Take the best of two worlds – how hybrid processing enhances the potential of nanoimprint lithography

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Within its 30 years of development, nanoimprint lithography (NIL) has seen both continuous advances in high-resolution patterning, necessary for advancing high-volume manufacturing (HVM) of semiconductor chips, but also a plethora of processes using different approaches, tools, materials, and process schemes. At PSI, as the largest research institute for natural and engineering sciences in Switzerland, we were able to contribute to HVM of next generation chips by using the "maskless" EUV-exposure capabilities of our synchrotron, the Swiss Light Source (SLS) [1]. Alternatively, due to my background in LiGA technique with its toolbox approach for the fabrication of high aspect ratio microstructures (HARMST) that was developed over 40 years ago, we always understood NIL as a downscaled LiGA process in which the molding was seen as a process to pattern functional materials that were not just sacrificial layers for pattern transfer [2]. LiGA (an acronym for Lithographie, Galvanik, Abformung), was developing from deep (etch) X-ray lithography to UV-lithography of SU-8 films, enabling the use in the fabrication of components for watches, microfluidics and micro-optics. Its process was more seen as a toolbox than as a strict sequence of lithography, electroplating and molding. Many ideas that have been taken up by NIL were already realized on a larger scale, and process downscaling often did not mean higher complexity, but simply more analytical requirements for the quality assessment, simply because of the smaller dimensions [3-5]. Using this approach, we saw NIL rather as part of material science than as lithographic process that could reach out to application fields from printed electronics to polymer replication methods such as injection molding to and roll embossing, and materials from metals to ceramics. In contrast to this, when NIL was seen as novel process where other patterning techniques were not available before, it reached out to new fields of nano-optics, hard disk manufacturing and X-ray optics [6].

By using hybrid manufacturing, its potential can be further enhanced because NIL can be combined with a range of processes, such as lithography (direct electron and laser beam writing) or other molding processes such as injection molding [7-9]. This is possible because a material is shaped by mechanical contact and material displacement, while often preserving other, inherent functionalities for patterning with alternative processes, e.g., by photolithography or thermal reflow. NIL also enables straightforward patterning of functional materials that cannot be easily patterned by photolithography, e.g., hybrid inorganic materials. By considering knowledge about materials and processes, it therefore combines the best of worlds.

In my talk I want to present NIL as a toolbox approach, with an emphasis on hybrid processing. I will show combinations of NIL with electron- and photon-based lithography, thermal reflow for selective surface smoothening. NIL can be combined with printed electronics and injection molding, and pattern hybrid glass inks that can be used for glass microfluidics.

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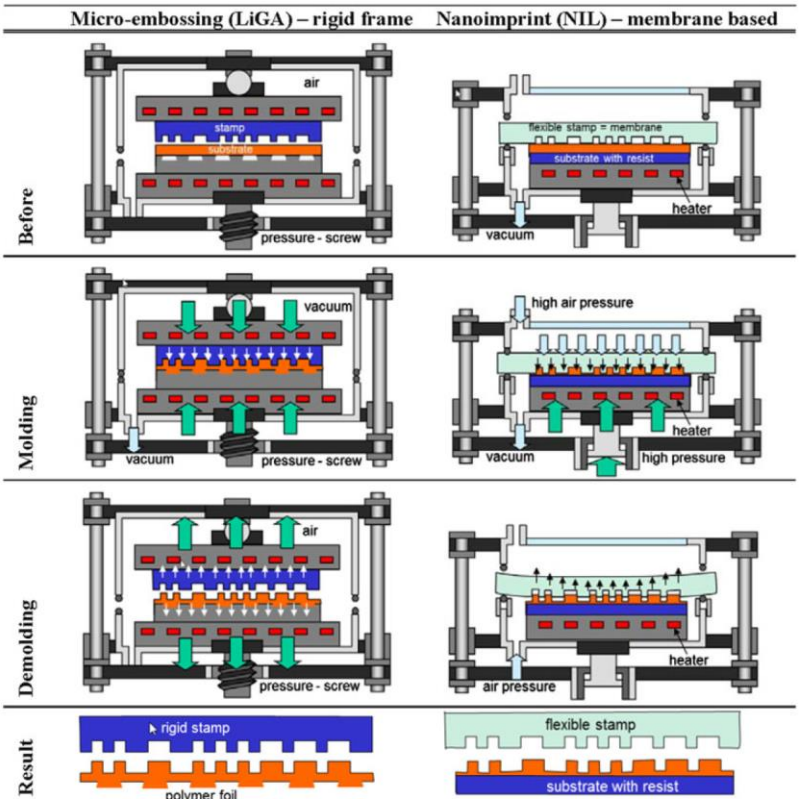

Figure 1. (a) Embossing machine with rigid frame for time/distance-controlled molding and demolding of microstructures, (b) imprint machine with flexible stamp and compliance membrane for pressure controlled molding of nanostructures.

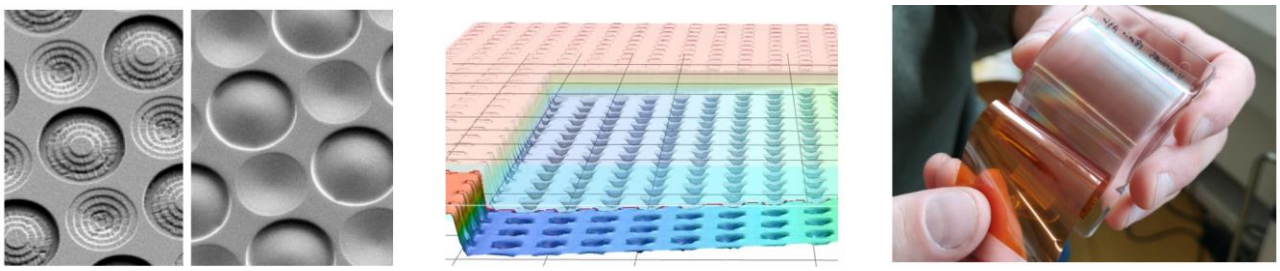

Figure 2. Examples for hybrid processes: left side: the e-beam lithography and thermal reflow, center: NIL and 3D photolithography, right side: NIL and injection molding.

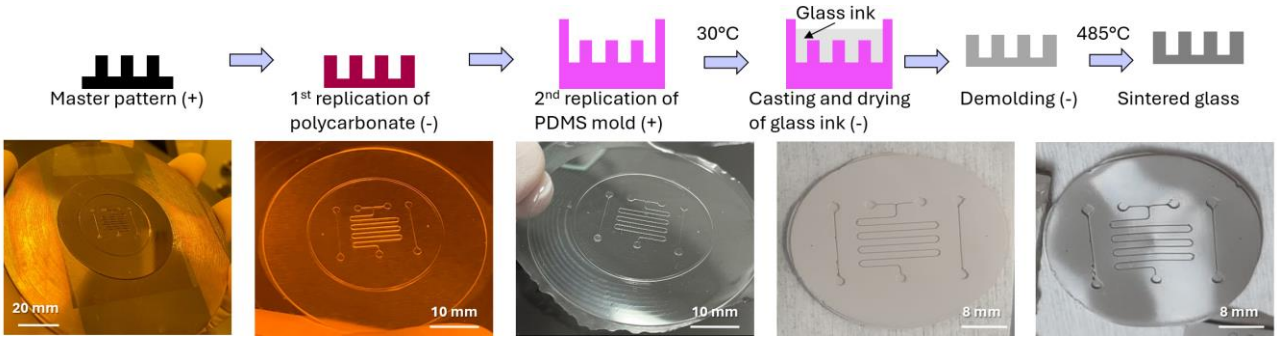

Figure 3. Process sequence for the fabrication of glass structures from hybrid glass inks by "room temperature" imprint and subsequent sintering.