SUPPORTING INFORMATION

Enrichment of nanoparticles and bacteria using electroless and manual actuation modes of a bypass nanofluidic device

In this paper, electroless Bypass nanofluidic device is used to concentrate 50nm polystyrene nanobeads and bacteria. The concentration process relies on the use of a pressure field. The symmetrical mode consists in concentrating the nanobeads at the entrance of the 50nm deep nanochannels using size exclusion effect.

NON CLOGGING VALIDATION

The bypass device consists in two 10µm deep parallel microchannels bridged by an array of 50 nanochannel (50nm in height ($H$)). The section $S_m$ of the sample microchannel which is connected to the nanochannel has a width $W$ of 50µm and a length $L$ of 1245µm. The buffer channel remains at atmospheric pressure whereas the sample channel is pressurized at 1 bar.
**Figure S1**: Top view of the bypass device used for Micro PIV and clogging effect measurements. 50 parallel nanochannels are connected to the 50µm wide microchannels. The sample channel is connected to a pressure generator and is pressurized at a pressure of 1bar during the concentration process. The buffer channel remains at atmospheric pressure. Each nanochannel drives a portion of the liquid at a flowrate of \( q_n \). \( Q_t \) is the total flowrate through the 50 nanochannels.

To validate that no significant clogging of the nanochannels occurs we conducted additional experiments which consisted in measuring the total flowrate \( Q_{t_{exp}} \) through the nanochannel at different time (\( t = 0\) min, 30min and 60min) during the concentration process of the 50nm beads. Indeed, if significant clogging would occur, we should observe a significant drop of the flowrate with time. The flowrate was measured by multiplying the slope \( a \ (s^{-1}) \) of the curve
(see figure 2d in the paper), obtained by micro PIV measurements, with the section

\[ S_m = W \times L \]

Then \( Q_t \exp = a \times S_m \times L \)

The experiments show a relatively constant flow rate around 0.1nl/min at each measurement’s time which means that no significant clogging of the nanochannels occurs during the steric concentration of the nanobeads (see figure S2). In addition, to confirm that no clogging occurs at \( t = 0 \) we conducted the same experiment using a control sample only containing 1\( \mu \)m polystyrene beads at a relatively low concentration to avoid any risk on clogging. The results show that similar flow rates (~0.1nl/min) are obtained using the control sample.

Because we neglect the slippage at the nanochannel walls and as the nanochannel height \( h = 50\)nm is much smaller than the width \( w = 20\)\( \mu \)m of the nanochannel then we can consider that the total flow rate \( Q_t \) through the nanochannels follows the Poiseuille law.

\[
Q_t = N \times q_n = V_n \times S_n = \frac{h^2}{12\mu} \times \frac{dp}{dy} \times S_n \quad \text{EqS1}
\]

with \( q_n \) the flow rate through each nanochannel, \( V_n \) the velocity of the fluid inside each nanochannel, \( S_n \) the section of the nanochannel, \( h \) the nanochannel height, \( \mu \) the viscosity and \( \frac{dp}{dy} \) the pressure drop through the nanosieve.

If we considered a pressure drop of 1bar and the water viscosity \( \mu = 10^{-3} \) Pa.s we found a theoretical value of 0.3nl/min. Deviation from the experiments (0.1nl/min) can be due to the uncertainty on the measurement of the nanochannel depth.
Figure S2: Evolution of the total flowrate during 1h when the sample channel is pressurized at 1bar. The flow rates were measured using Micro PIV. The blue curve represents the experiments done with the 50nm beads with an initial concentration of $10^{12}$ pl/ml. The pink curve represents the experiments done with the control sample containing only 1µm beads. In both cases the flow rate remains relatively constant ~0.1nl/min after 1h of experiments.

CONCENTRATION FOLD: THEORETICAL AND EXPERIMENTAL APPROACH

Here we propose a simple theoretical model for the estimation of the concentration fold $F$ of nanoparticles having a diameter $D \geq h$ which means that we assume that none of the particle is able to go through the nanosieve. To simplify the problem, we also consider that the concentration increases homogenously within a volume $V_0$ (which correspond to the section of the microchannel connected to the nanochannels times the height H of the microchannel, see figure S3) which is not observed in the experiments (accumulation effect in a small region in the center of the microchannel, see figure 2b in the paper). Using equation 6, and
considering a total flowrate $Q_t = 0.1\text{nl/min}$ and $t = 1\text{h}$ we found $F \sim 3$ which is much smaller than the 130 concentration fold found during the experiment in figure 2c in the paper. Indeed, in the experiments we have used a ROI (Region Of Interest) located in the maximum intensity which is located in a smaller area ($11\mu\text{m} \times 11\mu\text{m}$) in the center of the microchannel. Then the volume considered was much smaller than $V_0$.

$$C_0 = \frac{N_0}{V_0} \quad \text{EqS2.}$$

with $C_0$ the initial concentration of the nanobeads, $N_0$ the initial number of nanobeads contained in $V_0$ at $t = 0$.

$$C_1 = \frac{N_1}{V_0} = F \times C_0 \quad \text{EqS3.}$$

with $C_1$ the concentration at $t = t_1$, $N_1$ the total number of nanobeads at $t = t_1$, $F$ the concentration fold.

$$N_1 = N_0 + N(t) \quad \text{Eq S4.}$$

with $N(t)$ the number of nanobeads drove in the volume $V_0$ during a time $t = t_1$ by the total flowrate $Q_t$.

Then we define $N(t) = Q_t \times t \times V_0 \quad \text{Eq S5.}$

Finally,

$$C_1 = \frac{C_0 \times V_0 + Q_t \times t \times V_0}{V_0} = C_0 \left(1 + \left(\frac{Q_t \times t}{V_0}\right)\right) \quad \text{with} \quad F = \left(1 + \left(\frac{Q_t \times t}{V_0}\right)\right) \quad \text{Eq S6,7.}$$

Thus, to be able to compare the experiment with the theory we must consider the same ROI. Figure S3 shows the evolution of the concentration folds with time when the intensity is integrated on the volume $V_0$. As expected, the values of the concentration fold are considerably reduced as we integrate the fluorescence intensity in a larger volume. The
concentration fold increases linearly up to 6 fold after 1h of experiment which is in good agreement with the theory.

**Figure S3**: Evolution of the concentration fold in relation to time. 50nm polystyrene beads at an initial concentration of $10^{12}$ pl/ml are used. The fluorescence intensity is integrated in the volume $V_0$ which correspond to the portion of the microchannel which is connected to the 50 nanochannels.
Figure S4: Asymmetrical mode on 100nm cationic lipidic nanoparticles (lipidots®). (a) Schematic diagram of the device operated in the asymmetrical mode. Reservoir 1 is pressurized at 130mbar or 700mbar while reservoirs 2, 3 and 4 remain at atmospheric pressure. (b) Fluorescence imaging captured after 5 min of concentration operation using an epifluorescent microscope, highlighting positively charged nanoparticle enrichment and repealing. The positively charged nanoparticles exhibit opposite behaviour as compared to the negatively charged nanobeads as they are concentrated on the left hand side and repeated on the right hand side of the device. The enrichment effect is weaker as compared to the negatively charged particles because the positively charge particles have a lower mobility

\[ \sim 4.5 \times 10^{-8} \text{ m}^2 \cdot \text{s}^{-1} \cdot \text{V}^{-1} \]