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Integrated Active and Passive Polymer Optical Components with nm to mm Features

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Abstract: We present wafer-scale fabrication of integrated active and passive polymer optics with nm to mm features. First order DFB lasers, defined in dye doped SU-8 resist are integrated with SU-8 waveguides.

OCIS codes: (140.2050) Dye Lasers; (140.3490) Lasers, distributed-feedback; (130.3120) integrated optics devices
Additional key words: nanoimprint, combined nanoimprint and UV lithography, SU-8

We demonstrate wafer-scale fabrication of integrated polymer optics, comprising of nm to mm features, by combined nanoimprint and photolithography (CNP) [1]. 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 Borofloat glass buffer substrate, and with a 1^{st}-order DFB surface corrugation forming the laser resonator, see Fig. 1.

The fabrication process is shown schematically in Fig. 2. 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 the 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).

When optically pumped with 5 ns pulses at 532 nm, lasing is obtained in the wavelength range 559 nm – 600 nm, determined by the grating period, see Fig. 3. The chip design is shown in the inset of Fig. 4. A curved SU-8 waveguide is defined in front of the laser. The laser signal is measured with an optical fiber positioned next to the chip edge, as illustrated, which guides the light into a fixed grating spectrometer with a resolution of 0.15 nm. The main graph of Fig. 4 shows the intensity of the pump and laser light measured as a function of fiber position, relative to the end of the SU-8 waveguide. Clearly the light from the laser is guided to the edge of the chip. The pump signal, which is scattered from the several mm wide pump spot, is strongest next to the laser.

Our results with waferscale fabrication of single mode polymer lasers, combined with the possibility to integrate them with passive optical polymer components such as waveguides and fluid channels, opens possibilities for new all polymer integrated sensor systems for e.g. biological analysis.

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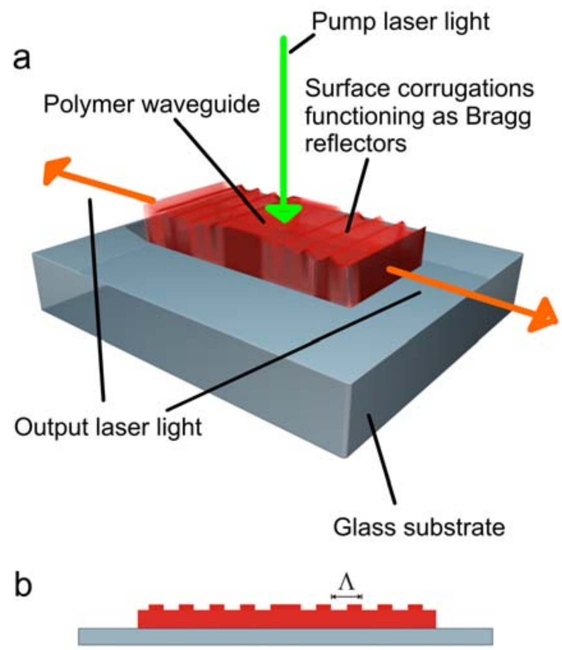

Fig. 1 Outline of the distributed feed-back (DFB) polymer dye laser device, formed as a slab waveguide on a borofloat glass substrate. It is 450 nm high with a footprint of 1 mm by 250 µm. Feedback is provided by 40 nm deep Bragg grating surface corrugations of period Λ ~ 200 nm.

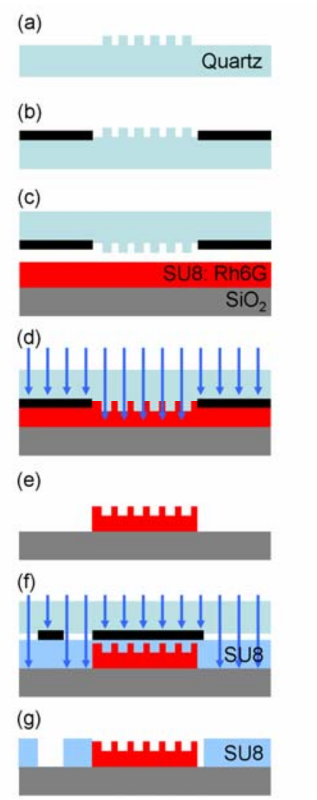

Fig. 2 Outline of the CNP fabrication process. (a)-(b): Combined UV mask and imprint stamp is used. (c)-(e): Embossing and UV exposure of dye doped resist to form DFB lasers. (f)-(g) Additional UV lithography step in un-doped SU-8 film to define polymer waveguides.

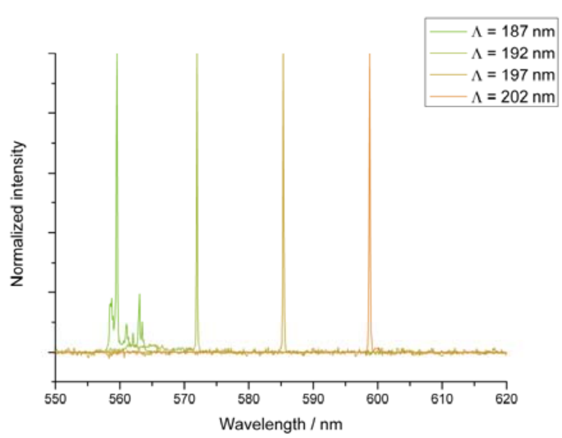

Fig. 3 Emission spectra from four DFB polymer dye lasers pumped at 39 µJ/mm^2. The longest wavelength lasers have emission peaks with FWHM below 1 nm, while the 559 nm device has some additional peaks

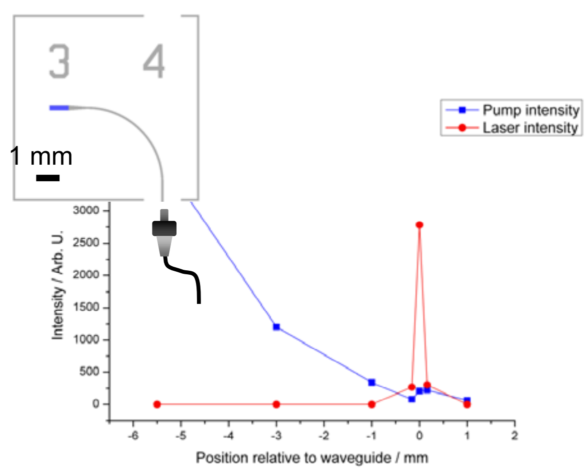

Fig. 4 Intensity of laser and pump signals as a function of position, measured with an optical fiber positioned next to the chip as shown in the inset.