Photonic Integrated Circuits fabricated by Deep UV and Hot Embossing

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We review our work in the field of deep UV modification of methacrylate-based polymers. Planar and rib waveguide structures are presented. A method of integrating polymer waveguides with organic light sources into all-polymer systems is shown.

Undoubtedly, polymers play a vital role in the field of photonics. They are often seen as high potential materials for optical communication, especially for passive components in Fiber-to-the-Home (FTTH) and Fiber-to-the-Desktop (FTTD) applications [1, 2]. Also in biofluidic systems, polymers are widely used. Their comparatively low cost renders them ideal for disposable devices, e.g. as analysis systems for point-of-care-diagnosis [3] or for the monitoring of living cells in laboratories. In order to use of these potentials, the processing technology for polymer photonic components and systems needs to be as cost effective as the material itself.

A simple and efficient way to induce waveguiding structures in methacrylate polymers such as poly(methyl methacrylate) (PMMA) is the local increasing of the refractive index by deep UV radiation [4]. We have demonstrated the possibility to fabricate passive optical components such as planar waveguides, splitters, and couplers using this approach [5]. The planar devices are patterned by conventional photolithographic technique using a quartz/chromium mask (see figure 1).

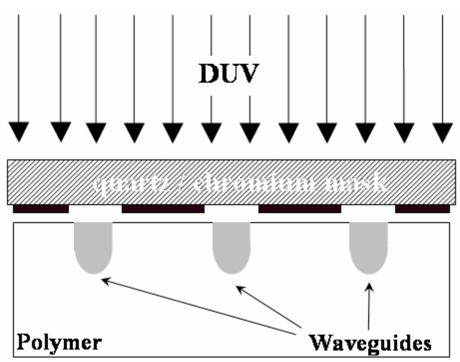

Figure 1: Fabrication of photonic integrated circuits by DUV induced modification.

This technique has several advantages with respect to common methods because only a single polymer layer is used, which serves as the substrate and waveguide as well. No further etching or development steps are required. The waveguides are fabricated using a commercial mask aligner (EVG 620 from EV Group) at a dosage between 3 - 5 J/cm² at 240 nm, leading to an increase in the refractive index between 0.008 and 0.015. A waveguide loss between 0.7 – 0.8 dB/cm is obtained at a wavelength of 1550 nm, which is mainly attributed to material losses. For visible light of 635 nm wavelength, losses as low as 0.1 dB/cm were observed.

Certain structures and devices such as sharp bends or resonators can, however, not be designed as planar structures, as they require strong guiding rib structures. To fabricate this type of structures, the combination of replication by hot embossing and refractive index modification is required. Figure 2 summarizes the principle processing steps for the manufacturing of the embossing tool (a,b), the replication of the molded part (c-e), and the realization of a photochemically altered surface layer for increasing the refractive index (f).

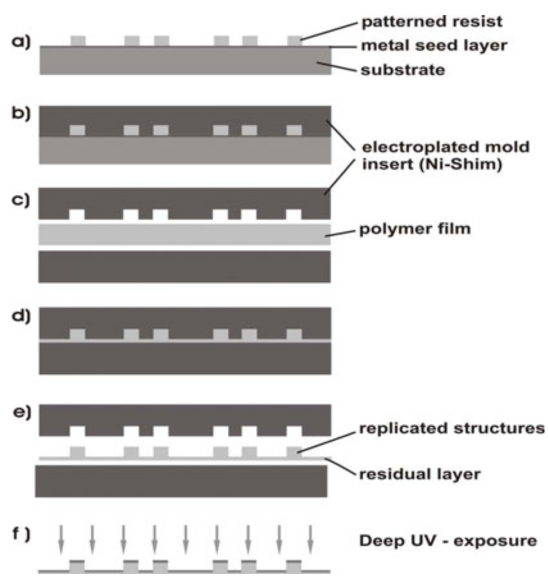

Figure 2: Process steps for tool manufacturing, hot embossing of ridge waveguide structures and deep UV flood exposure.

Straight single mode waveguides and multimode interference couplers for the NIR spectrum fabricated by this approach have already been demonstrated [6]. We believe that the process is also suitable for the realization of more complex structures such as ring resonators.

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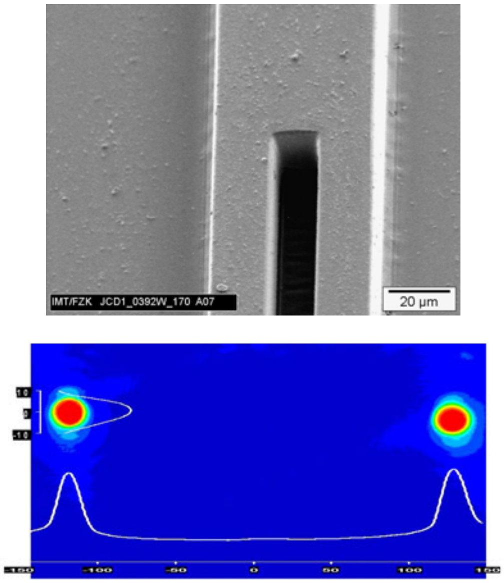

Fig. 3: Photograph of the output region and nearfield image of the facet of an embossed 1 x 2 MMI coupler.

Another important issue in the fabrication process of polymer optical integrated circuits is the coupling with detectors and light sources. These active components are needed for optical detection schemes like fluorescence and absorption measurements. An efficient fiber-chip-coupling is often a challenge, especially for single mode waveguides. A different approach is the direct integration of organic light sources and detectors on the same substrate, leading to an all-polymer photonic system. We already demonstrated the coupling of light from the organic laser material Alq_3:DCM into single mode waveguides on the same substrate [7]. For a lower lasing threshold and a more efficient coupling, a resonator needs to be formed on the waveguide before the deposition of the active laser active material. This can again be achieved by hot embossing of a sub-micrometer scale resonator structure prior to the deep-UV fabrication of planar waveguides and the deposition of the laser material. Figure 4 shows a SEM picture of a replicated grating; in figure 5 the principle of an optically pumped integrated laser source is demonstrated. Examples of fabricated devices will be presented.

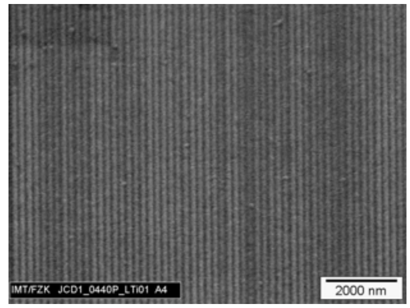

Fig. 4: Laser resonator structure replicated in PMMA by hot embossing. Period of the grating is 200 nm.

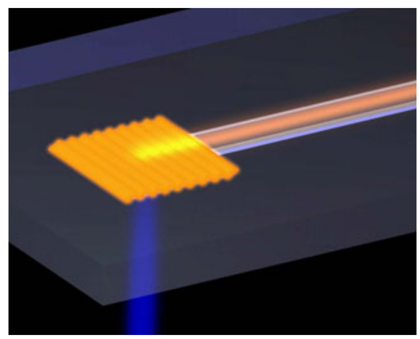

Fig.5: Scheme of an optically pumped waveguide-coupled organic laser.

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