POLYELECTROLYTE TRANSPORT IN NANOCONFINED CHANNELS

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Abstract

The transport of polyelectrolytes such as DNA in nanometer-confined channels has been investigated. We are interested in whether new modes of electrokinetic separations can be unveiled by reducing the lateral dimensions of channels to molecular scale. Two different size regimes have been explored: conditions where the size of the sample molecules is similar to but smaller than the channel half-depth, and the converse situation.

Keywords: DNA separations, nanochannels

1. Introduction

The transport mechanism of DNA in nanochannels may differ significantly from microchannels. Operating nanochannels with low ionic strength buffers, an overlap of the electrical double layer can readily be achieved [1, 2]. In that case the electroosmotic flow is expected to take a parabolic-like velocity profile [3]. The velocity gradient of the non-uniform flow profile can be used to separate components based upon their size. Smaller components approach closer to the channel wall than larger components. Consequently, smaller components have a lower average velocity than larger components that are restricted to the higher velocity regions near the center of the channel. This separation mode, which is much like hydrodynamic chromatography [4], we call electrohydrodynamic chromatography since the flow is generated electrokinetically. In cases where the polyelectrolyte molecules are larger than the channel half-depth, transport is likely to be determined by molecular viscoelastic properties and/or the probability of molecule/interface interactions. This may serve as a separation mechanism, where the mobility will decrease with increasing size.

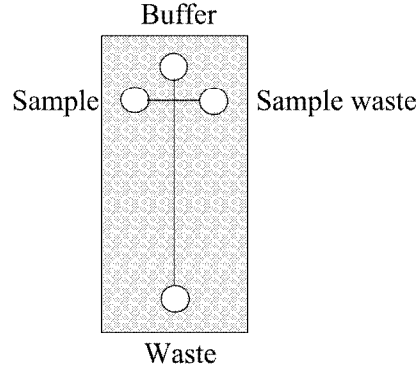

Figure 1. Chip layout of the nanofluidic devices. The width of the channels was 24 μm with depths ranging from 110-320 nm.

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2. Experimental

To test these transport conditions, simple cross chips were used (Figure 1), and the sample was dispensed using the pinched injection scheme. The lateral channel dimensions for the chips were 55, 110, and 160 nm at half depth. DNA fragments of 100 and 1000 bp with approximate radii of gyration of 10 and 60 nm were used to test the separation where double layer overlap was present. Experiments were also performed under normal electroosmotic flow conditions using a 1 kb ladder which had several fragments larger than the channel depth. This ladder had two fragments (1-2kb) with radii of gyration smaller than 110 nm and 13 fragments (3-15 kb) with radii of gyration ranging from 125 to 300 nm. The DNA was fluorescently labeled using the intercalating dye TO-PRO-1, and the components were detected 2 to 5 mm downstream of the injection cross.

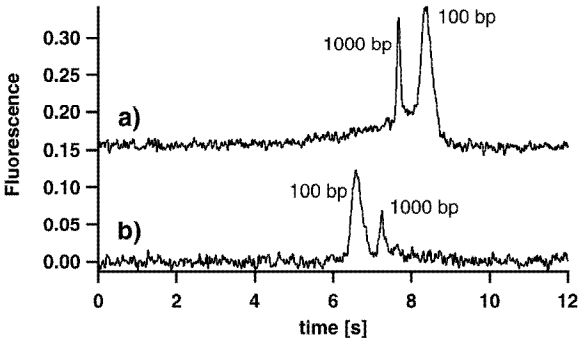

Figure 2. DNA separations on nanodevices where double layer overlap was present. Buffer 100 μM sodium tetraborate with no added sieving matrix. The applied electric fieldstrength, E, was 40 V/cm. Sample was 16 ng/μL 100 bp and 4 ng/μL 1000 bp ds-DNA. a) Separation performed on a 320 nm deep chip with a separation length of 3 mm. b) Separation performed on a 110 nm deep chip with a separation length of 2 mm.

3. Results and discussion

Figure 2a shows an electrohydrodynamic separation of the 100 and 1000 bp DNA fragments on the chip having a half depth of 160 nm. As the ratio of the radii of gyration to channel half-depth approaches or exceeds unity, interactions with the walls decrease the average velocity of these components relative to the smaller fragments. Figure 2b shows the separation of 100 and 1000 bp DNA fragments using the 55 nm half-depth chip where the elution order is reversed from the electrohydrodynamic separation (Figure 2a). This reversal in elution order is speculated to be due primarily to the 1000 bp fragment interacting with the channel walls and contorting to squeeze through the channel. The 100 bp fragment travels unobstructed through the nanochannels. Separation of DNA with several fragments larger than the channel depth is seen in Figure 3. The separation demonstrates that DNA larger than the channel depth can also be resolved at short separation lengths. The separations obtained using the nanodevices could not be achieved using the same buffer systems in microchannels.

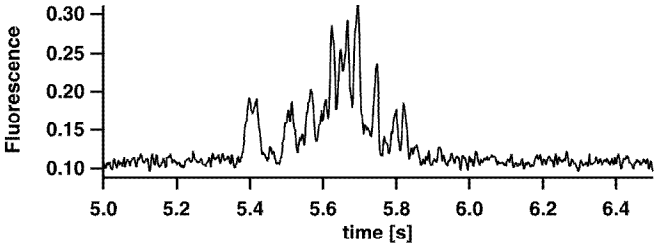

Figure 3. DNA separation on a nanodevice where the fragments are larger than the channel depth under normal EOF conditions. Buffer 9 mM TBE (Tris Borate EDTA buffer) and E= 220 V/cm. Sample: 20 ng/μL 1-15kb ladder in 1 kb increasements. Separation performed on a 220 nm deep chip with a separation length of 5 mm.

4. Conclusion

DNA separations based upon size can be achieved on the nanodevices either by using the non-uniform flow conditions created by electroosmotic flow under double layer overlap or working with channels smaller than the fragment seizes. These two separation methods are presently being optimized.

Acknowledgements

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