DEVELOPMENT OF A STREAMING DIELECTROPHORESIS NUMBER TO DESCRIBE A SYSTEM FOR CONTINUOUS PARTICLE SEPARATION

Rucha Natu, Monsur Islam, and Rodrigo Martine-Duarte

Multiscale Manufacturing Laboratory, Mechanical Engineering Department, Clemson University, USA

ABSTRACT

Here we present results towards the development of a Streaming Dielectrophoresis (DEP) number to describe a system for continuous particle separation. We characterized the streaming DEP using 1 μm latex particles in a 3D carbon electrode device both experimentally and numerically by varying different experimental parameters. Both experimental and numerical results showed that streaming DEP occurs in a specific range of the ratio of DEP force and hydrodynamic drag force. These results offer to combine all the experimental parameters into a non-dimensional streaming DEP number. This number will predict the streaming DEP in a given set of experimental conditions.

KEYWORDS: Dielectrophoresis (DEP), Drag Force, Particle Separation, Streaming DEP

INTRODUCTION

In Streaming dielectrophoresis (DEP), targeted cells are not trapped on the electrodes, rather continuously focused into parallel streams for easy retrieval (Fig. 1). The focusing of the cells depends on the equilibrium between DEP force (F_{DEP}) and hydrodynamic drag force (F_{Drag}). Since the DEP force depends on the membrane capacitance and the particle size, streaming DEP is advantageous over the use of other label-free techniques, such as acoustophoresis, inertial microfluidics and deterministic lateral displacement, because cells can be isolated not only based on size but also based on viability, age and fate potential [1]. Previous reports on streaming DEP are focused on the interaction of insulator DEP and Electrokinetic(EK) flow for the filtration of biomolecules and latex nanospheres [2],[3]. Our work uses fluid flow enabling high flow rates and use of 3D carbon electrodes [4] enables use of lower voltages than the case of insulator posts.

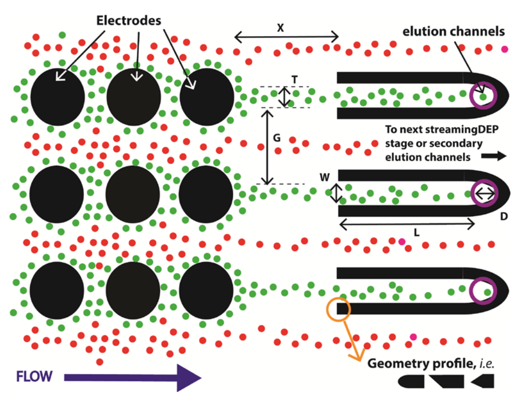

Figure 1: Several streams featuring concentrated population of targeted cells are present in the domain. Retrieval geometries aligned with such streams will facilitate rapid extraction of these cells. For example, the green particles experiencing positive DEP force towards the electrodes and a drag force due to the flow in the channel will flow in streams corresponding to the location of retrieval geometries which will collect pure green cells to be eluted through the holes to the collector.

EXPERIMENTAL

We performed the experiments (Fig. 2a) for streaming DEP using 1 μm latex particles in a 3D cylindrical carbon-electrode DEP device. Effect of different flow rates (25 to 300μl/min), voltages (10 to 20V_{pp}) and frequencies (5 to 10,000 kHz) were studied on the occurrence and quality of the streaming DEP in the experiments. A COMSOL simulation (Fig. 2b) was implemented for the experimental conditions to numerically study the effect of the experimental parameters and the effect of electrode geometries.

RESULTS AND DISCUSSION

Results from the experiments and the simulation (Fig. 2c-2e) clearly depict that streaming DEP occurred only in a limited range of flow rates, voltages and frequencies. This behavior can be explained in terms of F_{DEP} and F_{Drag}. Fig. 2f shows the range of F_{Drag}/F_{DEP} within which streaming DEP occurred is 1.75 to 3.1. F_{Drag}/F_{DEP} higher than 3.1 yielded to hydrodynamic focusing, whereas undesired trapping of particles occurred for F_{Drag}/F_{DEP}<1.75. However, this range of F_{Drag}/F_{DEP} for streaming changes with the electrode geometry (Figure 2f). Based on the results, it seems it is possible to combine all the experimental parameters into a non-dimensional streaming DEP number. The streaming DEP number can predict the flow and electric field parameters for simulating streaming behavior for a selected electrode geometry and particular cells of interest.

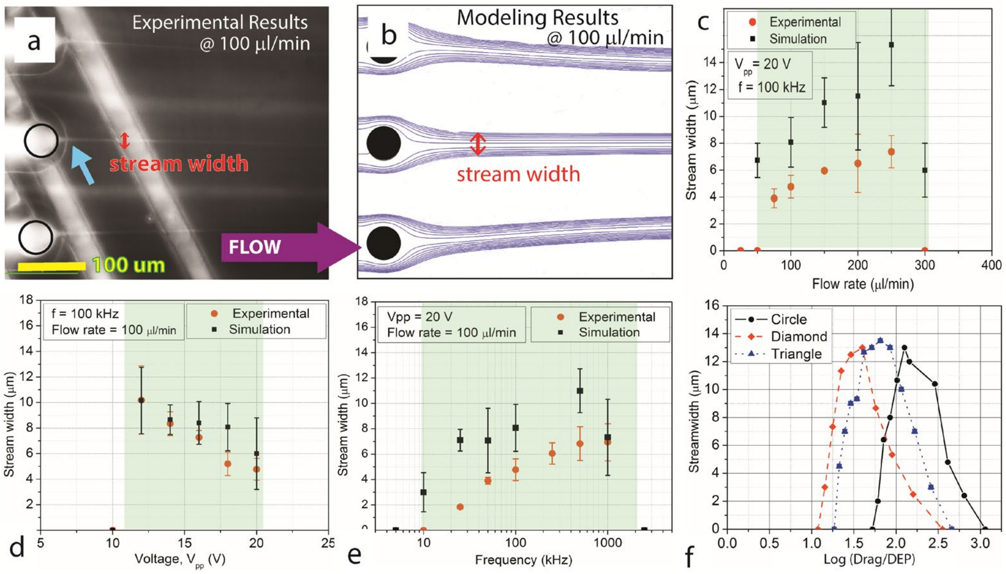

Figure 2: a) Experimental results for streaming of latex particles by positive DEP at 100 µl/min as compared to the streams simulated for similar conditions in (b). c-e) show stream widths obtained for different flow rates, voltages and frequencies for 1 µm latex beads at 100ul/min and 100kHz. f) Simulation results for stream widths with respect to force ratio showing the force range where streaming occurs.

CONCLUSION AND ONGOING WORK

Both experimentally and numerically, we have demonstrated that streaming DEP occurs in a specific range of experimental parameters and the width of the streams depends on the experimental conditions. These experimental parameters can be expressed in terms of F_{Drag}/F_{DEP} to explain the occurrence of streaming DEP. Results indicate the possibility to develop a non-dimensional streaming DEP number which can define the streaming zone for a particular set of parameters and predict the streaming DEP. Ongoing work is to determine the value of this streaming DEP number in terms of the experimental parameters.

REFERENCES

[1] D. R. Gossett, W. M. Weaver, A. J. MacH, S. C. Hur, H. T. K. Tse, W. Lee, H. Amini, and D. Di Carlo, "Label-free cell separation and sorting in microfluidic systems," *Anal. Bioanal. Chem.*, vol. 397, no. 8, pp. 3249–3267, Aug. 2010.

[2] E. B. Cummings, "Streaming dielectrophoresis for continuous-flow microfluidic devices," *IEEE Eng. Med. Biol. Mag.*, vol. 22, no. 6TY–JOUR Copyright 2004 Institute for Scientific Information, Inc., pp. 75–84, 2003.

[3] F. Camacho-Alanis, L. Gan, and A. Ros, "Transitioning streaming to trapping in DC insulator-based dielectrophoresis for biomolecules," *Sensors Actuators, B Chem.*, vol. 173, pp. 668–675, 2012.

[4] R. Martinez-Duarte, P. Renaud, and M. Madou, "A novel approach to dielectrophoresis using carbon electrodes," *Electrophoresis*, vol. 32, no. 17, pp. 2385–92, Sep. 2011.

CONTACT

* Rodrigo Martinez-Duarte; Email: rodrigm@clemson.edu