Extended Abstracts of the 2002 International Conference on Solid State Devices and Materials, Nagoya, 2002, pp. 98-99

F-1-6

Electrical Conduction Through Poly(dG) Single-stranded, Poly(dC) Single-stranded, and Poly(dG)-poly(dC) Double-stranded DNA Molecules

J. S. Hwang, G. S. Lee[1], K. J. Kong, D. J. Ahn[1], S. W. Hwang[2], and D. Ahn

Institute of Quantum Information Processing and Systems, University of Seoul
90 Jeonnong, Tondaemoon, Seoul 130-743, Korea
Phone: +82-2-2210-2695 Fax: +82-2-2210-2692 E-mail: jshwang@iquips.uos.ac.kr
[1]Dept. of Chemical Engineering, Korea University
Sungbuk, Anam, Seoul 136-075, Korea
[2]Dept. of Electronics Engineering, Korea University
Sungbuk, Anam, Seoul 136-075, Korea

1. Introduction

Electrical conduction through DNA molecules has received a great deal of attention recently because of possible applications to nanometer-scale molecular electronic devices. There have been many transport studies of DNA molecules over the last few years [1,2]. And, many results suggest electrical conduction through DNA molecules until now. However, the exact mechanism of the transport is still under active discussion [3]. In this work, we report direct measurements of electrical conduction through three types of DNA molecules; poly(dG) single-stranded, poly(dC) single-stranded, and poly(dG)-poly(dC) double-stranded.

2. Experiments

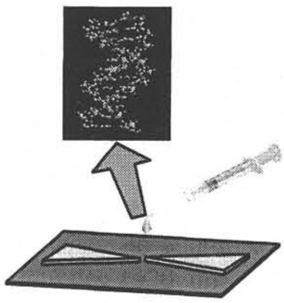
Figure 1 (a) shows the experimental setup for the DNA transport measurement. Figure 1 (b) shows the scanning electron microscope image of metal electrodes. A standard e-beam lithography and lift-off process was employed for the fabrication of nanometer scale electrodes. The electrode pattern was transferred by a thermal evaporation of 5 nm-thick Ti and 10 nm-thick Au. Three samples are prepared by dropping the diluted DNA molecules on the pair of metal electrodes with the gap of 20 nm. The first sample is 60 bases of poly(dG) single-stranded DNA molecules. The second sample is 60 bases of poly(dC) single-stranded DNA molecules. The third is 60 base pairs of poly(dG)-poly(dC) double-stranded DNA molecules.

3. Results and Discussion

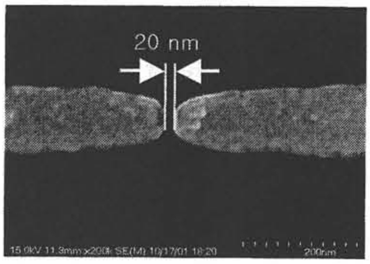
Figure 2 and Fig. 3 show room temperature current-voltage (I-V) and differential conductance-voltage (dI/dV-V) characteristics of those three samples. The sample with poly(dG) single-stranded DNA molecules exhibits approximately 1 V wide, clear staircases both in the I-V and in the dI/dV-V (Fig. 2(a)). The sample with poly(dC) single-stranded DNA molecules shows almost monotonic increase of the current with the increase of the bias in the I-V, and the dI/dV-V shows an almost constant value(Fig. 2(b)). Figure 3(a) and (b) show the I-V and the dI/dV-V measured from two different poly(dG)-poly(dC) double-stranded DNA molecules. Approximately 2.5 V wide, clear staircases and small kink structures can be identified in the I-V and in the dI/dV-V.

All the observed I-V and dI/dV-V characteristics are completely reproducible and there is no possibility of ionic conduction. Thus, clear staircases in the I-V and dI/dV-V are induced from the energy gap structure of DNA molecules. In addition, the size of the gap between two electrodes (~20 nm) is comparable to the size of the length of the 60 base pairs (20.7 nm). Therefore, it is possible that the staircases observed from the 20 nm gap sample are originated from a small number of DNA molecules in between the gap.

The transport mechanism of poly(dG)-poly(dC) double-stranded DNA molecules is recognized as the electron hopping through the bases. The results of Fig. 2 and Fig. 3 strongly suggest that the nonlinear behavior measured in previous studies [2] of poly(dG)-poly(dC) double-stranded DNA molecules originated from the energy gap structure of poly(dG) DNA molecules.



(a)



(b)

Fig. 1 (a) Sample preparation schematic for DNA transport measurements. (b) Scanning electron microscope image of metal electrodes. The size of the gap is 20 nm.

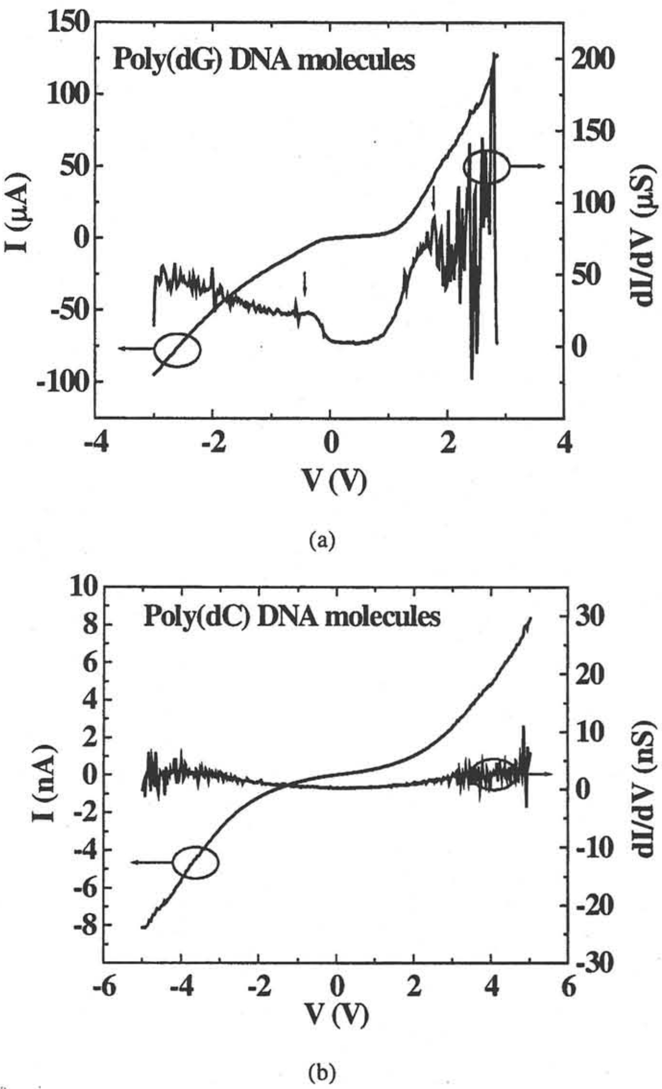


Fig. 2 Room temperature I-V and dI/dV-V characteristics measured from the electrodes with the gap of 20nm after dropping the diluted (a) poly(dG) single-stranded DNA molecules and (b) poly(dC) single-stranded DNA molecules.

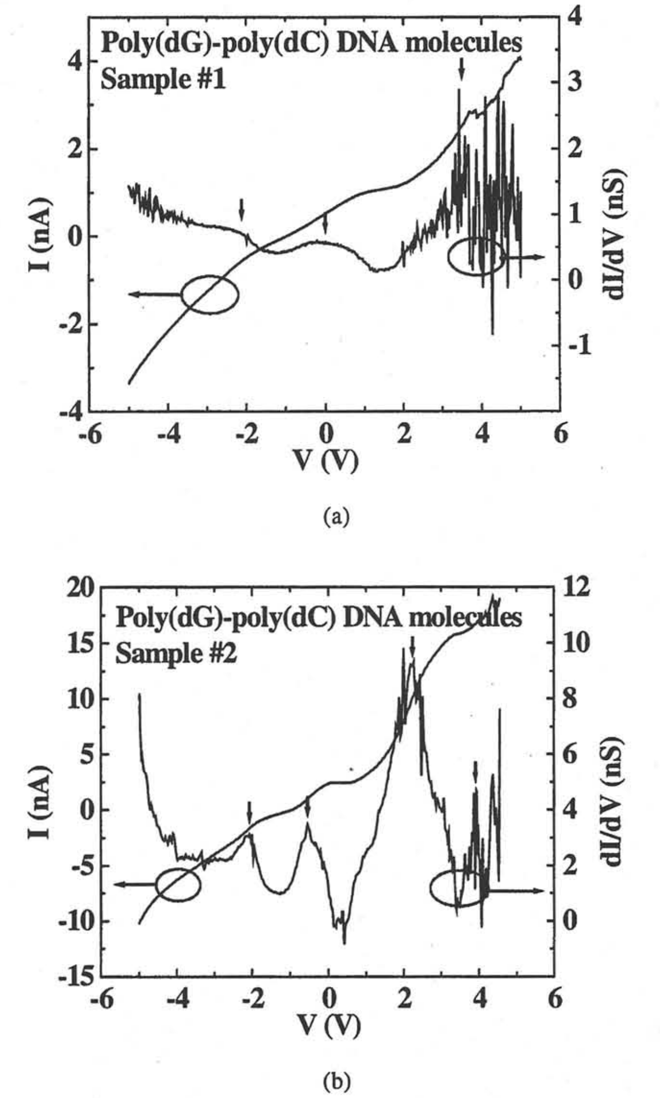


Fig. 3 (a), (b) Two different room temperature I-V and dI/dV-V characteristics measured from the electrodes with the gap of 20nm after dropping the diluted poly(dG)-poly(dC) double-stranded DNA molecules.

4. Conclusions

We have investigated electrical conduction through three types of DNA molecules on the electrodes with the gap of 20 nm. The samples with poly(dG) single-stranded and poly(dG)-poly(dC) double-stranded DNA molecules exhibit clear staircases in the I-V and dI/dV-V characteristics. However, the sample with poly(dC) single-stranded DNA molecules shows almost linear behavior in the I-V and the dI/dV-V characteristics. This result strongly suggests that the nonlinear transport behavior of poly(dG)-poly(dC) double-stranded DNA molecules originated from the energy gap structure of poly(dG) DNA molecules.

Acknowledgments

This work is supported by the Korean Ministry of Science and Technology through the Creative research Initiatives Program under Contract No. M1-0116-00-0008. The work at Korea Univ. is supported by the Brain Korea 21 project in 2002.

References

[1] H. W. Fink and C. Schönenberger, Nature **398**, 407 (1999)

[2] D. Polath, A. Bezryadin, S. de Vries, and C. Dekker, Nature **403**, 635 (2000)

[3] A. J. Storm, J. van Noort, S. de Vries, and C. Dekker, Appl. Phys. Lett. **79**, 3881 (2001)