ACCELERATION OF ABSOLUTE NEGATIVE MOBILITY FOR PARTICLE SORTING IN A MICROFLUIDIC DEVICE

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ABSTRACT
Recent designs in microfluidic devices extend common separation concepts by exploiting new non linear phenomena for molecular dynamics on a length scale of 10 microns and below, giving rise to novel manipulation tools and non-intuitive phenomena for microseparations. A rather paradoxical and new migration phenomenon termed absolute negative mobility (ANM) using thermal fluctuations in a non-equilibrium environment generates average motion of particles in the direction opposite to an applied static force [1]. Here, we propose how ANM can be accelerated in order to improve maximum velocities for future applications such as purification or sorting of colloidal particles, cells and cell compounds.

Keywords: absolute negative mobility, particle sorting, thermal noise, non linear dynamics

1. Introduction

ANM for colloidal particles in solution can be evoked in an array of periodically arranged rows of posts separated by alternating small and large gaps (see fig. 1). Polystyrene microbeads at low concentration in aqueous buffer solution are driven through this geometry by application of electric fields along the *y*-axis. Particle diameters and gap widths are chosen such that the beads can pass through the large gaps but not through the small ones. Thus, the small gaps together with the electric field act as traps. Conditions far from thermal equilibrium are realized by an unbiased AC-voltage U_{AC} switching periodically between $\pm U_0$. Upon application of a small static offset voltage U_{DC} and adequate driving parameters for U_{AC} ANM can be observed [1].
Numerical simulations of ANM adopted to experimental conditions are in very good agreement with our experimental observations [1]. Such calculations further reveal that this migration effect can be suitably tailored to drive colloidal particles of different size into opposite directions [2], thus providing a new tool for particle sorting in microfluidic device format. However, the maximum velocities achieved for ANM of µm-sized spheres are small, i.e. in the order of nm per second. Here, we focus on the adaptation of the post array geometry in order to reduce lateral diffusion times of colloidal particles in the microdevice and thus accelerate ANM of colloidal particles.

2. Methods

The motion of a single bead in the periodic microstructure is modelled by a stochastic Langevin dynamics as previously reported [1; 3]. The simulation is performed for colloidal particles with a diameter of 1.9 µm, a diffusion coefficient D of 0.13 µm^2/s and a velocity v of 0.28 µm/s at an applied voltage of 1V over the whole device. A periodical driving, U_{AC} with an amplitude of U_0 = 120 V and a frequency of 0.03 Hz is used for the square geometry (fig.1a) and, correspondingly, U_{AC} with an amplitude of U_0 = 90 V and a frequency of 0.05 Hz for the layout in fig.1b. The monolithic poly(dimethylsiloxane) (PDMS) device is made by soft lithography, as previously reported [1]. Improved UV-lithography of SU-8 photoresist via a pre-designed photomask is achieved by a home built pneumatic mask contact device.

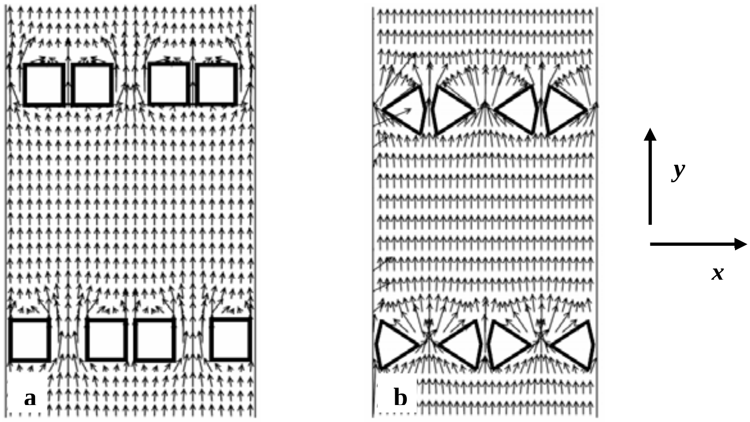

Fig. 1: Section of microstructured post array designs for ANM in a microchannel with simulated force field (arrows): a) Square posts and b) sharpened posts.

3. Results and Discussion

The probability for the particles to avoid a trap in the post array critically depends on the diffusion and the electrokinetic driving of the particles. Allowing a more efficient avoidance of the traps in lateral (*x*-) direction, one would expect faster ANM velocities. We have thus designed two new geometries in which the lateral dimension of the posts is decreased compared to our previous device [1]. In the first approach, square posts with a base of 4µm are envisaged (fig. 1a). In the second approach (fig. 1b) the posts are designed trapezoidally.

Numerical simulations within these two designs were performed for colloidal particles with a diameter of 1.9 µm. Fig. 2a and 2b reveal that maximum velocities of ANM are enhanced up to a factor of 20 for case *a* and up to 30 for case *b*, respectively, compared to our previous study [1].

Based on these results we designed layouts adapted to fig. 1a and b on a master wafer photolithographically structured with SU-8 photoresist. Casting of PDMS resulted in corresponding PDMS microstructures as exemplarily demonstrated for the square design in figure 3. The electron microscopy image shows posts of 3.3 x 3.3 μm^2 base and a height of 9 µm in channels of equal height. The aspect ratio thus results in a value of three and the smallest post distance (serving as particle trap) resulted in 1.8 µm. We could thus demonstrate the fabrication of improved geometries in order to accelerate ANM of colloidal particles with simple UV-lithography combined with PDMS casting.

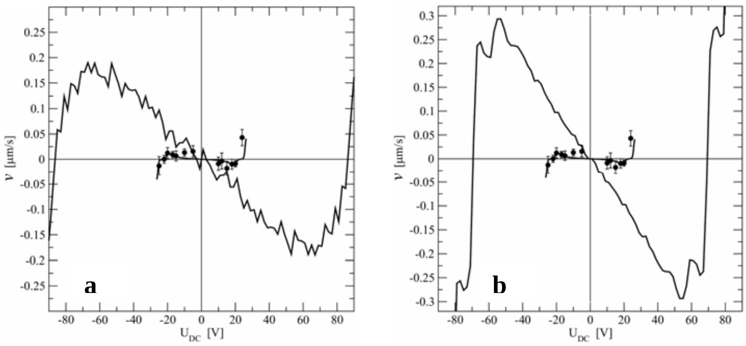

Fig. 2: Numerical simulation of particle velocity for 1.9 µm sized particles versus applied static offset force U_{DC}. a) Simulation for the design demonstrated in fig. 1a. For comparison, recently published [1] experimental data with numerical simulations are shown around the origin in both a) and b) (dots with line around the origin). b) Simulation for the design demonstrated in fig. 1b

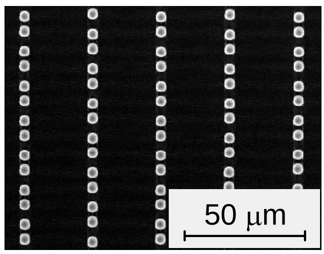

Fig.3: Scanning electron micrograph of PDMS structures obtained for the square design according to fig.1a.

4. Conclusion

Numerical simulations reveal that the non-intuitive migration phenomenon ANM can be accelerated by an optimized geometry. We demonstrate the fabrication of optimized post arrays in microfluidic channels by soft lithography with sufficiently high aspect ratio and sufficiently small post distance in order to trap colloidal particles >1.8 µm diameter. The acceleration of ANM in both new designs for colloidal particles with pre-defined mobility and diffusion coefficients in aqueous solution is currently under experimental investigation.

5. References

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