Studies of electrical conductivity in 12-mer single-stranded DNA by using scanning tunneling microscope

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DNA is a molecule that stores genetic instruction in living things for making other large molecules. The main structure of DNA consists of sugar phosphates and bases. There are four kinds of bases in DNA, namely adenine (A), guanine (G), cytosine (C), and thymine (T).[1)] These bases contain a ring of atoms known as an aromatic group, and they are electron-rich in nature. If their electron clouds overlap within the bases, π-π interactions are created and become a medium of electron transport.[2)]

Electron transport in DNA is important in biological processes, especially for understanding the DNA damage and repair mechanisms. According to previous studies,[3,4)] electrons travel through the DNA to scan the damaged area and repair it by using repair protein. Therefore, the main question here is whether DNA is an electrical conductor or not? If DNA is conductive, how do the electrons move along the DNA strand?

In order to answer this question, we carried out scanning tunneling microscope (STM) measurements on a simple sequence DNA. Our samples were composed of 12-mer single stranded synthetic DNA (12-mer ssDNA), and each strand had only one type of base (12mer-ssG, 12mer-ssC, 12mer-ssA or 12mer-ssT). In this report, however, we only show the results of cytosine.

We prepared our 12mer-ssC sample for STM measurements by dissolving of 0.1 mg of powder sample in 2 ml pure water. This solution was shaken by using an ultrasonic vibrator for about 60 min. Then, we deposited a droplet of the sample on a graphite stage and dried it in a space lined with silica gels for about 2 h. The values of the bias voltage and current we used in our STM measurement were 1.0 V and 0.1 nA, respectively.

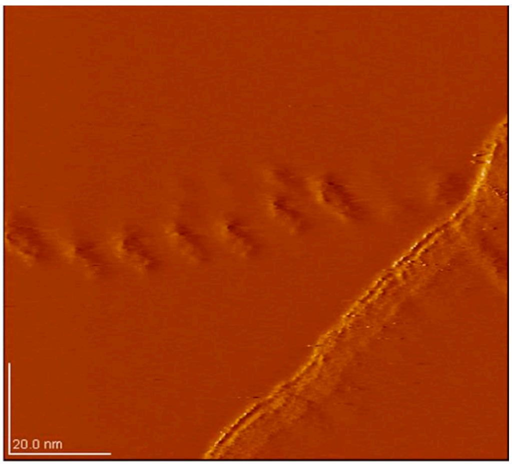

Fig. 1. STM image of 12 mer single stranded cytosine molecule aligned in a one-dimensional chain structure.

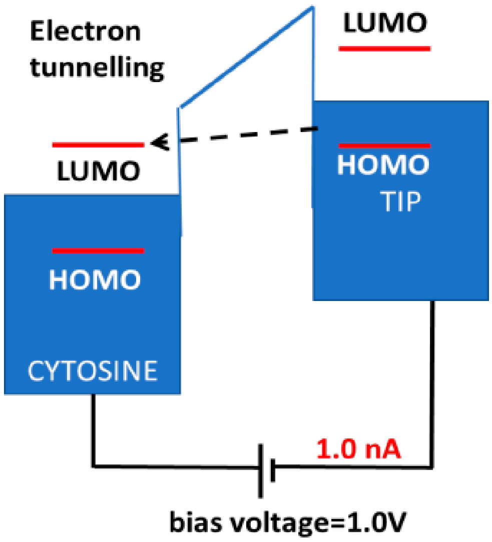

Fig. 2. Schematic picture of the electron tunnelling from the highest molecular orbital (HOMO) of the tip to the lowest molecular orbital (LUMO) of the sample.

From our STM measurements, we successfully observed the molecule image of 12mer-ssC as shown in Fig. 1. This means that the sample is conductive. We understood that electron tunneling occurs from the highest molecular orbital (HOMO) of the tip to the lowest molecular orbital (LUMO) of the sample. Besides, we also observed that the sample molecules are aligned parallel to each other forming a one-dimensional chain structure. Figure 1 shows the STM image of sample in a one-dimensional chain structure. This structure might cause electron transfer in a one-dimensional pass across the edges of the molecules, due to the overlapping of π orbitals between the strands of molecules. This result agrees well with the results of muon spin relaxation: electron transport occurs in the quasi one-dimensionality at room temperature.

References
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