Fully Automated Hot Embossing Processes Utilizing High Resolution Working Stamps

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The low-cost fabrication of disposable, polymer based devices needed for emerging point-of-care diagnostic or bio-sensing devices can be realized by hot embossing processes at low cost. The similarities in regards to process parameters and equipment specifications between wafer bonding and hot embossing processes have led to the modifications of wafer bonder systems used for thermo-compression bonding processes to accommodate embossing processes some years back [1]. Hot embossing processes are generally used to address different applications ranging from polymer-based lab-on-chip systems, where imprinting is done on thick polymers substrates, to the fabrication of sub 100 nm features for bio-sensing or data recording applications which requires imprinting into spin-on polymers. The first method requires hard stamps mostly made of Ni, brass or stainless steel depending on the expected feature size. Those replicated structures are used directly as functional devices deployed in microfluidic devices [2]. In the later case a pre-structured stamp made of Si is used to transfer a pattern into a spin-coated Si substrate. Those structures can be transferred into Si by dry reactive ion etching and their size can be in the nm-range if the stamp is fabricated by e-beam writing. Development of commercial applications based on the hot embossing NIL processes requires, however, fabrication systems and processes with throughputs that are beyond the R&D tools existing today. This requires fully-automated process implying an automated de-embossing process of stamp and imprinted substrate; a reliable and residual free separation of stamp and imprinted substrate post imprint by using an anti-adhesive monolayer on the stamp surface [3]; and the use of compliant layers that ensure imprints uniformity over large areas. The first fully automated hot embossing system was developed for the hard disc industry for double side patterning of hard disks using Ni-stamps [4]. S. Merino, et.al. have proposed a method for automated de-embossing by mechanically fixing a Si stamp on a top chuck and separating the substrate by an “air knife” using a mechanical frame to hold the substrate in place [5]. Another proposed way is to fixation of the substrate by utilizing the high adhesion force of a Si wafer to a PDMS layer described in the same paper. While both methods are successful in separating the stamp and the imprinted substrate in a fully automated way, a full automation process including substrate and stamp handling might be difficult to realize with the proposed method. This paper demonstrates the realization of a fully automated hot embossing system for spin-on polymers on the EVG®750 (Figure 1), the first one of its kind that includes both substrate and stamp handling as well as automatic embossing and de-embossing. In contrary to the process described above using hard stamps, the process we are reporting here on the EVG®750 system employs soft working stamps materials which exhibit manifold benefits over Si stamps: (1) soft working stamps can be fabricated at low cost from expensive e-beam written masters, (2) soft working stamp can be used for multiple imprints, (3) the use of soft working stamps does not require compliant layers as they already exhibit this trait and (4) these stamps are fully compatible with optical alignment to a structured Si substrate. UV-curable soft stamps are bonded to a glass backplane and can be used for top side live alignment, i.e., the alignment keys of both the polymer stamp and the Si substrate are visible at the same time. Features sizes in the sub-µm range and down to 50 nm utilizing working stamps are demonstrated in Figure 2 by applying a fully automated process mode in the EVG®750. This paper will provide detailed insights in the design and the functions of the fully automated hot embossing systems as well as details of the working stamp fabrication process, alignment, imprinting and de-embossing process.

[1] N. Ross, et.al., Nanoimprint Lithography with a Commercial 4 Inch Bond System for Hot Embossing, Proc. SPIE 4343, (2001), 427-435.
[2] Mizuno, et. al., Fabrication of novel type microfluidic devices by hot embossing technology, Proceedings of the 9th International Conference on the Commercialization of Micro and Nano Systems, August 29- September 2, 2004, Edmonton, Alberta, Canada, pp. 389 -392.
[3] Neil S. Cameron, et.al., Hot Embossing Lithography : Release Layer Characterization by Chemical Force Microscopy, Mater. Res. Soc. Symp. Proc. Vol. 872, 2005.
[4] P.Dorsey, et. al., Discrete Track Recording (DTR) Media Fabricated using Nanoimprint
[5] S. Merino, et.al., The use of automatic demolding in nanoimprint lithography processes, Microelectronic Engineering 84, (2007), 958-962.

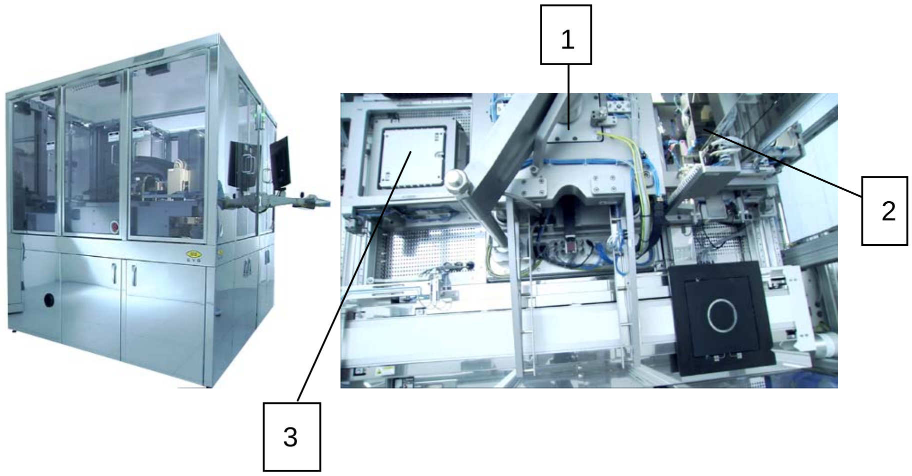

Figure 1: Left: System overview of EVG750 fully automated hot embossing system; Right: Close-up of EVG750 modules: (1) imprinting module, (2) alignment station, (3) cooling station

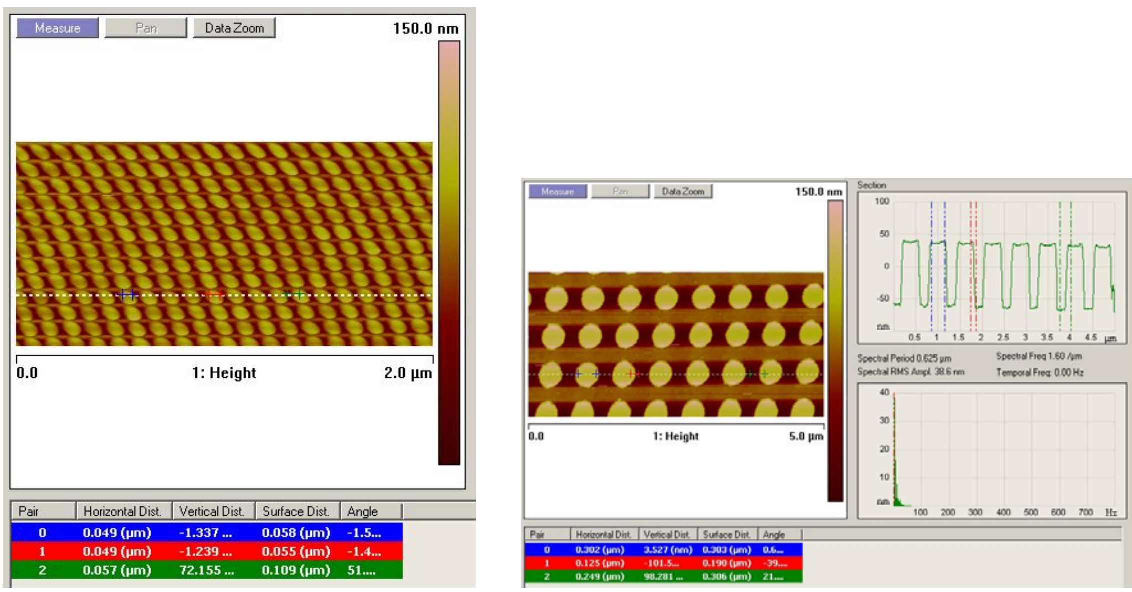

Figure 2: Left: AFM picture of imprinted features with resolutions of 50 nm; Right: AFM picture of imprinted features with resolutions of 300 nm and imprint depths of 100 nm