Final Summary – MC IOF PLASBIORES (M1-M36)

During this project, an integrated device that can be used for single DNA molecule manipulation and detection was developed. The core idea is based on the combination of nanofluidics and plasmonics (Figure 1 (a)). This lab-on-a-chip is capable of advanced liquid manipulation at the micro and nanoscale, and can confine substances down to the zL scale. In addition, it has on-chip detection capabilities by using plasmonic nanoantenna, which confine and enhance optical fields into sub-diffraction limited spots inside the nanochannels.

A robust technology for the fabrication of the integrated devices by wafer scale processes was developed. It is based on direct imprint lithography, and allows to fabricate multifunctional, multidimensional micro and nano fluidic channels in one single step. It requires just few minutes and no alignment is necessary. For the integration of plasmonic elements, an original method - also wafer-scale with parallel processing- was developed. It uses the shadow evaporation of a sacrificial layer and a selective lift-off. This process is self-aligned, and allows to integrate the gold structures perfectly aligned and at the same level of the nanochannel. Images of the device are shown in Figure 1 (c)-(f).

Both structures - nanoantenna and nanochannels – were studied and analzyed separately. The nano antenna were characterized using different optical techniques. Two Photon Photoluminescence measurements gave a signal enhancement in the order of 10^4 when compared to a non-structured gold surface. The optimal operational range was found by dark field scattering: it lyes in the range of 680 nm – 900 nm, depending on the specific antenna geometry and dimensions. On the other hand, the flow of different liquids along the nanochannels was successfully studied by fluorescence microscopy.

The dependence of the resonant peak position was studied as a way to probe the inside of the nanochannel. It shifts depending on the refractive index of the liquid flowing along the nanochannel, with a sensitivity of 100 nm/RIU for a change in the tiny 30 zL volume at the antenna gap (Figure 2, right). Simulations show a good concordace with the measurements (30 nm peak shift for water, n=1.3; 50 nm shift for toluene, n=1.5) (Figure 2, left). These simulations also predict a 5nm shift for a 10 nm particle with a refractive index n=1.5 suspended in water. This result opens the way to detect DNA as a shift in the plasmonic antenna resonance, without the need of using labels. The peak duration can be associated to the molecule's lenght.Raman spectroscopy was also studied as an approach for label free detection of (bio)molecules. The antenna give a good signal enhancement compared to the same experiment without antenna. But it was founded that improvements in the measuring system are needed to achieve single molecule detection, and also molecule denaturation was observed due to heating.

Single DNA molecules were flown into the device, manipulated and driven trough the 30 x 30 nm nanochannels by electrophoresis (Figure 1 (b)). The stretched molecules were measured: a length of 18.7 μm was obtained, as compared to the theoretical fully stretched length, that would be 21 μm. This gives a stretching factor of 0.89, that is one of the largest ones found in the literature for single molecules in nanochannels.

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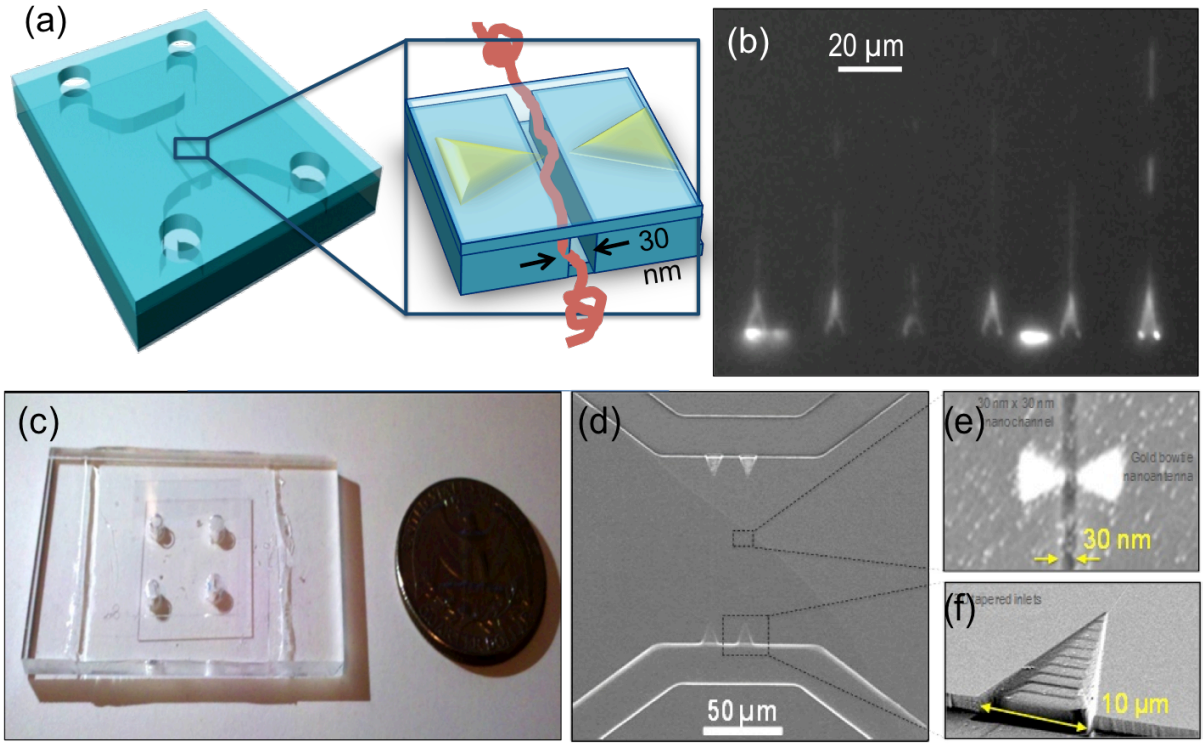

Figure 1. (a) Sketch of the device concept. (b) Fluorescence images of DNA single molecules stretched along the nanochannels. (c) Picture of one of the devices, where access inlets can be seen. (d)-(f), SEM images of the different parts of the device: microchannels, nanochannels, triangular tappered inlets and gold bowtie nanoantenna.

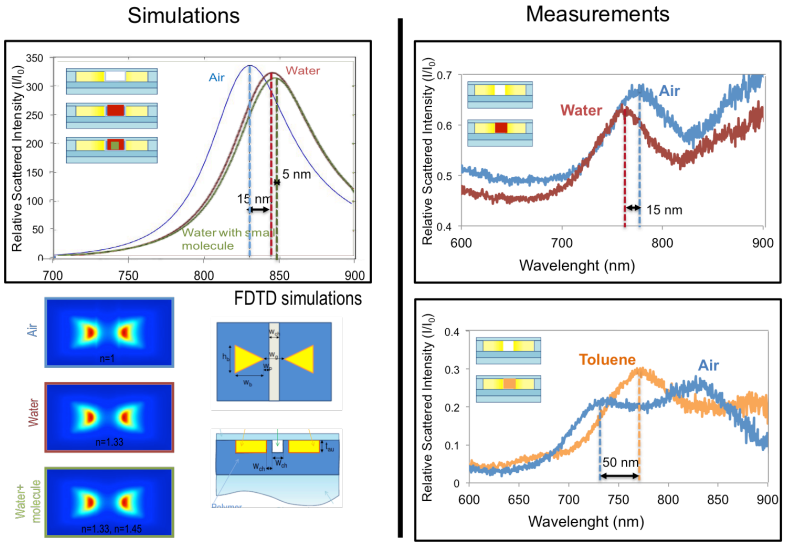

Figure 2. Use of the device for label free probing inside the nanochannel. Simulations are shown in the left, and measurements on the right. The shift of the resonance peak of the antenna can be used to quantify the refractive index inside the nanochannel. The system is sensitive to 30 zL of liquid.