Progress Report

Lee See Kei

10.09.08

Mechanism of Charge Transport in Single Oligothiophene Molecules

1. Purpose:

As the miniaturization of electronics is driven to its ultimate limit, electronic devices build from single molecules is an important goal. Thus, it is important to have a good understanding regarding the nature electrical conduction through single molecule. It have been thought when molecule lengths increases, tunneling mechanism would gets weaker and would eventually be replaced by hopping in which charges hop from one site to the next along the molecule. In my experiment, I would conduct experiments on oligothiophene wires at various temperatures to clarify the charge carrier transport mechanism.

2. Research background:

The molecular electronics is interesting as the idea or prospect of size reduction in electronics offered by molecular-level control of properties, would allows the extension of Moore's Law. Studies are done to find the suitable molecule which has the suitable characteristic for this purpose. In one of the previous work of our research group, it has been found that oligothiophene molecule holds the potential of being a suitable candidate for this purpose, displaying a change in the conduction mechanism, from tunneling to hopping. The results shown that scaling of conductance behavior of oligothiophene molecular wires with the lengths ranging from 2nm to 9nm changed from exponential to linear at the molecular length of approximately 5.6nm. However, it is difficult to conclude that the change of conductance behavior for the molecular wires were solely due to the two different charge carrier transport mechanism.

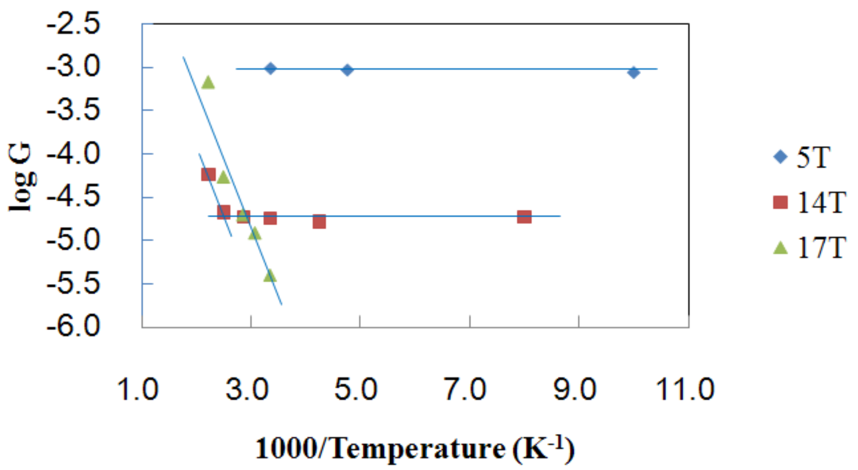
3. Purpose of the individual experiment

In my research, I would conduct experiments on oligothiophene wires at various temperatures to clarify the charge carrier transport mechanism. When the conduction mechanism is due to tunneling, it will not show any dependence with temperature, thus no change in the electrical conductance value would be expected but if the conduction mechanism is due to hopping, the electrical conductance value would change.

4. Method

Conductance of the molecules was determined by the break junction method. In this technique, the tip of scanning tunneling microscope (STM) is repeatedly brought into contact to a substrate. When the tip is retracted from the surface, the metal/molecule/metal (MMM) junction is temporally formed. The conductance of the molecule is determined from the conductance histogram created from hundreds ~ thousands of conductance traces measured during the tip retracting process. Up until now, I have conducted break junction testing on 5T-di-SCN, 14T-di-SCN and 17T-di-SCN molecule at various temperatures by using the home-built instrument for low temperature purpose and commercial STM for measurements at temperature higher than ambient temperature.

5. Result and Discussion



As shown above, results showed that 5T-di-SCN and 14T-di-SCN (< 300 K) oligothiophene molecule doesn't display any change of conductance values even at low temperature, 100K. This shows that the conduction mechanism is dominated by tunneling as according to theory. As shown in the figure, there's a change in the charge transport mechanism from tunneling to hopping in the 14T-di-SCN molecule at temperature higher than 350 K. At 350 K, the conductance value for the molecule is ~$1.8\times10^{-5}G_0$ while the conductance values at 400 K and 450 K are ~$2.1\times10^{-5}G_0$ and ~$5.7\times10^{-5}G_0$ respectively. The reason for the change in the dominant transport mechanism could be because as the temperature increases, the electron is thermally excited to a higher level, thus the occurrence of hopping mechanism. More results were obtained for 17T-di-SCN molecule at different temperatures, which shows clear dependence of the molecule with the temperature, indicating hopping transport.

6. Difficulties

- Molecular Junction Formation

As the molecular length becomes longer, the difficulty in forming the molecular junction increases. This is because the probability of the molecules to appear in the same substrate area decreases. Thus, there will be times when no plateaus will be observed.

7. Next plan

- To conduct experiment at higher temperature (300 K to 450 K) for 5T-di-SCN oligothiophene molecules.
- To reconfirm the results obtained for 14T-di-SCN oligothiophene molecules