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## Single-Nanostructure Device fabricated by alternative technologies

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For the last ten years, alternative technologies for nanofabrication and nanostructure localisation/assembly have targeted new approaches for low-cost, high throughput fabrication of single nanostructure devices. For example, NanoImprint Lithography (NIL) <sup>[1]</sup> is now competitive with electron beam lithography for nanopatterning and many novel techniques have already been introduced for manipulation and localization of colloidal nanostructures using chemical functionalization <sup>[2]</sup>, capillary forces <sup>[3] [4]</sup>, and dielectrophoresis (DEP) <sup>[5]</sup>. In this work, we demonstrate a new strategy to collectively fabricate Single Nanostructure Device (SND) by combining thermal NIL and carefully define an AC-DiElectroPhoresis (AC-DEP) trap.

First, a tri-layer NIL lift-off process detailed elsewhere <sup>[6]</sup> was developed to fabricate metallic nanoelectrodes with connexion pads on a 100 mm wafer using one imprint step (Fig1a). For localisation experiments (Fig.1 (b)), a droplet of gold colloid was deposited over the electrode gap, and the trapping of nanoparticles by AC-DEP was followed using real-time microscopic imaging (Fig.1b). Several dynamical regime were optically identified depending on the applied electric field: Brownian motion regime, Coulomb force regime and AC-dielectrophoresis regime (Fig.2).

The AC-DEP force ( $\vec{F}_{DEP} \sim \Re(f_{CM}) \cdot \vec{\nabla} |E|^2$ ) influences the motion of uncharged polarizable particles in a dielectric medium when a nonuniform electric field is present. Here,  $\Re(f_{CM})$  represents the real part of the Clausius-Mosotti (CM) factor, which gives a measure of the dielectric contrast between particles and the surrounding medium. As such, particles can be attracted to the electrodes or repelled from them using only the frequency dependence of  $\Re(f_{CM})$ . Real-time tracking of nanoparticles was used to determine the transition frequency  $f_0$  where the DEP force shifted from attractive to repulsive behaviour (Fig.3). By working in the attractive regime near  $f_0$ , we show that it is possible to find experimental conditions to trap a single gold particle (200 nm – 50 nm) with a rate of success up to 20% (Fig4.) for the biggest particles sizes. Figure 5 presents SEM pictures of several single nanostructure devices fabricated by this technique. Current-Voltage measurements from a 50 nm gold particule device show coulomb staircase in the temperature regime up to 50 K without any molecular tunnel barrier like observed in other works [2,6].

This talk will highlight electrode fabrication using NIL, real-time imaging and statistical control of the particle trapping process at the single nanostructure level. We will also detail electronic transport on these systems.

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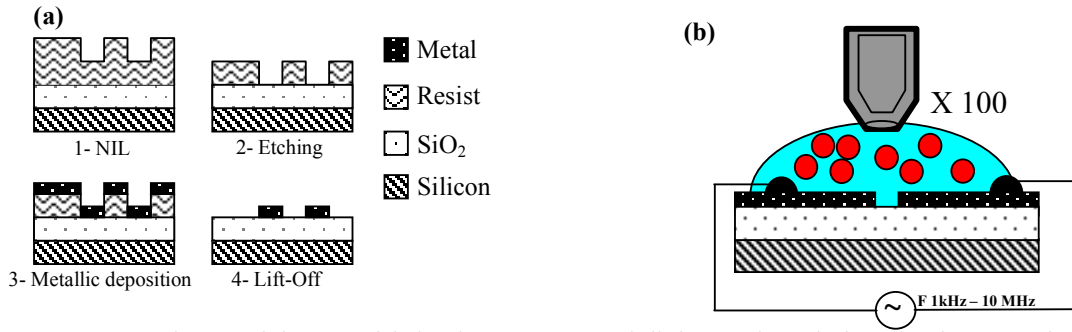
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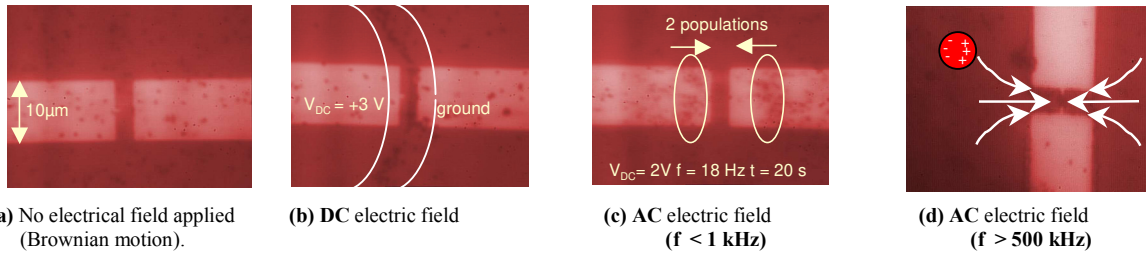
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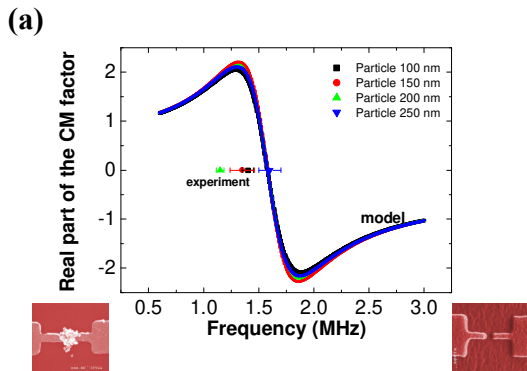
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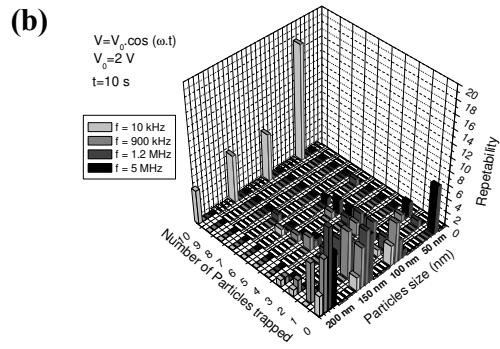
**Fig. 1 :** Scheme of the nanofabrication process and dielectrophoretic localization experiments.  
**(a)** NIL process for metallic (Ti 5nm /Au 35 nm) nanoelectrodes fabrication on SiO<sub>2</sub> (100nm)/ Si.  
**(b)** Dielectrophoresis experimental set-up for direct imaging of gold colloid trapping.



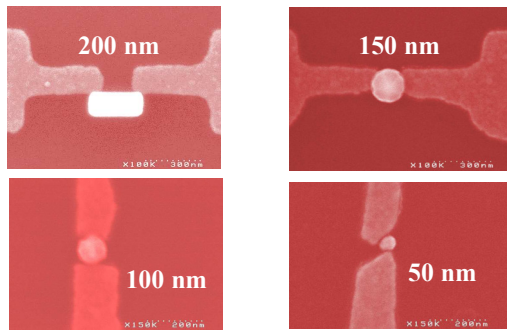
**Fig. 2 :** Real time optical observation of 200 nm gold nanoparticles repartition inside the drop.



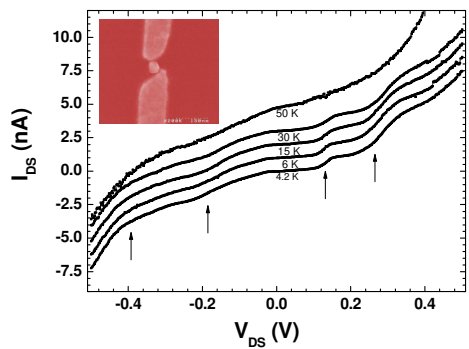
**Fig. 3 :** Experimental determination of the real part of the Clausius-Mossotti factor and comparison with a bilayer model.



**Fig. 4 :** Statistical analysis of the number of particles trapped for different AC-DEP frequencies and for several nanoparticle sizes.



**Fig. 5 :** SEM pictures of single Au nanoparticle trapping from different sizes by combining nanoimprint lithography and dielectrophoresis.



**Fig. 6 :** Current-Voltage curves measured for a junction with a single 50 nm Au nanoparticle as a function of the temperature (4K < T < 50K). [inset: SEM picture of the device]