Functional materials for one step UV-NIL manufacturing of disposable microfluidic devices

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Standard manufacturing technologies for microfluidic chips are mainly conventional photolithography, soft lithography, or molding techniques [1]. Most of the applied materials are generic ones like conventional elastomeric polydimethyl-siloxane (PDMS), thermoplastic materials like polymethyl methacrylate (PMMA), cyclic olefin copolymers (COC) or polystyrene (PS), or even photoresists like ma-N1410 [1-3]. If a certain surface function is needed for the final application, e.g. reactive side moieties at the top surface of the microfluidic channels for subsequent bio-immobilization, additional cost intensive process steps are obviously essential. In contrast to such standard manufacturing methods UV-nanoimprint lithography (UV-NIL) is a nano-fabrication method providing the possibility of a direct structuring of functional materials. For high throughput and large volume production, roll-to-roll UV-nanoimprint lithography (R2R UV-NIL) is proposed to be a low cost manufacturing technology for such microfluidic devices in one single step [4]. The capability of direct surface functionalization without additional process steps will have a major influence and potential in academic as well as industrial developments with respect to low cost manufacturing of bio-chips and paves the way for new applications in the field of microfluidics as well as bio-sensors.

In this contribution we will demonstrate the development of a photo-curable and biocompatible NIL resist especially designed for the application in R2R UV-NIL mass prototyping featuring selected material characteristics for microfluidic device fabrication as well as for cell attachment: high optical transmission in the visible range of the spectrum, high hydrophilicity beside low hygroscopicity, fast curing rate during photo-radiation and good adhesion to several plastic films like PET or PC without any surface treatment. A great focus was put onto the concrete selection of each single component of the newly developed formulation in order to gain maximum possible biocompatibility after curing. We have monitored a large variety of different polymers, oligomers, monomers, as well as different radical photo-initiators and additives to achieve biocompatibility of the cured and structured resist, demonstrated by ISO10993-5 cytotoxicity tests. With the developed formulation, we will demonstrate how we can incorporate specific functional moieties (e.g. carboxylic acids and thiols), allowing subsequent immobilization on the materials imprinted top surface. We are able to show a direct covalent post immobilization either via base-catalyzed hetero-Michael addition to the surface active thiols, or via an active ester-mediated amide-coupling [5] to the free carboxylic acid groups (Fig. 1). This method enables us to alter the surface properties such as hydrophilicity, but also to directly couple different biomolecules like covalently bonded collagen, fibronectin, and laminin to the nanostructured top surface of a microfluidic chip fabricated via NIL.

The potential of the new formulation being able to replicate both micrometer-sized structures as well as nanometer sized patterns, respectively, were pre-evaluated by plate-to-plate imprints (Fig. 2). Preliminary high throughput manufacturing tests (Fig. 3) applying the newly developed formulations in a roller NIL process will be shown and characterized.

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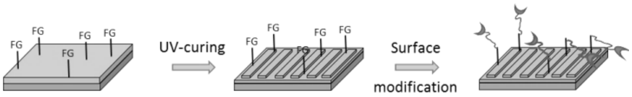

Figure 1: Direct immobilization of bio-molecules via covalent chemical bonding on the top surface of an imprinted functional material.

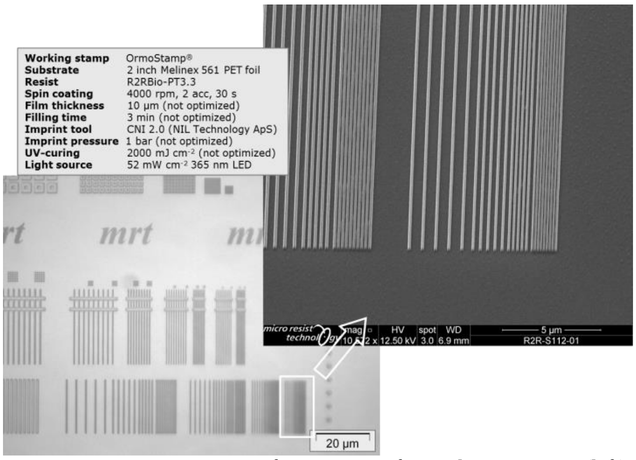

Figure 2: Microscope image of an imprint of mixed test patterns (left) and corresponding SEM image (right) showing L&S patterns with different dimensions ranging from 800 nm to 75 nm and a depth of 200 nm (inset: imprint parameter).

Figure 3: Preliminary high throughput manufacturing of microfluidic devices with the newly developed resist; from R2R imprinting demonstrating R2R capabilities.