Supplementary Information for

Low-Electric-Potential-Assisted Diffusiophoresis for Continuous Separation of Nanoparticles on a Chip

Kyunghun Lee^{1†}, Jongwan Lee^{1†}, Dogyeong Ha¹, Minseok Kim^{2*} and Taesung Kim^{1*}

¹Department of Mechanical Engineering, Ulsan National Institute of Science and Technology (UNIST),

50 UNIST-gil, Ulsan 44919, Republic of Korea

²Department of Mechanical System Engineering, Kumoh National Institute of Technology, 61 Daehak-

ro, Gumi-si, Gyeongsangbuk-do 39177, Republic of Korea

[†]These authors contributed equally to this work.

***CORRESPONDING AUTHOR:**

Minseok Kim Department of Mechanical System Engineering Kumoh National Institute of Technology 61 Daehak-ro, Gumi-si, Gyeongsangbuk-do, Republic of Korea E-mail: mkim@kumoh.ac.kr Tel: +82-54-478-7345 Fax: +82-54-478-7319

Taesung Kim Department of Mechanical Engineering Ulsan National Institute of Science and Technology (UNIST) 50 UNIST-gil, Ulsan 44919, Republic of Korea E-mail: tskim@unist.ac.kr Tel: +82-52-217-2313 Fax: +82-52-217-2409

Supplementary Table

	1,3	2	4,6	5	7,8
Navier-	Velocity inlet	Velocity inlet	Pressure outlet	Pressure outlet	Wall
Stokes	$\mathbf{u} = 5 \text{ mm/s}$	$\mathbf{u} = 1 \text{ mm/s}$	p = air pressure	p = air pressure	$\mathbf{u} = 0$
Nernst- Planck	Concentration $C_{1, NaCl} = 100 \text{ mM}$ $C_{3, K-acetate} = 100 \text{ mM}$	Concentration $C2_{, NaCl} = 0.1 \text{ mM}$	$\begin{array}{c} \text{Outflow} \\ -n \cdot D_i \nabla c_i = 0 \end{array}$	$\begin{array}{c} \text{Outflow} \\ -n \cdot D_i \nabla c_i = 0 \end{array}$	No flux
Electric current	Potential $V_1 = \text{ground}$ $V_3 = \text{applied potential}$	Insulation $n \cdot J = 0$	Potential $V_4 = \text{ground}$ $V_6 = \text{applied potential}$	Insulation $n \cdot J = 0$	Insulation $n \cdot J = 0$

Table S1. Computational boundary conditions.

We conducted numerical simulations to theoretically describe the migration behavior of nanoparticles in the presence of LEPDP effects. Figure S3 below shows a two-dimensional computational domain of our numerical simulation. A central part of the device was used as a numerical domain to reduce computational time and cost. Briefly, Navier-Stokes, Nernst-Planck, and Poisson equation were simultaneously solved by using the same boundary condition as experiments. The equations are described as follow;

$$\rho\left(\boldsymbol{u}\cdot\nabla\boldsymbol{u}\right) - \nabla\cdot\left[-p\mathbf{I} + \mu\left(\nabla\boldsymbol{u} + \left(\nabla\boldsymbol{u}\right)^{T}\right)\right] = 0$$
⁽¹⁾

$$\nabla \cdot \left(-D_i \nabla c_i - \frac{D_i}{RT} z_i F c_i \nabla V \right) + \boldsymbol{u} \cdot \nabla c_i = 0$$
⁽²⁾

$$\nabla \cdot \sigma E = 0 \tag{3}$$

Here, ρ and μ are the viscosity and density of water, D_i , c_i and z_i are the diffusivity, concentration, and ionic valency of species *i*, *F* is the Faraday constant, *R* is the ideal gas constant, *T* is temperature, *V* is electric potential applied, and σ is the net electric conductivity of solution, respectively. The width of the main and neighboring two side channels is 500 µm. The SAPMs is 100 µm wide and 685 µm long. The gap between SAPMs is 15 µm. Three channels are connected by a bundle of SAPMs. Boundary conditions are described in Table S1 above. And we considered an electric resistance of the SAPM in the numerical simulation. In detail, SAPMs were assumed to be a porous membrane of which the resulting pore size was theoretically calculated to be 15 % of the particle size for an FCC structure¹. Electric conductivity was also estimated from the electrolyte concentration inside the SAPM, which has been reported in our previous study². Note that a significant electric potential drop takes place across the SAPM structure, and both the boundary conditions for the porous membrane and the estimated electric conductivity act as electric resistances in the numerical simulation.

Supplementary Figures



Figure S1. Comparison of DP and EP mobility according to particle zeta potential in NaCl solution ($\beta < 0$).



Figure S2. A current monitoring method was used to determine the effect of electroosmosis, which was neglected in all the experiment.



Figure S3. A computational domain used for numerical simulations is the central part of the device. The numbers correspond to the boundary conditions used, which are listed in Table S1.



Figure S4. Trajectories of 200-nm (blue) and 50-nm (pink) nanoparticles along the main channel in the presence of LEPDP effect, respectively. DP was generated and electric potentials were applied to the nanoparticles. (a) 0 V. (b) 0.25 V. (c) 0.5 V. (d) 0.75 V.



Figure S5. Trajectories of nanoparticles by EP effect about 6 electric potential cases (i.e., black = 0.75 V, red = 1.0 V, blue = 5.0 V, purple = 10.0 V, dark yellow = 25.0 V, and olive = 50.0 V). PS nanoparticles with diameter of 500-nm and 200-nm were tracked along the channel. 100 μ M NaCl solutions were introduced at sample and sheath inlet to avoid DP effect. Nanoparticles mainly moved toward the anodic channel side at the inlet region, after that flowed along the stream. The amount of nanoparticle movement becomes bigger by high applied electric potential. In the electric potential region, which was effective of LEPDP effect, little movement of nanoparticles was observed due to small electric potential gradient in the main channel. Because electric potential was mainly consumed inside SAPMs. For this reason, the movement of nanoparticles began to be observed over 10.0. For example, in case of applied potential is 10.0 V and 50.0 V, the nanoparticle cases, it has similar tendency but different amount of movement with 500-nm particle about applied electric potential. However, separation performance is lower than LEPDP cases. When applied potential is even 50.0 V, the distance between two nanoparticles is about 5.4 μ m at x = 14.6 mm. This separation performance is lower than LEPDP effect despite high electric potential.



Figure S6. Trajectories of nanoparticles in the presence of LEPDP effect. PS nanoparticles with diameter of 500-nm and 200-nm, respectively, were tracked along the channel while DP in conjunction with external electric potential of 1 V was generated and applied to the nanoparticles.

REFERENCES

- E. Choi, C. Wang, G. T. Chang and J. Park, *Nano Lett*, 2016, **16**, 2189-2197. M. Jia and T. Kim, *Anal Chem*, 2014, **86**, 7360-7367. 1.
- 2.