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Continuous Manipulation of Micro Particles by Use of Asymmetric Electrodes Array

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1. Introduction

Year after year, number of patients with chronic kidney disease (CKD) has been increased [1]. Artificial kidney dialysis with semipermeable membrane has been used for treatment of CKD. This method needs large dialysis device and large amounts of dialysate solution, and needs several hours for treatment. The treatment with the artificial kidney dialysis forces patient to bear the physical and costly burdens. To lighten these burdens, small and wearable artificial kidney is needed. The artificial kidney should have functions such as, ionic adjustment in the body, extraction of water and waste products. It is necessary for wearable artificial kidney to have the function that separate ion and cell dynamically. In a microchannel device, many functional parts to control fluid could be integrated in one-chip. And particles in a fluid also could be controlled by electrophoresis and dielectrophoresis (DEP), etc. In DEP, nonuniform electric field is used, and for a formation of this field shape of electrodes has been discussed [2]. For a continuous manipulation of cells, Christmas tree electrode array was discussed [3-4]. In these studies two opposited-notched electrodes were used and energized, however the motion of cells was governed by Brownian motion of particle. For absolute manipulation of cells by DEP, appropriate shape of electrodes should be suggested.

In this work, for separation of blood cells, asymmetric electrode array was suggested, and micro particles were locally manipulated by DEP in microchannel chip.

2. Experiments

For a formation of electrodes, titanium (Ti) and platinum (Pt) layer were deposited on the quartz glass substrate by RF sputtering, at the thickness of 50 nm and 200 nm, respectively. Then, Pt/Ti layers on the substrate were patterned for electrode by photolithography and Pt/Ti layers were etched by fast atom beam etching with SF_6 gas. A PDMS microchannel was formed by SU-8 molding. The microchannel has the width of 500 μm and the depth of 50 μm. The microchannel and quartz glass substrate with electrodes were bonded after O_2 plasma treatment for 10 sec. Figure 1 is cross-sectional schematic of microchannel chip. Figure 2 is a photograph of fabricated microchannel chip. The asymmetric electrodes that had several acute angles at the tip were designed. In Figure 3, the schematic of electrodes was shown, and in this electrode the angle θ was designed at 30°, 45° and 60°. The vertical gap L and the distance between the tips of the electrodes are fixed at 25 μm and 10 μm, respectively. Figure 4 shows the electric field distribution calculated by the finite element method in the configuration of asymmetric electrodes. Micro particles are driven to the maximum electric fields by positive DEP. Micro particles were manipulated by controlling the pair of electrodes that generated electric field gradient at the gap of electrodes. In experiments, a pair of electrodes was driven by a sinusoidal differential signal with the voltage of 8.0 V peak-to-peak at 100 kHz. The electrodes pair was energized at intervals of 5 seconds. Figure 5 shows a schematic of measurement system. Polystyrene beads with a diameter of 3μm were introduced into the microchannel by the electro-osmotic pump. The motion of micro beads in the microchannel was observed by the fluorescence microscope with CCD camera.

3. Results and Discussions

Figures 6 shows the results of manipulation of micro beads at the tip angle of 30°. By applying sinusoidal signal on the electrode pair, micro beads were gathered at the gap. In Figures 6 (a), (b), (c) and (d), micro beads moved downward by changing the energized electrodes. Figure 6 (a) shows a photograph at 5 seconds after the application of sinusoidal signal. And Figures 6 (b), (c) and (d) were also photographs at 5 seconds after changing the energized electrodes. Also the transportation probability from one electrode pair to next pair was investigated. This probability was averaged with six times observation at the three angles, respectively. Table 1 shows the results of average transportation probabilities at the tip angles. In the three angles, the maximum probability was 74.8% at the tip angle of 60°. Figures 7 shows the comparison of experimental results and the simulation results of electric fields at the three tip angles. At the tip angle of 60°, micro beads were gathered widely by reflecting the gradual electric field distribution. On the other hand, at the tip angle of 30°, the electric field distribution was abrupt, and micro beads were moved at the top of the electrodes. These results show that trapping range of micro beads is wide as the tip of angle is large, and the tip angle of 60° was suitable for manipulation of micro particle by the DEP electrode array.

4. Conclusion

We demonstrated manipulation of micro particle by the DEP asymmetric electrodes array in a microchannel chip. A pair of electrodes was driven by sinusoidal signal with the voltage of 8.0 Vp-p at 100 kHz. The voltage signal was applied to electrode pairs in turn, and the micro particles moved along the energized electrodes pair. We have obtained average transportation probability as a function of the each tip angle of electrode. At the tip angle of 60°, average probability exhibited maximum value of 74.8%.

5. Acknowledgment

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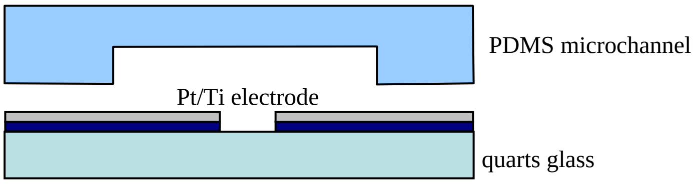

Fig.1 Schematic of microchannel chip.

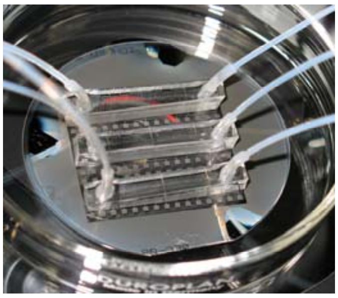

Fig.2 Photograph of a fabricated microchannel chip.

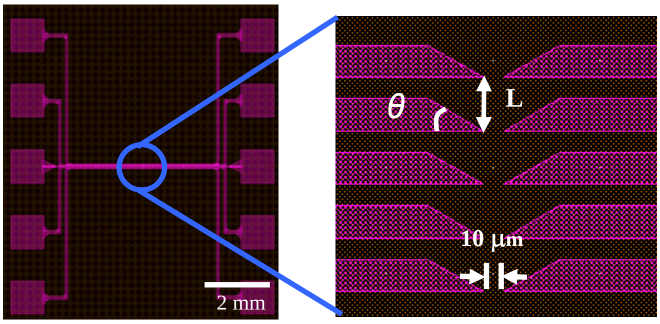

Fig.3 Schematic of electrode pattern.

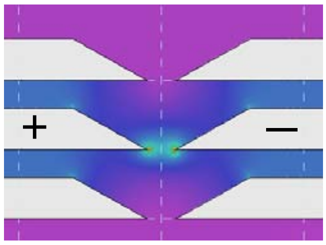

Fig.4 Simulation of the electric fields.

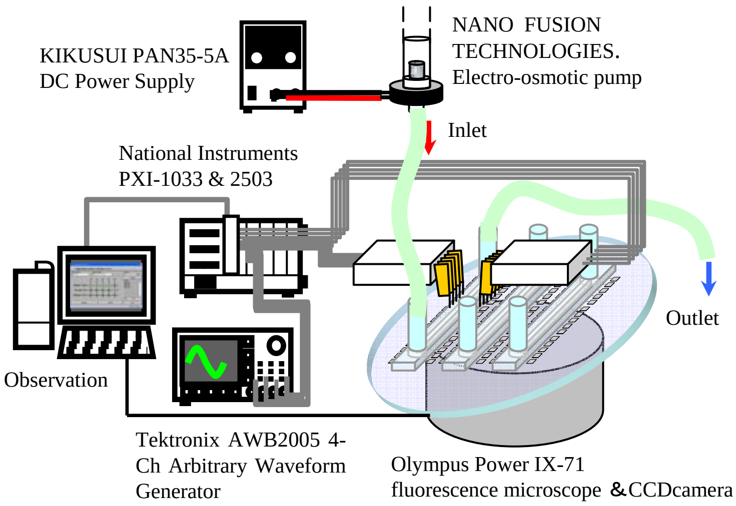

Fig.5 System of measurement.

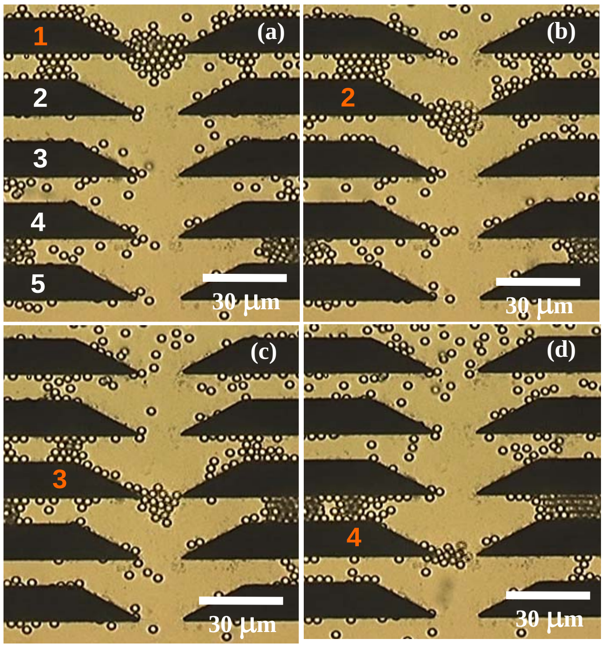

Fig.6 Continuous motion of micro beads by energized electrodes. The number is energized electrodes.

Table 1 Average probability of movement.

	30°	45°	60°
Average probability of movement [%]	50.8	67.8	74.8

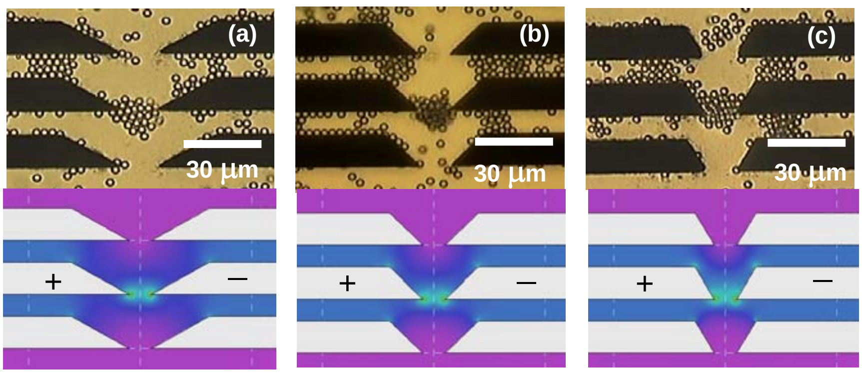

Fig.7 Difference of gathering micro beads and simulation of electric fields about three angles at the tip of electrode. Angle (a) 30° (b)45° (c) 60°