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Electrical Properties of Self-Assembled Monolayers Using STM

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1. Introduction

To investigate the properties of the single molecule, we attempt to measure morphology and electrical properties of the self-assembled organic monolayers on Au(111) substrate with STM(scanning tunneling microscopy)[1]. To deposit the self-assembled monolayers(SAMs) onto Au(111) substrate, we transfer the prefabricated nanopores into a 0.5m*mol*/*ml* self-assembly molecules in THF(tetrahydrofuran) solution. Au(111) substrates were prepared by ion beam sputtering method of gold onto the silicon wafer. As a result, we measured the Voltage-current properties and confirmed the negative differential resistance(NDR) properties of self-assembled organic monolayer and measured, using STM.

2. Experimental

Expressed chemical structure of organic molecule that use by this research to figure 1. Preprocessed that wash Organic molecule as is clean in flowing water after soak Au (111) substrate for 5～10 minute using Piranha Solution (H_2SO_4/H_2O_2, 3:1) before Self-Assembly summer period. Surface of Au (111) substrate is important organic monolayers that do surface treatment as is clean because cause definite effect in adsorption process of molecular film only. Organic molecule that reason is done self-assembled organic monolayers for the first time adsorb that it only molecular film because is made by chain to surroundings of molecule.

Washed Au (111) substrate soaks to grain of plain boiled rice liquefy in THF solution as get into integrate organic molecule 0.5m*mol*/*ml* density, and kept reaction receptacle in nitrogen gas atmosphere after remove oxygen by vacuum pump (15～25mmHg). Add NH_4OH about 5 *μl* per composed organic molecule 1mg that is smelted in THF solution lastly and formed 24 hours, organic molecule that is done self-assembled reacting each only molecular film [2] .

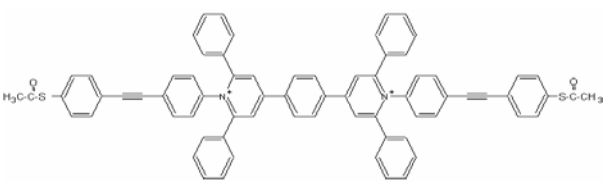

Fig. 1. The structure of organic molecular used in this study

Structure of self-assembled organic monolayers Au (111) substrate was used to have structure of Si/SiO2/Cr/Au (111)/SAMs film, and measure electrical characteristic after dry. Temperature kept 20～30℃, humidity 30%, and used STM (DI multimode IV) among air, and measured by constant current mode and constant height mode really on experiment condition. STM uses tunneling phenomenon quantum dynamics enemy who walk voltage between free medical care and probe and occurs when closed up. Because do probe (tip) that is surface and conductor of free medical care that is conductor or semi-conductor to do access by about 10Å lows without being conterminous, current passes despite was not conterminous if supply fixed bias voltage to both. This tunneling current is compared with fixed reference voltage by voltage of several volt passing electric current amplifier (pre-amplifier).

This tunneling current and difference of standard current regulate distance between probe and surface to distance that correspond to standard current via amplification operation. This process is repeated until get into distance that distance between probe and surface corresponds to standard current, and if get into the distance, form homeostasis and keep the state. This time, need converter that can regulate voltage by the change amount of distance, and this uses PZT (piezoelectric transducer). In this way, scan x/y plane by probe when keep distance between probe and surface changelessly. Quantity of tunneling current according to bends of electric charge distribution of surface can know bends of surface because change. Also, STM uses tunneling phenomenon quantum dynamics enemy who occur between sample and tip, and there is STS (scanning tunneling spectroscopy) [3] by different view derivation technique.

Fundamental purpose of a STS experiment is that explain electrical special quality that explain relation of tunneling current of free sample care surface and local density of state of free sample care surface.

$$\frac{dI}{dV} \propto \rho_s(E_F - eV) \qquad (1)$$

The equation (1), ρ_s is Density of states function, E_F can refer to Fermi level sub-officer and know truth that contribute equally in tunneling current. Current - measured, and used Pt-Ir probe for marketing by probe, and approved voltage 600mV between tip and free medical care because electrical special quality of voltage (I-V) uses STS and tunnel current established by 200pA.

2. Results and discussion

Figure 2 is image which measure surface of self-assembled organic monolayers by STM. Could confirm that SAMs is formed as that measure SAMs section analysis and RMS roughness. I-V measurement was performed using scanning tunneling spectroscopy(STS) at room temperature.

During measurement, tip was positioned over a single molecule and the bias voltage between tip and sample was applied in the range 0.5V ~ 1V. The I-V properties show the symmetry. NDR(negative differential resistance) phenomenon was observed with good repeatability in the range of 0.4V ~ 0.6V. To explain this NDR, we proposed "double barrier junction model" by Gorman et al. [2]. That is, the molecule between au substrate and the molecule and air gap between the molecule and the tip are composed of double barrier junction.

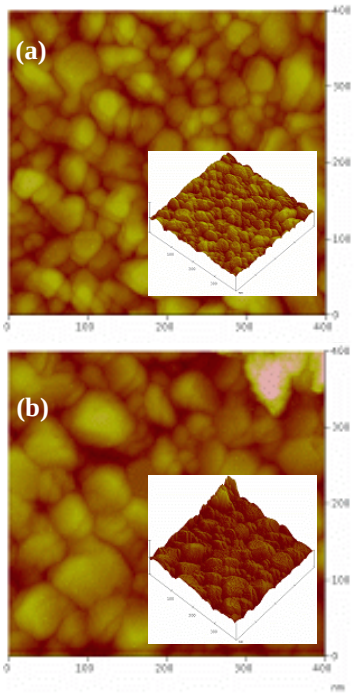

Fig. 2. STM images of self-assembled organic monolayers on Au(111) substrate at different concentrations: (a) Au(111) scan size 400 x 400nm^2, (b) SAMs 24hrs scan size 400 x 400nm^2.

First, upon positive bias of the Au substrate, the molecular states are shifted to a lesser degree than that of the Au substrate. As the system approaches a resonance between the tip and terpyridine-platinum-pyridine in the molecule, tunneling current increase (0.4V ~ 0.5V) and moving out of resonance, the current decreases (0.5 ~ 0.55V). Finally, the current increase after the potential is large enough to allow thermionic emission (over 0.55V).

And we consider that the tunnel barrier heights and position of the tip on the molecule influence the position of NDR, which should be varied. NDR phenomenon is not understudied completely, so further complementary studies are needed.

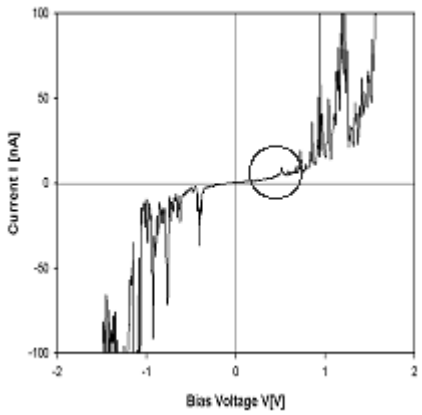

Fig. 3. I-V properties of SAMs in Au(111) substrate.

3. Conclusions

That is self-assembled organic monolayers on Au (111) substrate upside could observe morphology by STM. SAMs could confirm through section analysis and roughness. Also, got self-assembled organic monolayers i-v characteristic curve by STS. When voltage increase in about 0.4V ~ 0.6V time, could observe NDR phenomenon that current decreases. NDR special quality that is noted in this research is expected to become many helps by organic molecule function control as peculiar special quality of organic molecule and in manufacture of molecular element in the future.

Acknowledgements

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References

[1]G. Binnig, H. Rohrer, Ch. Gerber, and E. Weibel, Phys. Rev. Lett. 49, (1982) 57.

[2] Christopher B. Gorman, Richard L. Carroll and Ryan R. Fuierer, Langmuir 17, (2001) 6923-6930.

[3]R. J. Hamers, R. M. Tromp, J. E. Demuth, Phys. Rev. Lett. 56, (1986) 1972.