of a CNP fabricated surface corrugation, forming the Bragg gratings. The period is $\Lambda = 188$ nm. This grating is expected to yield 1st order Bragg reflection at a vacuum wavelength of 577 nm. In Fig. 3b we show the emission spectra from four lasers of different DFB grating period Λ .

References:

- [1] X. Chen and L. Jay Guo, "One-step lithography for various size patterns with a hybrid mask-mold", *Microelectron. Eng.* 71, 288 (2004)
- [2] S. Balslev, T. Rasmussen, P. Shi, and A. Kristensen, "Single mode solid state distributed feedback dye laser fabricated by grey scale electron beam lithography on dye doped SU-8 resist", *J. Micromech. Microeng.*, Vol. 15, 2456 (2005)
- [3] D. Nilsson, S. Balslev, M. M. Gregersen, and A. Kristensen, "Micro-fabricated solid state dye lasers based on a photo-definable polymer", *Applied Optics*, Vol. 44, 4965 (2005)