

# The Mathematical Model for the Electric Field Effect on Counterion Number in the Double Layer Surrounding a DNA

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Gene study and gene therapy have attracted researchers' attentions for many years, as gene therapy is one of the perspective methods to cure cancers. However, to study and characterize genes need to analyze a huge amount of gene information. Rapid DNA sequencing thus becomes an important protocol. A single nanopore was selected to measure and study DNA characteristics to develop the protocol. The final goal is to utilize the nanopore to sequence DNA in seconds. The basic concept of this application is that while DNA is traversing the nanopore, the ionic current will fluctuate due to the pore blockage. Therefore, the four bases on the DNA could be discriminated by the current fluctuations. The first DNA measurement with a biological nanopore was reported by Kasianowicz [1]. In his experiments, different pulse heights were observed corresponding with the subgroup of bases A, G and C, T. Synthetic nanopores were later developed by some other groups [2], [3], [4], [5]. These nanopores were used to characterize the DNA electrophoretic mobility, DNA length [6], [7], [8], and stretch DNA with large electric fields [9]. Besides DNA characterizations, the behaviors of the ionic current in nanoscale were found different from those in microscopic view with the nanopore [10]. In the past, the ionic current generated by the movement of the counterions in the double layer surrounding DNA was immeasurable and negligible in bulk; however, this current component was then proved as a dominating component in nanoscale with a single nanopore. Therefore, the calculation and estimation of counterion number become significant when the measurements of ionic current are taken in nanoscale.

In this paper, we will propose a mathematical model for the counterion number under large electric fields based on our previous work relevant to DNA and counterion measurements [11]. In the previous work, the counterion number was discovered changing with different electrophoretic biases. This fact could be a result of the external electric field polarizing the counterions, and even removing them from the

double layer [12], [13]. Initially, the counterions could be easily released from the double layer under a smaller electric field; however, the remaining counterions under a larger electric field could have stronger attachments to the negative ions on DNA. As a result, the releasing rate would decrease. Based on the above hypothesis, the counterion number could be an exponential function of the electric field. Fig. 1 shows the measurement results from our previous work, and the mathematical model is plotted in Fig. 2. By comparing the two figures, the model does have a good agreement to the experimental trend in Fig. 1. As aforementioned, counterion number can be a significant factor in the ionic current in nanoscale. This work provides researchers a simple way to estimate counterion number around DNA. The future work will be to determine accurate values for the parameters in the model, and develop the advanced model.

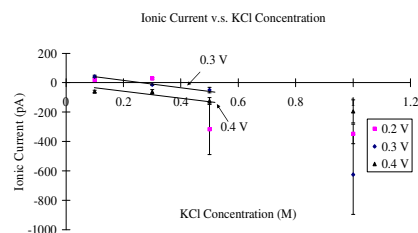


Fig. 1 DNA measurement results from previous work [11]. Note: The amplitude of the ionic current is related to counterion number.

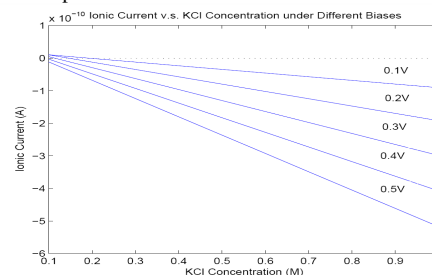


Fig. 2 The plot of the mathematic model proposed in this paper. It has a good agreement with the measurement results shown in Fig. 1.

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