Fabrication of sub-20nm nanochannels integrated with bowtie nanoantenna

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Single molecule detection has become a very interesting topic recently, since it allows to manipulate and characterize the properties of molecules individually, with a resolution and accuracy without precedents. To achieve such objective, it is necesary to combine state-of-the-art nanofabrication techniques with very sensitive transduction systems. In particular, we are interested in studying *non-labeled DNA* molecules stretched in very small nanochannels [1], by analyzing the *shift of the resonant peak* of plasmonic resonators (*bowtie nanoantenna* [2]) when the molecules flow in-between the gap. This configuration, where the analyte is brought right into the plasmonic "hot spot", would allow real time, label-free high resolution detection.

For this, we have developed a parallel approach, based on a double nanoimprint (NIL) replication, for the fast fabrication of multiple micro/nano fluidic Lab-on-Chip devices. The device layout and geometry is schematized in Figure 1.

The fabrication process is shown in Figure 2. A **master silicon stamp** is fabricated first in a 4 inch wafer: the nanochannels and the bowtie antenna are defined by electron beam lithography (EBL) and reactive ion etching (RIE) (a); the microchannels are fabricated by photolithography and RIE (b), and the triangular tapered inlets are milled by focused ion beam (FIB) (c). Then, a **first replica** is made of a UV curable polymer by UV-NIL (d). This replica (e) is used as a stamp to fabricate **the final structures**, again by UV-NIL (f). Four reservoirs are milled by sandblasting, and then the sample is bonded to a glass coverslip [3] (g). 16 devices are fabricated simultaneously, what allows having different bowtie geometries and nanochannels with different widths in the same wafer.

Figure 3 shows SEM images of a silicon stamp (a,b) and of a final device (i.e., 2nd replica) (c,d). An overview of a device can be seen (a,c), as well as a detail of the connecting inlet (inset in (a)). *Nanochannels as small as 12 nm wide have been successfully fabricated*, as shown in (b). For the fabrication of the integrated Bowtie nanoantenna, the shape is defined together with the channel, where gold nanostructures will be patterned by using Induced Deposition Mask Lithography, recenty developed in our laboratory [4]. Figure 4 shows the tapered inlets, fabricated by FIB milling in the silicon stamp to facilitate the flow of the DNA molecules into the nanometric channels.

First flow tests using different DNA molecules have been made, and the results will be shown at the conference.

[1] J. Tegenfeldt, C. Prinz and H. Cao, *PNAS*, 101, 10979 (2004)

[2] Z. Zhang, A. Weber-Bargioni, S. W. Wu, et. al., *Nano Letters*, 9, 4505 (2009)

[3] X. Liang and S. Y. Chou, *Nanoletters*, 8, 1472 (2008)

[4] A.Weber-Bargioni, A.Schwartzberg, M.Schmidt, et. al, *Nanotechnology* 21 065306 (2010)

Figures:

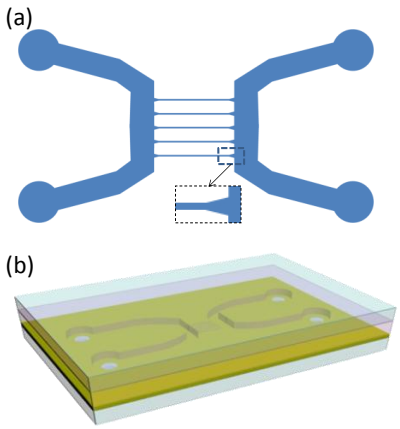

Figure 1. *Scheme of the device*. (a) Feature distribution: 4 big reservoirs (to pipette the liquid into the system), microchannels, nanochannels, and tapered microinlets, to connect by the micro and the nanochannels and to facilitate the flow. (b) 3D scheme of how the device.

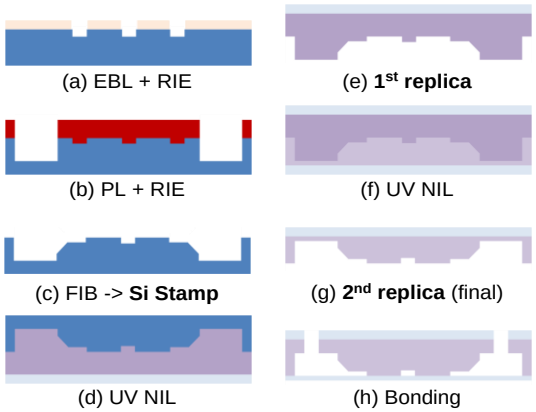

Figure 2. *Fabrication process*. A first master stamp is fabricated in a silicon wafer, by high resolution EBL (100kV and cold development), photolithography, and RIE, (a) (b). FIB is used to mill 3D tapered inlets (c). This stamp is replicated by UV NIL (drop cast of monomer, pressure and UV curing), (d), (e), and the replica is used to imprint the same material (f) again by UV NIL. These structures (g) are bonded to a glass coverslip, to seal the device after milling four macro inlets by sandblasting (h), and used for the experiments.

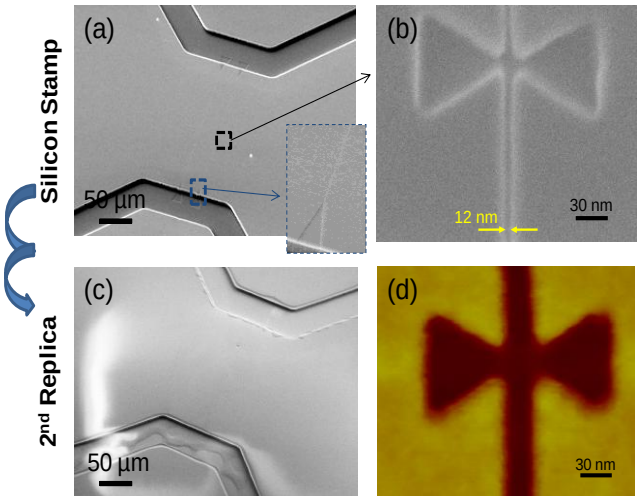

Figure 3. *Images of a device* of the *silicon stamp* ((a), (b)), and the *second replica* made of UV-curable material((c),(d)). The microchannels can be clearly seen in (a) and (c), as well as the tappered inlet that connets them with the nanochannels (inset in (a)). These are shown in (b) and (d), together with the bowtie antenna. Since the fabrication is done in wafer scale (in parallel), several different geometries and dimensions have been fabricated, where the channel lateral dimensions vary from 12 nm, as shown in (b) up to 50 nm wide, as shown in a replica in (d).

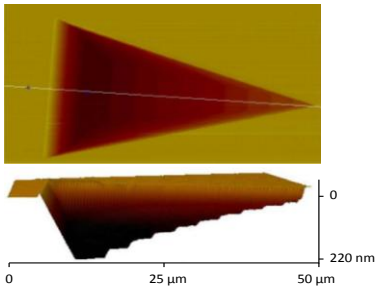

Figure 4. AFM image and profile of the *tapered inlet*, fabricated by FIB in the silicon stamp. The 3D structure is used to connect the micro with the nanochannels, to maximize the number of DNA molecules that flow into the smallest structures.