Study of DNA mobility in 20 nm channels using AC and DC electric fields

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We studied the mobility of λ-DNA in 20 nm channels using combined AC and DC fields. We present the mobility results of using 1kHz AC fields added to DC fields. Mainly we found that at DC fields below 20kV/m, the DNA mobility was significantly increased by the added AC, however, at DC fields above 20kV/m, no influence was observed.

In a previous investigation of the DNA transport in 20nm channels under DC electric fields, it was observed that the DNA mobility was strongly dependent on the applied field strength [1]. The mobility increased with the field, and the DNA moved fluently. But above 30kV/m, the DNA moved intermittently and the mobility decreased. For the explanation of this behaviour two hypotheses were made: steric trapping and dielectrophoretic (DEP) trapping [1]. Here we use the AC fields to try to increase the DEP forces possibly generated by imperfections on the channel surface, when the DC fields were applied

The nanochannels were manufactured in fused silica chips by wet etching. Nanochannels were 3μm width, 20nm height and 500 μm length, connecting two microchannels containing the sample and buffer. The surface roughness measured by AFM was 0.7 nm rms. The λ-DNA (48kbp) was labelled by YOYO-1 and diluted in a TBE buffer containing 2.5% polyvinylpyrrolidone (PVP) to reduce electroosmotic flow and 3% β-mercaptoethanol to suppress DNA photobleaching [1]. The measurements were done with an inverted microscope and a fluorescence camera.

Figure 1 schematically presents the experimental setup used to apply the electric field. We used a function generator to supply an AC signal with 1kHz, where the amplitude defined the intensity of the AC field, and the offset defined the DC field. In order to apply the required high voltage to move the DNA in the nanochannels we used a high-voltage amplifier, which was connected to the chip via the waste reservoirs. We characterised the amplifier response in order to know the relation between the generated signal and the applied signal. We detected a deviation of 0.5 V DC voltage and 0.01V amplitude.

Figure 2 shows the observed variation in the mobility due to the AC applied amplitude. As mentioned earlier, when the DC field is below 20kV/m the amplitude increases significantly but when the field is above 20kV/m there is no effect of the AC field. This is shown in the in the 40 and 120kV/m plot where the mobility is practically stable. Note that the 120kV/m plot shows a significant decrease in the mobility, which is in agreement with the effect previously published when only DC fields were used [1].

Figure 3 shows the existence of a similar behaviour for the mobility as a function of the DC field applied whatever the amplitude of the AC signals (5V, 40V and 80V). It is shown a strong dependency with the DC voltages applied (note, that at low DC voltages the mobility increases with the amplitude as shown in Figure 2). The final conclusion is that these results are in contradiction with a dielectrophoretic explanation of the observed intermittent movement, because it is not affected by the introduction a more inhomogeneous field. We therefore

conclude that the trapping of DNA is due to the steric effects, which at high DC fields could be important, due to the strong elongation of the DNA in the direction of movement.

References:

[1] G.B. Salieb-Beugelaar, J.Teapal et al., *Nano Lett.* 80 (2008) 8095-8101.

Figures:

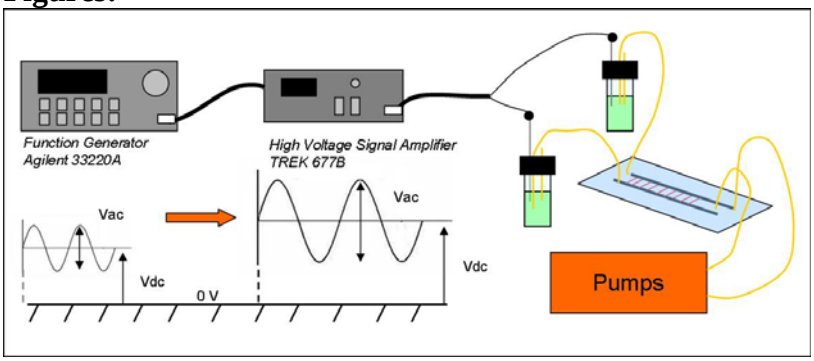

Figure 1: Experimental setup, it shows the electronic devices used to generate the signal, which combines both DC and AC voltages. The output of the amplifier is connected to the chip by two reservoirs. Due to the high conductivity of the TBE buffer the field is applied homogenously a long of the two microchannels, which are connected by the 100 nanochannels. The buffer is applied by the syringe pumps via powder-blasted holes and fused silica capillaries.

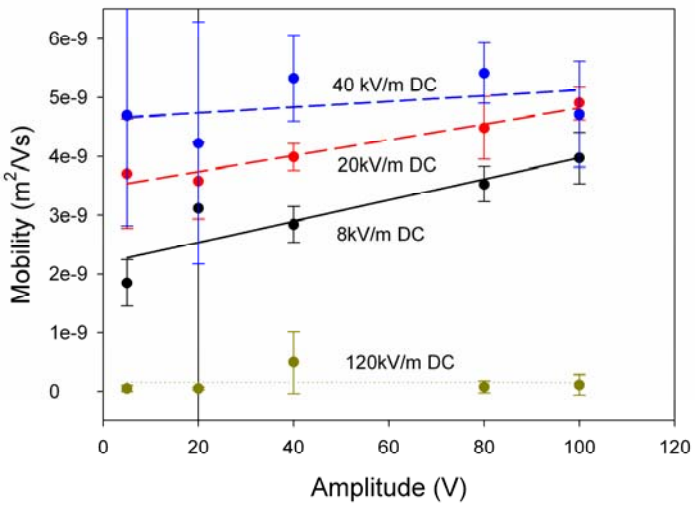

Figure 2: The measured mobility of DNA versus the applied amplitude in volts, for different intensities of DC field. The mobility increases significantly when DC fields below 20 kV/m were applied, at 40 kV/m the mobility is not influenced. And for higher fields the mobility decrease drastically and there no effect with the mobility too.

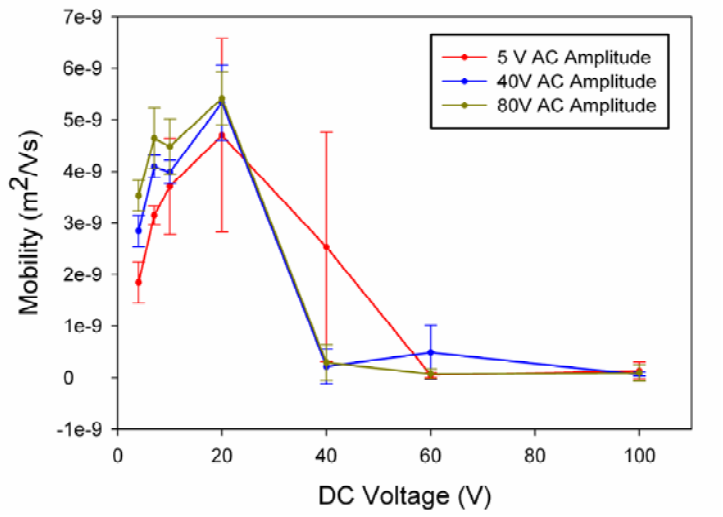

Figure 3: The measured mobility of DNA versus the applied DC voltage, for different AC amplitudes in Volts. There are no general effects of the different AC intensities, and the mobility decreasing for DC voltages over 20V is also produced, which correlates with the intermittent movement reported. It indicates no influence on the behavior by the addition of AC, showing the hypothesis of the steric effects.