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PARTICLES SEPARATION AND ALIGNMENT TECHNIQUE IN MICROCHANNEL FLOW USING DIELECTROPHORETIC FORCE

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1. INTRODUCTION

Controlling the position of the particles, the interval (space) between the particles, and the timing when they pass the specific location in the microchannel is an important technique to perform the sensing, sorting, and encapsulation accurately in microfluidic devices [1-3]. We developed a technique which can control the interval (space), velocity and timing of the particles in microchannel flow by exerting dielectrophoretic force on the particles periodically over time and space using the boxcar-type electrode. Regions of dielectrophoretic force accelerating and decelerating the particles were formed periodically in the streamwise direction. The force was activated periodically over time by turning the applied voltage on and off. We showed that the combination of these two schemes could align the particles and Jurket cells with equal space and intervals [4, 5]. In this paper, we will demonstrate the performance of the proposed technique using boxcar-electrodes: especially, separation of the two particles located within one periodic region of the boxcar-electrode will be discussed. Numerical simulations and measurements for 12μm polystyrene particles flowing in the boxcar electrode region are conducted to visualize the particle separation effect of two particles located in the same periodic region of the boxcar electrode, analyze the particle motion during separation, and evaluate the particle alignment performance [6].

2. METHODS

Figure 1 show the schematic and dimensions of the microchannel and electrodes. The rail-electrodes and boxcar-electrodes were patterned on the bottom wall, and the ground electrode covered the top wall of the main channel. The particles supplied from the center inlet of the sheath-type flow focus on the centerline in the rail-electrode region by the dielectrophoretic force F_{DEP}, and flow in to the boxcar-electrodes.

The flow rate was 3.9 μL/min, giving an average flow velocity of 6.4 mm/s. The Reynolds number based on the channel hydraulic diameter and particle size of 12 μm in this case, were 0.37 and 0.055, respectively.

We applied an alternating current to the boxcar-electrode using a function generator with a peak-to-peak voltage of $V_{p\text{-}p}$ = 16.8 V and frequency of f_V = 10 MHz. This voltage was turned on and off periodically with a frequency of $f_{on\text{-}off}$ = 125 Hz. The duty rate of the applied voltage was fixed at 50%.

Polystyrene microparticles with diameters of 12 μm (Thermoscientific Co., 4212A) were used in the measurements. The particles were mixed in Milli-Q water at a concentration of 0.2 %. Sodium lauryl sulfate

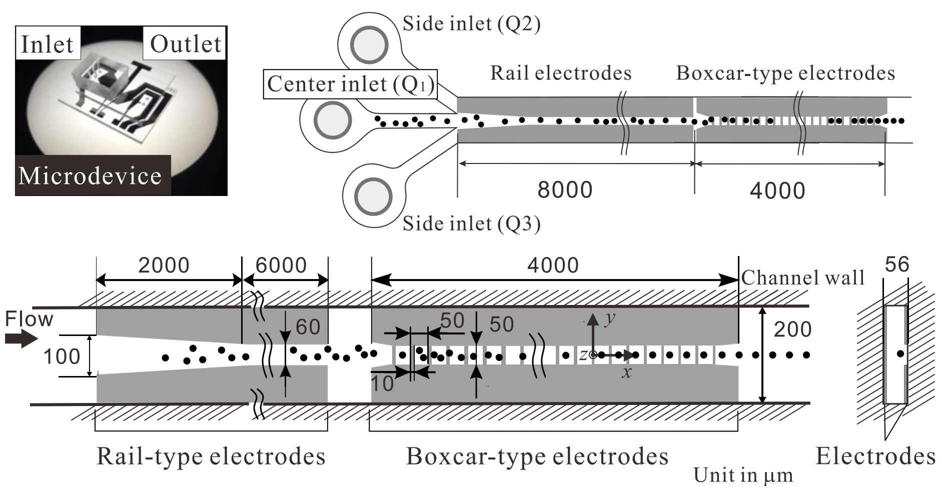

Fig. 1 Photograph and schematic of the microchannel and boxcar-type electrodes.

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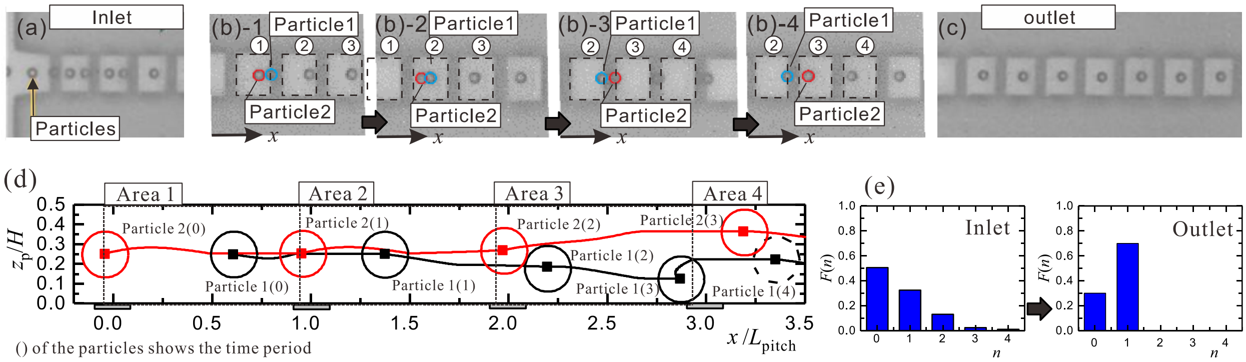

Fig. 2: (a) Photograph of particles at inelet of the boxcar-electrode region. (b) Snapshots of the two particles located in the same periodic area separating and align in the downstream region. Numbers shown over the boxes show the same spatial box. (c) Particles at outlet (aligned). (d) Motion trajectory of the two particles initially located in the same periodic region (computation). (e) Probability density function of the number of particles located in the same periodic region (period).

was added to the solution at a concentration of 0.1 wt% to prevent the adhesion of particles to the wall.

In the computation, the equation of motion of the particles was solved considering the effects of the F_{DEP} and the hydrodynamic forces exerted on the particles [4, 5]. The multipole method using a third-order Clausius–Mossotti (CM) function was applied to calculate the F_{DEP} distribution from the electric field gradients. The hydrodynamic forces were based on the Stokes force for spheres, to which the models considering the effects of the velocity gradient and the wall were applied.

3. RESULTS AND DISCUSSION

Figures 2 (a)-(c) show the photographs of the particles entering the boxcar-electrode region, the motion of two particles located in a periodic region of the boxcar-electrode, and particles at the outlet. The particles randomly are aligned by the boxcar-electrodes and flows over the outlet region with even space. In Fig. 2 (b), the two particles approach, contact, and separate having the particle initially located in downstream side move to the upstream periodic region. The computation gave the same results as shown in Fig. 2 (d): the upstream particle is accelerated while the downstream particle reduces its speed due to the F_{DEP}, and the upstream particle pass over the other particle. The downstream particle is strongly decelerated and remains in the same spatial periodic region which makes it changing its period to the next cycle. The particle will follow the same pattern until it reaches a vacant one. Thus, each particle is located in different periodic region, and all particles align with even space equal to the streamwise pitch of the boxcar-electrode. The accuracy of the alignment can be confirmed by the probability density function shown in Fig. 2 (e).

4. CONCLUSIONS

The particles with random space entering the boxcar-electrode region could be aligned in the downstream at even space. The boxcar-electrode could separate two particles located in the same periodic region, and disperse them over the boxcar-electrode leading to the accurate alignment of 100% yield.

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REFERENCES

[1] Abate, A. R., Chen, C-H., Agresti, J. J., Weitz, D. A., “Beating Poisson encapsulation statistics using close-packed ordering”, *Lab Chip*., 9, pp. 2628-2631, (2009).

[2] Edd, J. F., Di Carlo, D., Humphry, K. J., Köster, S., Irimia, D., Weitzb, D. A., Toner, M., “Controlled encapsulation of single-cells into monodisperse picolitre drops”, *Lab Chip*., 8, pp. 1262-1264, (2008).

[3] Chen, T., Wu, T.-H., Kung, Y.-C., Teitell, M. A., Chiou, P.-Y., “3D pulsed laser-triggered high-speed microfluidic fluorescence-activated cell sorter”, *Analyst*, 24, pp. 7308-7315, (2013).

[4] Tatsumi, K., Kawano, K., Shintani, H., Nakabe, K., “Particle timing control and alignment in microchannel flow by applying periodic force control using dielectrophoretic force”, *Analytical Chemistry*, 91, pp. 6462-6470, (2019).

[5] Tatsumi, K., Noma, A., Honma, R., Kuriyama, R., Nakabe, K., “Timing and Spacing Control in Microchannel Flow by Applying Periodic Force over Space and Time”, *Microfluidics and Nanofluidics*, 25, p. 15, (2021).

[6] Honma, R., Tatsumi, R., Kuriyama, R., Nakabe, K., “Particle separation and alignment technique in microchannel flow by dielectrophoretic force using boxcar-type electrode”, Trans. JSME, 86 (890), 20-00117, (2020).