Nanopatterned micromechanical elements by polymer injection molding with hybrid molds

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Polymer microelements can exhibit combinations of optical or biological functionalities combined with mechanical properties. Two examples are cantilevers as mechanical transducers in biological sensing platforms; and fiber connectors for optical communication via fiber-to-fiber coupling, in which holes or clamps form registration for the alignment of entire fiber arrays, either directly or via collimating optical elements [1]. While it is possible to manufacture molds with both micro- and nanopatterns using combined nanoimprint and photolithography, it is much simpler to use hybrid molds directly for injection molding [2]. In this contribution, we present two methods in which such hybrid molds were used.

Thin mechanical microlevers for fiber connectors were fabricated in a so-called LIGA process, in which deep (etch) X-ray lithography (DXRL) was used to pattern 500 µm thick PMMA resist with vertical sidewalls and transferred into Nickel by electroplating. This enables to define outlines of micromechanical levers with a wide range of freedom in design. The 7×7 mm^2 high aspect ratio structure was aligned and clamped onto another metal mold with 3D surface microstructures made with grayscale photolithography and electroplating and inserted into a molding tool. For easy filling and demolding of the 200 µm thick levers without distortion, injection was performed from a multitude of inlets. This way, since the levers are designed symmetrical, they keep the metal guide pins centered in the plane along the fiber array. The Fresnel lenses at the front face and are fabricated to meet the collimation demands of the fiber connectors (Fig. 1).

For the surface patterning of polymer microcantilevers (µC) the requirements of alignment are much more relaxed. A modular injection molding tool has been developed, with the laser machined mold cavities located on the closing unit and a polished steel plate with one injection gate on the mirror unit of the injection molding machine (Fig. 2). Molding results in an array of 20 µm thick µCs connected to larger body. Instead of replicating the mirror surface directly, we attached a thin, patterned polymer foil onto it. This 100 µm thick foil-like mold was prepared by hot embossing and forms the interface between the two units. The main advantage of the method lies in the simple integration of gratings onto the surface of cantilevers with different sizes and orientations.

In both cases, while closing the mold, a by topography is transferred onto one surface of the molded element whose outlines are defined by the mold cavity. It allows for independent development of functional properties.

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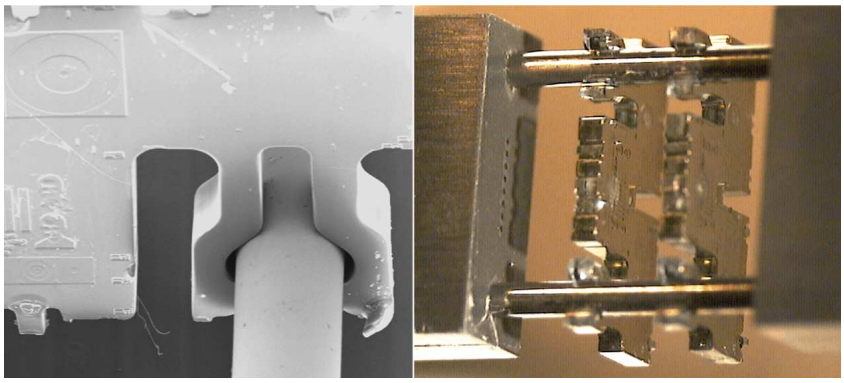

Figure 1: Collimation arrangement for fiber-to-fiber coupling using injection molded microelements. Two micro-optical elements in polycarbonate are clamped on MT-connector guide pins (700 µm). The lenses at the front side of the elements are designed to be collimating light of 8 fibers.

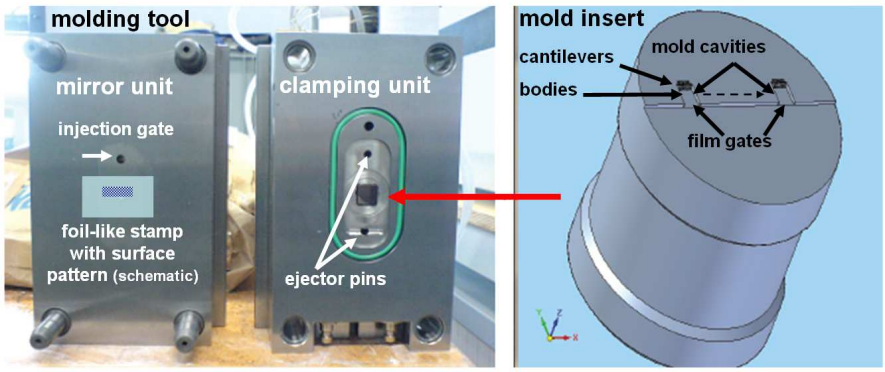

Figure 2: Molding tool (handy mold) with two sides (left side). The mirror side contains the gate (top) and the location, where the patterned foil is placed. The clamping unit contains the mold insert (right side) with two mold cavities.

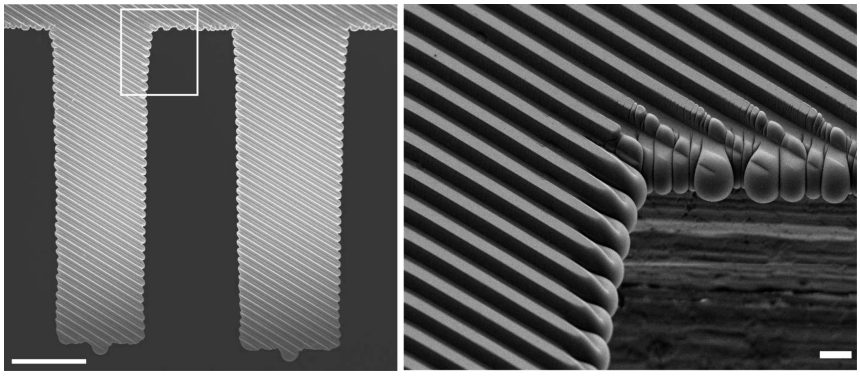

Figure 3: SEM micrographs of the line pattern (period 10 µm, depth 5 µm, width 5 µm) transferred during the molding process from a foil-like mold to the surface of two molded microcantilevers (left side, size 500×80×20 µm^3). In contrast to the non-patterned original beams, the surface patterned beams are slightly (10%) wider due to high injection pressure and the softness of the PC foil (see extract at right side).