30 nm nanochannels with plasmonic bowtie nanoantenna

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The combination of plasmonic resonators with nanofluidics opens up the possibility of controlled delivery of the analyte right into the plasmonic hot spot. This represents a new type of super-sensitive biosensing, with label free single-molecule real time detection capabilities.

Here we present a wafer-scale parallel method for the fabrication of complete fluidic chips, with sub-30 nm nanochannels, integrated with plasmonic bowtie nanoantenna, as well as the fluidic and optical characterization results.

The fabrication of the fluidic device is schematized in *Figure 1 (a)*. A silicon stamp, containing micro and nanochannels and 3D tapered inlets is first fabricated. Adjacent to the nanochannels, two triangular shapes are defined. Then, it is replicated in a UV-curable hybrid polymer (Ormostamp, from microresist technology) by UV nanoimprint lithography (UV-NIL) to make a negative working stamp. Finally, the all-transparent polymeric device is made by direct UV-NIL using the negative replica to imprint the same hybrid polymer. *Figure 1 (b)* shows images of a device: the microchannel distribution, the tapered inlets, and the nanochannels can be seen. Fluidic experiments using a fluorescent dye have shown the continuity of the nanochannels [1].

To define the bowtie antenna, the nano-triangles are selectively filled with gold following the procedure shown in *Figure 2*. First, a shadow evaporation of a 5 nm layer of chromium is done on the polymer device, by tilting the sample in such a way that everything but the triangular holes is metalized. Then, 20 nm of gold are evaporated on top. After the chromium lift-off in a commercial etchant, only the triangles remain metalized, defining the gold plasmonic bowtie antenna perfectly aligned and level with the channels (see *Figure 3(a)* and *(d)*).

Dark field scattering measurements show that the antenna resonate in the interval of 700-850 nm, depending on the gap size. Two-photon photoluminescence (TPPL) measurements were done using a Ti:sapphire laser (τ =120fs) at λ=830 nm, which confirm the light focusing into the gap.A quantitative analysis reveals **an intensity enhancement as high as α^2=9000**, obtained by comparing the time averaged TPPL intensity from the 35nm gap antenna to that from a similar flat gold surface on the same sample [2]. *Figure 3 (a)* and *(d)* show images of two nanoantenna with 35nm and 200nm gaps respectively. The corresponding TPPL intensity images are shown in *(b)* and *(e)*, obtained at 100 µW laser intensity, with the polarization parallel to the antenna main axes. *Figure 3(c)* shows the TPPL intensity for perpendicular polarization. *Figure 3(f)* shows the TPPL signal obtained from a flat gold surface. The laser intensity needed to be increased 25 times (up to 2.5 mW) in order to get a comparable signal. *Figure 4* shows the intensity profiles from the optical images of Figure 3.

[1] I Fernandez-Cuesta et. al. *J. Vac. Sci. Technol. B* **29**, 06F801 (2011)
[2] P. J. Schuck et. al. *Phys. Rev. Lett.* **94**, 017402 (2005)

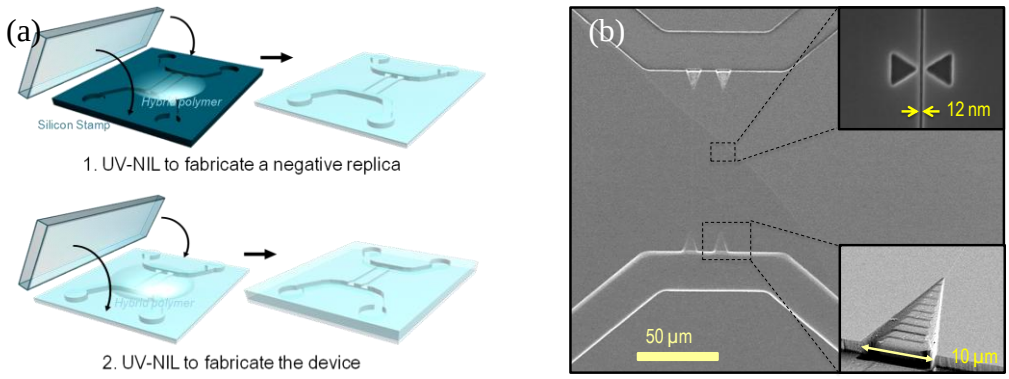

Figure 1. *(a) Device Fabrication process.* A silicon stamp is replicated to make a negative working stamp, using a hybrid polymer (Ormostamp). The device is made by direct UV-NIL using the negative stamp. *(b) Images of the device*, where the microchannels, nanochannels, tapered inlets and triangular bowtie-shaped hole can be seen.

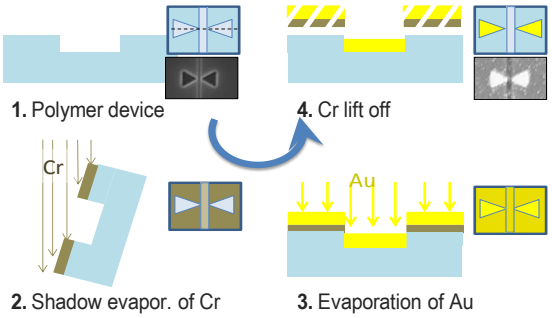

Figure 2. *Bowtie nanoantenna fabrication*. The polymer sample (1) is selectively covered with chromium by shadow evaporation (2). Then, metalized with gold (3). After a lift-off (4), the bowtie nanoantenna are defined, aligned to and level with the nanochannels. The insets of in steps (1) and (4) are SEM images of the polymer device before and after the process.

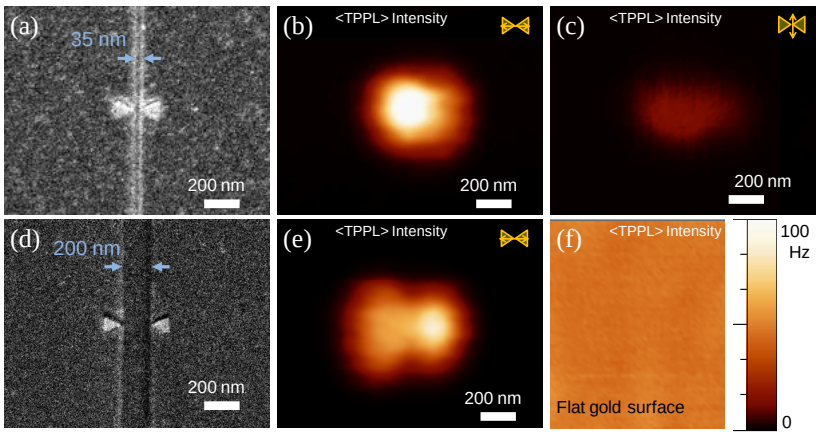

Figure 3. *Two-photon photoluminescence (TPPL) characterization*. (a) and (d) show SEM images of two plasmonic nanoantenna, with 35 nm and 200 nm gap. (b) and (e) show the TPPL intensity for 100µW laser intensity, and the polarization parallel to the main axe of the antenna. In (c), the results for perpendicular polarization for 35 nm gap antenna are shown. (f) shows the TPPL signal from a flat gold surface, excited at 2500 µW.

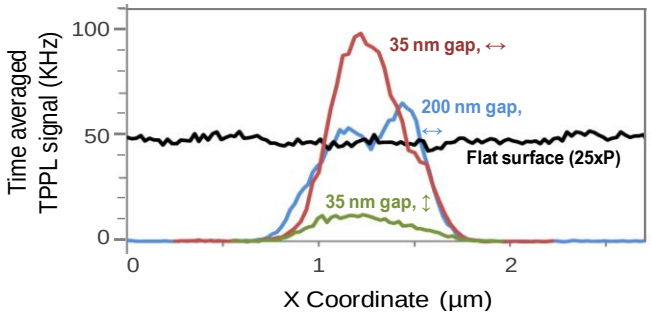

Figure 4. *Time averaged TPPL intensity summary*. Intensity profiles from the images in Figure 3: a 35 nm gap with parallel (red line) and perpendicular (green line) polarizations, a 200 nm gap with parallel polarization (blue line), and a flat surface (excited at higher power) (black line).