Argon ion multi-beam nanopatterning of Ni-Cu inserts for injection molding

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Polymer based photonic devices require the replication of nanostructures with sub-100 nm feature sizes by cost-effective mass-production technologies. While hot embossing and in particular nanoimprint lithography are very well suited for nanopatterning of polymer surfaces, injection molding has the inherent advantage that an entire polymer device is fabricated simultaneously with its implemented nanostructures. We have already demonstrated the replication of nanostructures with features sizes below 50 nm from electron beam lithography patterned 1.5 mm thick 2”-Si wafers by injection molding [1]. With respect to robustness, metallic mold inserts are preferable. Thus the CHARPAN (charged particle nanopatterning) ion multi-beam technology [2] has been applied for patterning of a Ni-Cu mold insert.

By employing this insert we have successfully achieved the replication of nanostructures as small as 100 nm by injection molding of the thermoplastic polymer polymethylpentene (PMP). This specific polymer offers attractive characteristics for the realization of micro optical and photonic devices in a wide range of applications.

Specific photonic test structures have been designed for resistless electrostatic step exposure [3] with the CHARPAN tool. A corresponding Si stencil mask was fabricated for the CHARPAN tool employing a 200x reduction projection ion-optics, which results in a 25µm x 25µm exposure field. A Cu stamp (diameter 50 mm, thickness 12,7 mm) has been coated with a Ni-layer, which was high-precision diamond-milled to a thickness 50 µm with a surface roughness of $R_a < 3$ nm. The stamp was nanopatterned with 10 keV Ar ion multi-beam milling to a depth of ~ 100 nm and directly employed as insert for injection molding into PMP. The thickness of the PMP substrates was 1,5 mm. Standard parameters were used for the injection molding process, no pre-evacuation of the mold was employed. Cycle time was about 30 sec.

Fig. 1 shows the test patterns fabricated in the Ni-Cu-stamp by CHARPAN Ar ion multi beam nanopatterning, while Fig. 2 shows the respective structures in the PMP substrate fabricated by injection molding. Fig. 3 shows a detail of a pillar array with diameter of 100 nm patterned into the Ni-Cu-stamp, while Fig. 4 shows the respective dot pattern in the PMP substrate. The presented results are preliminary without optimizations. Improvements of the process and detailed characterization including AFM metrology are in progress and will be presented and discussed.

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[3] C. Ebm, E. Platzgummer, H. Loeschner, S. Eder-Kapl, P. Joechl, M. Kuemmel, R. Reitinger, G. Hobler, A. Koeck, R. Hainberger, M. Wellenzohn, F. Letzkus, and M. Irmscher, J. Vac. Sci. Technol. B 27, 2668-2673 (2009).

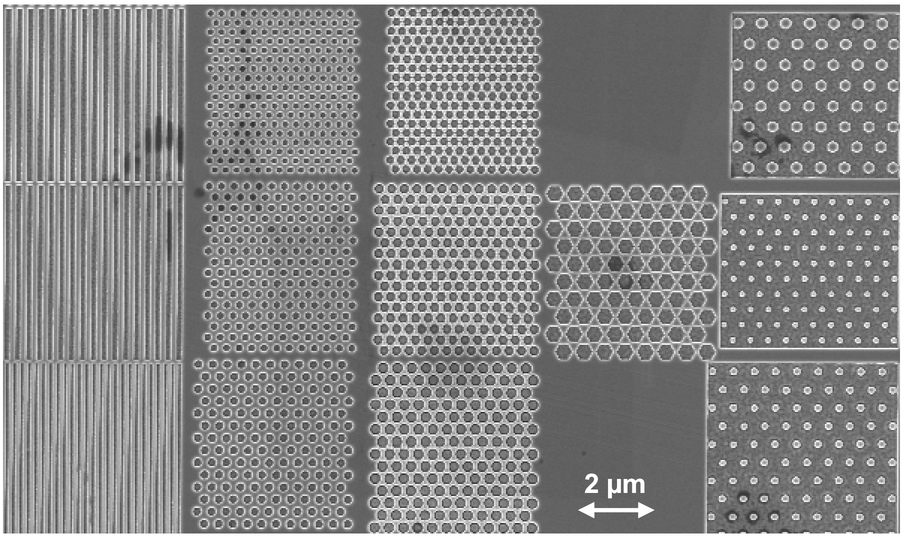

Fig. 1: Test patterns fabricated in the Ni-Cu-stamp by resistless 10 keV Argon ion multi-beam nanopatterning. All test patterns were milled simultaneously. The milling depth is ~ 100 nm.

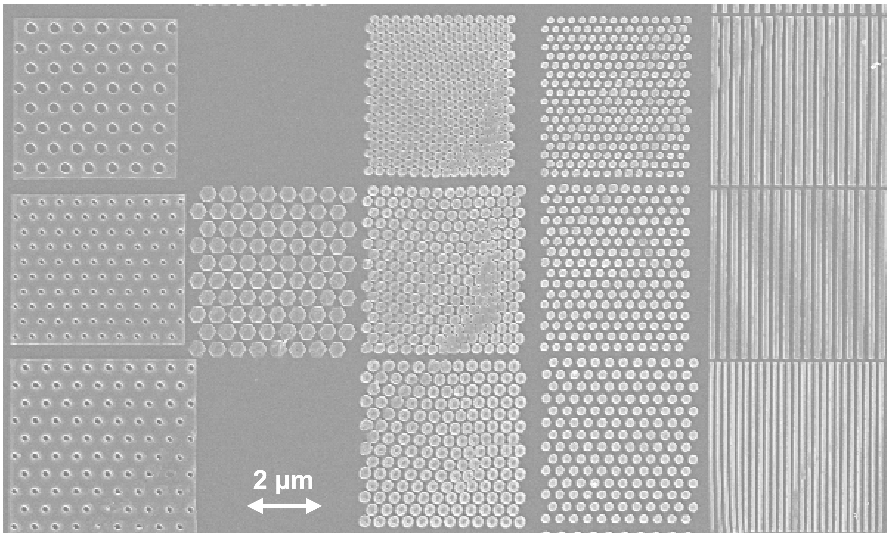

Fig. 2: Respective test patterns in the PMP substrate fabricated by injection molding technology.

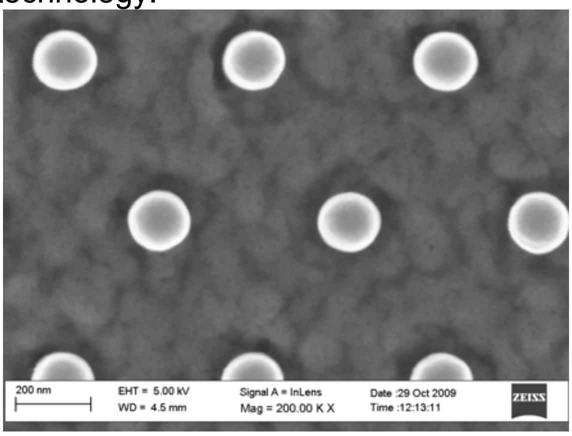

Fig. 3: Array of pillars with diameter of 100 nm patterned into the Ni-Cu-stamp to a depth of ~ 100 nm.

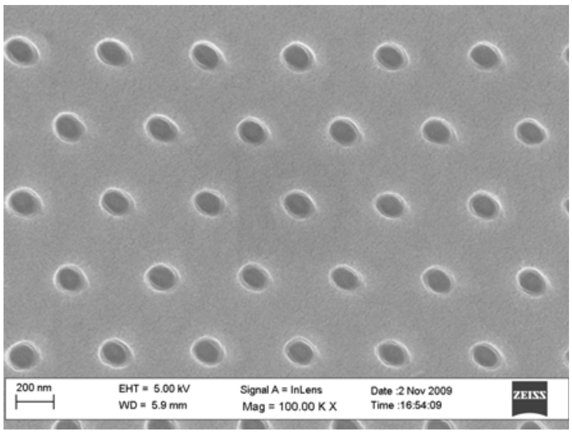

Fig. 4: Respective dot pattern in the PMP substrate fabricated by injection molding.