Rotation speed control of Janus particles by dielectrophoresis in a microfluidic channel

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Anisotropic particles, known as Janus particles, have shown particular potential in photonic or electronic devices [1, 2, 3,4]. When coupled to light emitting process, this latter possibility could lead to local reconfigurable patterns that may provide new type of display devices, as long as the sweep frequency is high enough for the human eye ($f_c > 24$ Hz). Recently, 3-D dielectrophoretic handling and rotation of Au/PS Janus colloids has been demonstrated [5]. This work presents the performance of the dielectrophoretic rotation of such Janus particles.

Janus colloids are manufactured by combining fluorescent polystyrene particles single layer deposition on a substrate, metal evaporation and redispersion in solution [5]. To obtain high concentrations of Janus particles injected in the microchannel, it is necessary to increase the number of PS particles available on the substrate before metal deposition. Several methods had been used but the most efficient one seems to be spincoating or direct deposition of an evaporating droplet [6]. Such methods were evaluated and results on Figure 1 shows that evaporating a 100 µL droplet of 1 µm PS colloids in ethanol give the best efficiency. Figure 1 presents also micrographs of final Au/PS Janus particles for several Au thicknesses.

Janus particles are then injected in a 3D microfluidic chip that is capable of exerting local electrical fields whose gradients can induce dielectrophoresis in particles [7]. Figure 2.I shows pictures of such chip and trap. Sweep in frequency of the applied potential, $V=V_{p\text{-}p}\cos(2\pi f_p)$, where performed on the 3 types of Janus particles. We monitored the optimal frequencies at which the gold side hid the fluorescent, namely “flip”, and at which the fluorescent side was totally visible, namely “flop”. Figure 2.II shows that the flip-zone remained at high frequencies ($f_p > 1$MHz) for all Janus particles whereas the flop–zone lowered in frequencies ($f_p < 50$ kHz) when the thickness of Au increased.

Trapped colloids are then exposed to both chosen flip and flop frequencies and their fluorescence intensities are monitored in time. In order to evaluate the performance of the dielectrophoretic rotation, the flip-flop frequencies are commuted at the commutation frequency f_c. Figure 3 shows samples of temporal plots of the applied voltage that changed between the flip-flop frequencies, and the corresponding monitored fluorescent intensities of Janus particles. Combining the total amount of fluorescence intensities of the Janus particles, the efficient commutation frequencies f_c of the flip-flop were determined for the 3 types of Janus particles. Figure 4 shows that 100 nm Au Janus particles were able to respond to a commutation frequency as high as 20 Hz whereas 500 nm Au Janus particles could respond only to frequency up to 1 Hz.

The presentation will highlight the capability to manufacture large amount of Janus particles. We will then present the capabilities of the dielectrophoretic trap to perform the flip-flop of Janus particles. Finally, we will discuss the rotational speed performances of the flip-flop for the three types of particles.

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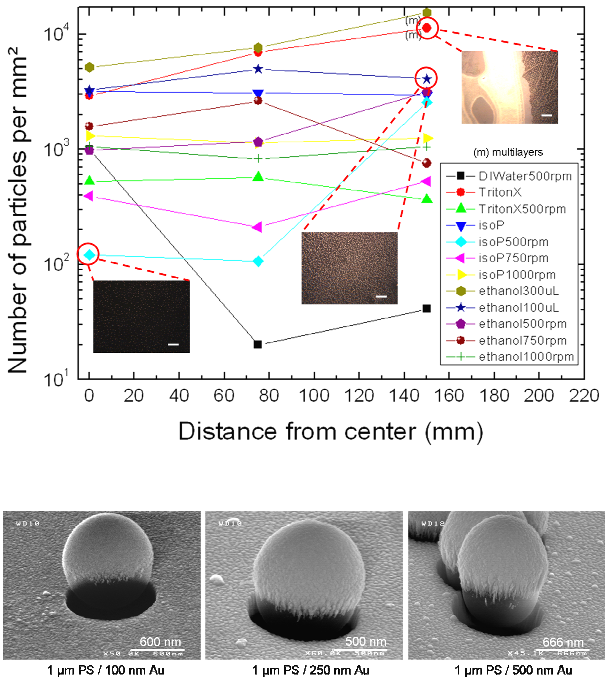

Figure 1 Polystyrene particles spatial distribution on a glass wafer by spin coating or direct deposition. Inserted are optical pictures of particles after deposition. Scale bar is 100 µm. The micrographs show Au/PS Janus colloids after Au evaporation for 100 nm, 250 nm and 500 nm Au thicknesses.

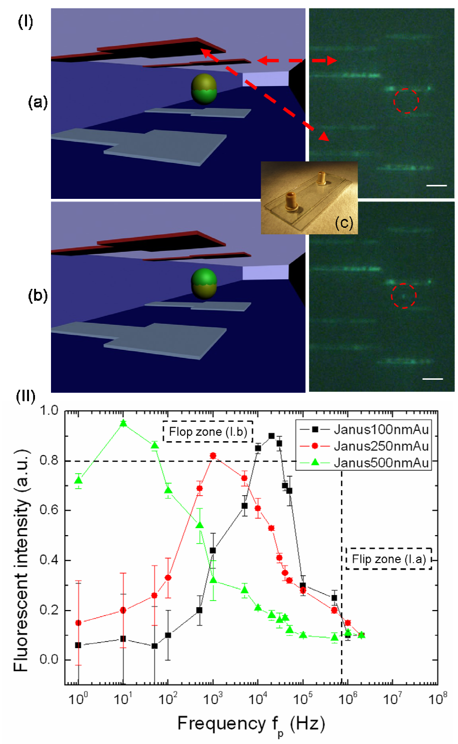

Figure 2 (I) Schematic principle pictures and fluorescent optical pictures from above of the dielectrophoretic flip-flip trap. The electrodes in red are linked to the applied potential and the electrodes in grey are grounded. The trapped Janus particle is (I.a) “flipped” and (I.b) “flopped”. Scale bar is 10 µm. (I.c) Picture of the microfluidic chip. (II) Frequency f_p sweep of the applied alternative potential and the fluorescent intensity of the 100 nm, 250 nm and 500 nm Au evaporated Janus particles.

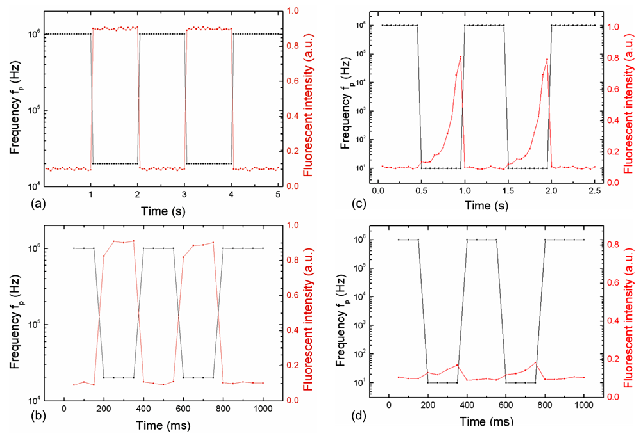

Figure 3 Temporal plots of the frequency f_p and fluorescent intensities of the trapped particles for 100 nm Janus particle with a commutation frequency f_c of (a) 1 Hz and (b) 20 Hz; 500 nm Janus particle with a commutation frequency f_c of (c) 2 Hz and (d) 20 Hz.

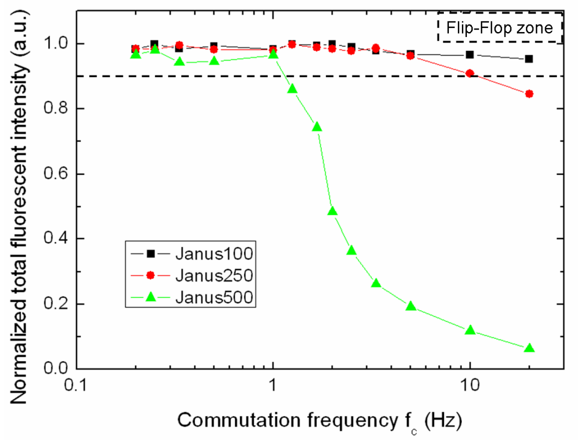

Figure 4. Plot of the normalized total fluorescent intensity of the trapped Janus particles vs. commutation frequencies between the corresponding flip and flop frequencies of the 100 nm, 250 nm and 500 nm Janus particles.