

# REDUCTION OF MICROFLUIDIC END EFFECTS IN MICRO-FIELD FLOW FRACTIONATION CHANNELS

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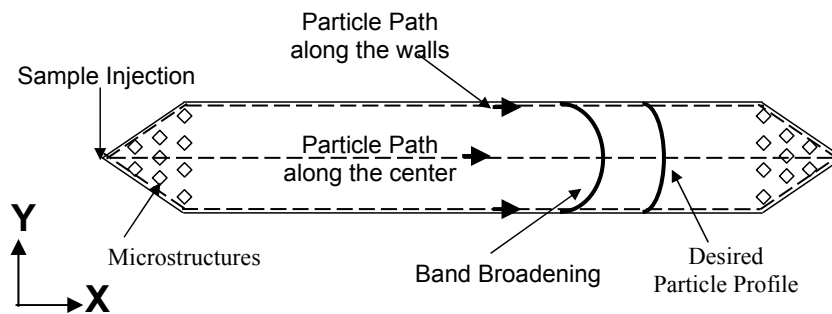
## ABSTRACT

This work introduces a novel approach for the reduction of fluidic end effects, which give rise to the particle band broadening and zone dispersion, a critical performance parameter for micro- field flow fractionation (FFF) and other separation systems [1]. The approach includes the implementation of pillars in the microchannel to help ensure that all particle paths are identical in length. Modeling results show significant reductions in plate heights and these results are confirmed experimentally.

**KEYWORDS:** Microfluidics, plate height, chromatography, field flow fractionation

## INTRODUCTION

Typically, FFF based systems consist of a channel sandwiched between two parallel plate electrodes (for electrical FFF) and these electrodes are separated by the insulation layer that defines the channel walls. The input and output sections of this channel consist of triangular sections for the smooth and uniform transition of sample particles from a point injection to the full width of the channel. Due to the presence of the triangular end pieces, the sample entering the channel takes different paths in the channel as shown in Figure 1 and there is a considerable time lag between the samples that travel through center and along the edges. This phenomenon leads to a considerable zonal dispersion of the sample and subsequent increase in the plate height and in turn, loss of separation efficiency in the device [2,3]. In this work, we have incorporated an

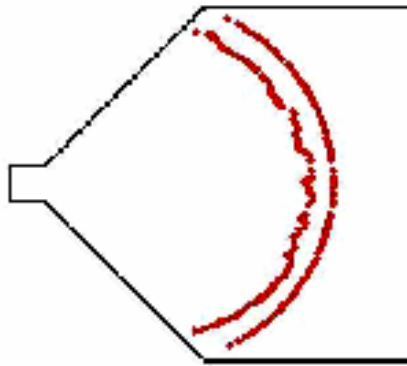


**Figure 1 Top view of the micro-FFF channel showing particle path and microstructures in the end triangular segments**

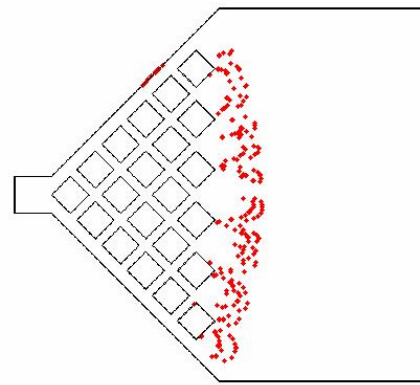
array of columns in the path of fluid to optimize the fluid path and to obtain a more uniform particle distribution in the X-Y direction (Figure 1) and also reduce the volume of the triangular end piece.

## MODELING

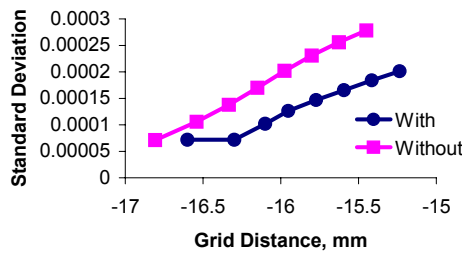
The fluid flow in the endpieces was simulated to help optimize the design of the column array. The flow simulation was done using Fluent (Fluent Inc.), CFD (computational fluid dynamics) analysis software. In this work, both two-dimensional and three-dimensional flow analyses were carried out. A variety of constrictions were employed to determine the optimum constriction geometry, which in turn were incorporated into the test channels. The distances traveled by the particles at a given time were simulated for the channels with obstructions and without obstructions. Typical particle traces obtained during the simulation is shown in Figure 2 and Figure 3. Figure 2 shows the particle positions with no structures in the endpiece and demonstrates the significant curvature that occurs in the sample band. Figure 3 shows how the sample plug flattens out after moving through an endpiece with added columns. This indicates a reduction in band broadening when compared to Figure 2. The best configuration results so far are shown quantitatively in Figure 4, which plots the standard deviation of the distances traveled by the particles at a given time. These plots clearly demonstrate that the standard deviation for the channel with obstructions was less when compared to the channels without columns.



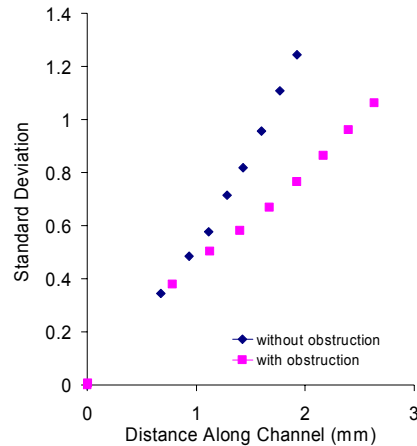
**Figure 2 Particle trace snapshot at 0.5 seconds after injection in a channel with no columns in the endpiece. Channel dimensions are 3.5 mm x 2 mm x 25  $\mu$ m. The velocity used is 1.5 mm/sec**



**Figure 3 Particle trace snapshot at 0.2 seconds after injection. Channel dimensions are 3.5mm x 2mm x 25 $\mu$ m with 200  $\mu$ m square columns. The velocity used is 1.5 mm/sec.**



**Figure 4 Best results for an obstruction pattern so far in simulation showing a 47% improvement for microscale systems when adding obstructions. These results are for the configuration shown in Figure 3.**



**Figure 5 Results for a channel with a 60° endpiece and rhombus columns showing a 39% improvement when compared to channels with no obstructions.**

### EXPERIMENTAL

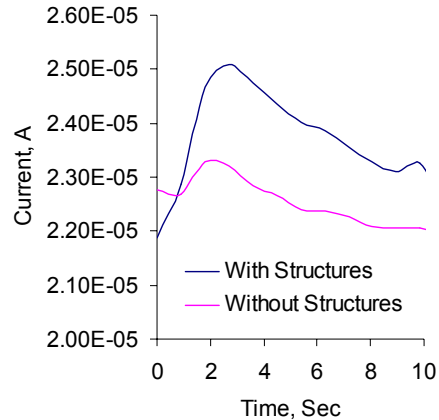
$\mu$ -FFF channels and an on-chip conductivity detector were fabricated on a glass substrate as described in the earlier communications from our group [4] and used to verify the simulation results. DI water was flowed through the channels 25  $\mu$ m tall and 2 mm wide at 1 mL/hr. 0.1  $\mu$ l salt water samples were injected into the flow and the current across the conductivity detector was observed in order to calculate the sample plug width.

### RESULTS

A typical detector response for the micro FFF channel without any constriction structures and with half of triangular section having 200  $\mu$ m structures is shown in Figure 6. The half peak width for the structures is tabulated in Table 1. The structures reduced the peak width by about 35%, which is approaching the results for simulations of that structure. Thus, there appears to be a strong possibility that the addition of structures will reduce plate heights. One concern that arose during some tests with particles is that clogs develop more easily and the structures increase the surface area for interaction with the samples, possibly dispersing the sample. Further work is being done to quantify these effects.

## CONCLUSION

Fluid flow simulations have clearly shown that plate heights in FFF channels can be reduced by including columns in the triangular end pieces. Experimentation verified the trends determined in the simulations. There are still some experimental problems to work out including possible interaction of samples with the increased surface area of the improved endpieces. This approach of using microstructures to improve the sample injection and the overall separation results should be applicable to improving the performance of other microfluidic devices of similar geometries.



**Figure 6 Acetone peak for the test channels with structures and without structures**

**Table 1 Peak width for different structures in micro FFF test channels**

Type of Structure	Peak width, (s)
Without structures	4.9
200 $\mu\text{m}$ columns endpiece	3.2

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