A lab-on-a-chip with 30 nm nanochannels and plasmonic bowtie nanoantenna

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Plasmonic bowtie nanoantennae are able to nano-focus and enhance the light by several orders of magnitude into a very small spot: the sub-50 nm gap. This hot spot is ultra-sensitive, what can be exploited for single particle (bio)sensing. But there is a major challenge: how to place the target element right at the hot spot.

Here, we have integrated a nanochannel crossing the antenna gap (with exactly its same dimensions and perfectly aligned to it), what allows to deliver the analyte right into the sensitive area in a controlled fashion (Figure 1). The nanochannel is connected to a complete fluidic system, as shown in Figure 1. This represents a new type of super-sensitive (bio)sensor, with label free single-molecule real time detection capabilities.

We have developed a wafer-scale fabrication process, based on nanoimprint lighotraphy (NIL), for the device fabrication[1]. The silicon stamp is fabricated by electron beam lithography, photolithography and reactive ion etching to pattern the micro and nanochannels; gray-scale electron beam lithography plus thermal reflow is used to pattern 3D tapered inlets[2,3]. A negative replica of the stamp is made in Ormostamp (a hybrid polymer commercially available from microresist technology) by UV nanoimprint lithography. Finally, the all-transparent polymeric device is made by direct UV-NIL using the negative replica to imprint Ormostamp. The plasmonic nano-antennae are defined by shadow evaporation of a sacrificial layer of chromium, a normal evaporation of gold, and lift-off using a chromium etchant. Images of the device are shown in Figure 2.

Two-photon photoluminescence measurements confirm the light focusing into the gap with an intensity enhancement as high as $\alpha^2=10^4$. Preliminary sensing results show a dark field scattering resonance in the interval of 650-750 nm and a shift of ~15 nm when the channel is filled with water (Figure 3). Simulations show a good agreement on this result (Figure 4).

The nanochannels have been used to stretch λ-DNA by electrophoresis. Figure 5 shows a time sequence of a molecule passing from the microchannel on the left (t=0 s) entering the tapered structures and stretched in the nanochannel (t = 20-60 ms) and finally getting into the right microchannel (t = 80-100 ms). Figure 6 shows detaisl of the intensity profiles and lengths of single molecules stretched into nanochannels of different cross sections: 27 nm x30 nm, 80 nm x 30 nm, 120 x 30 nm.

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[1] I. Fernandez-Cuesta et. al., J. Vac. Sci. Technol. B 29, 06F801 (2011)
[2] I. Fernandez-Cuesta et. al., NNT 2012
[3] A. Schleunitz et. al., J. Vac. Sci. Technol. B 29, 06FC01 (2011)

Figures:

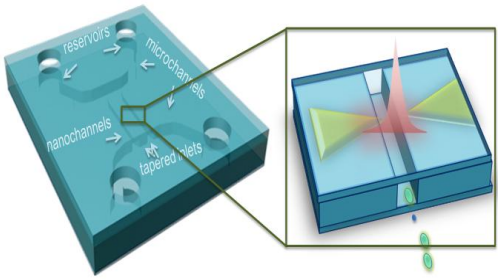

Figure 1 *Device concept.*A full micro/nano fluidic system is integrated with plasmonic bowtie nanoantenna. This allows delivering the target element into the plasmonic hot spot.

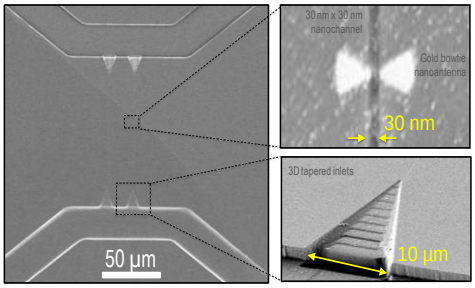

Figure 2. *Images of the device*, where the microchannels, nanochannels, tapered inlets and gold bowtie nanoantenna aligned and level with the channel can be seen.

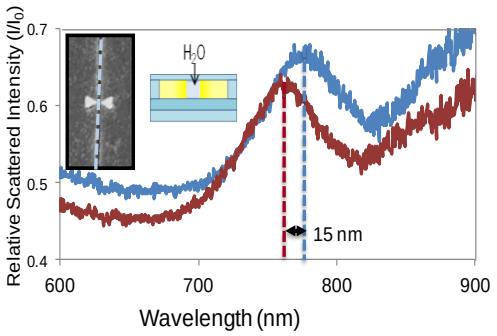

Figure 3. *Dark field spectroscopy sensitivity.* The resonant signal of the antenna facing an emtpy channel shifts 15 nm when the channel is filled with water. A sensitivity of 50 nm per refractive index unit has been calculated.

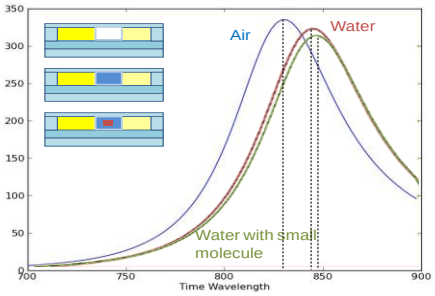

Figure 4. *Sensitivity simulations.* A shift of 15 nm for a nanochannel filled with air or water is calculated. A 5 nm shift is predicted for a small molecule crossing the antenna gap (10x10x10 nm^3 cube with a n=1.5)

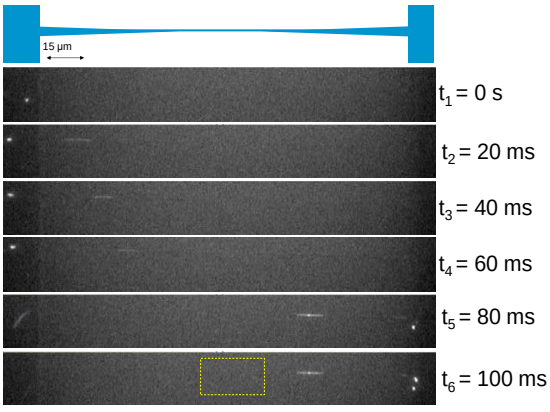

Figure 5. *DNA stretching in nanochannels*. λ-DNA are driven by electrophoresis from the left microchannel to the right one, passing along the tapered inlets and stretched in the sub-30 nm nanochannels. The nanochannel area is marked with a yellow dashed square, and stretching details shown in Figure 6.

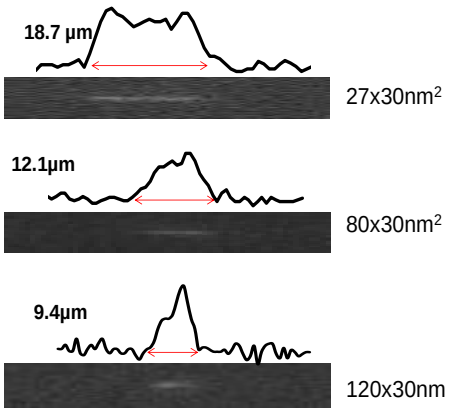

Figure 6. *DNA stretching in nanochannels.* Intensity images and profiles of single DNA molecules stretched in nanochannels with different cross-sections: 27 nm x30 nm, 80 nm x 30 nm, 120 x 30 nm, from top to bottom.