Ion Beam Lithography for sub-50 nm Patterning of Metal Mold Inserts and Replication by Injection Molding

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Polymers are attractive materials for the realization of photonic and biomedical devices in a wide range of applications and allow for cost-effective mass production. The development of polymer based optical biosensors with integrated Mach-Zehnder interferometer configurations[1,2] require for the replication of nanostructures of sub-100 nm feature sizes. Replication by injection molding has the inherent advantage that the entire polymer biosensor device is fabricated simultaneously with its implemented nanostructures (Fig. 1). With respect to robustness metallic mold inserts are preferable but also difficult to pattern with low edge roughness by conventional lithography and plasma etching. Nanopatterning of a Ni-Cu mold insert by the ion multi-beam technology using Ar ions and Si stencil masks has been demonstrated before achieving features as small as 50 nm, which were successfully replicated in polymethylpentene (PMP) samples by injection molding[3].

Ion beam lithography (IBL) based on milling with a focused Gallium beam is an excellent technology of producing high resolution patterns with very low edge roughness, which is crucial for the realization of photonic waveguide structures. In addition IBL is more flexible as compared to the stencil mask approach and provides the capability of fabricating complex 3D shaped structures such as microlenses or blazed grating. The setup we use (Raith *ionLiNE*) is a true lithography system and can add sub-10 nm patterns to an existing microstructure by mix and match. Moreover a continuous patterning mode enables long paths without stitching (Fig. 2) and can be used to create a smooth envelope over millimeters while the area within the lines is removed by conventional lithography and etching, for example.

We created various test patterns including dots, lines, lines and spaces as well as various positive and negative shapes with feature size below 50 nm. These nanostructures have been patterned by IBL in a Ni-Cu metal stamp, which was directly employed as mold insert in order to investigate the replication limit of

injection molding. The minimum achieved features size as well as the influence of feature size, feature density and 3D shape on the replication process and quality is shown. Improvements of the process and detailed characterization including AFM metrology are in progress and will be presented and discussed.

[1]R. Bruck, R. Hainberger, Proc. SPIE Vol. 7138, 71380N (2008)
[2]R. Hainberger et al., Microelectron. Eng. 87, 821–823 (2010)
[3]A. Köck et al., J. Vac. Sci. Technol. B 28 (6), C6B1-C6B6 (2010)

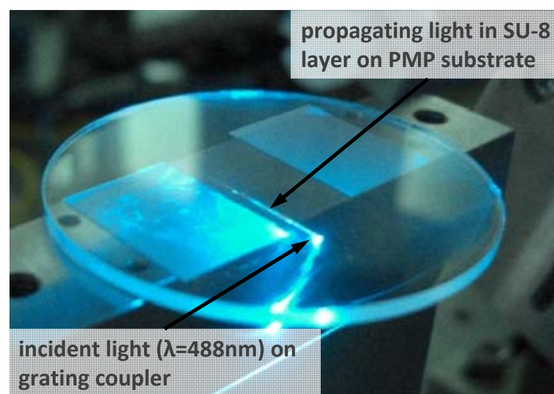

Figure 1: Example of polymer biosensor based on waveguide structure with grating coupler fabricated in PMP by injection molding.

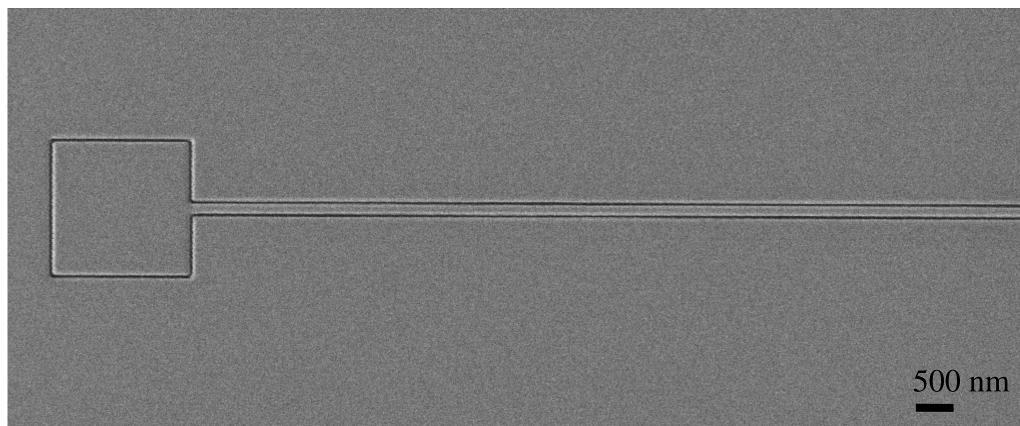

Figure 2: Ion beam lithography created 20 nm wide lines using a continuous patterning mode over 1 mm² total area. Image taken with a scanning ion beam, substrate is Si with 30 nm of Cr on top.