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Fabrication of Electrically conductive Chemically adsorbed monomolecular layer with polypyrrolyl groups

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1. Introduction

In the present paper, we investigated directly conductivity measurements of an electric path in the lateral direction with two Pt electrodes using a conductive probe of AFM, which may contain super-long polypyrrolyl conjugated bonds. We succeeded that we searched the conjugated path and un-conjugated area in a surface of transparent monomolecular layer with the conductive probe. The samples with the electric path we used were prepared by a chemical adsorption technique with N-[11-(trichlorosilyl)undecyl]pyrrole (PNN) on a glass substrate followed as an electro-oxidative polymerization with pure water. We could detect the high conductive image of electric path in the lateral direction as a super-long polypyrrolyl conjugated polymer between the edges of two Pt electrodes in the air with the conductive probe under a small bias voltage.

2. Experiments

2.1. PNN material and Procedure process

The monomolecular layer was introduced to prepare a path of conjugated bonds of pyrrolyl group by the electro-oxidative polymerization. The sample of a long-chain molecule was synthesized, which has a pyrrolyl group at the molecular end, a trichlorosilyl group at the other end, and a hydrocarbon group at the middle portion was used. The molecular length was 2nm, and length of a pyrrolyl group was about 0.2 nm. In addition to the polymerization of pyrrolyl group, a trichlorosilyl group was attached strongly to the surface of the glass substrate having an active hydrogen, such as a hydroxyl group (-OH), with chemical adsorption (CA). The electric conductance of this monomolecular layer was increased after the electro-oxidative polymerization.

2.2 Apparatus of AFM

The AFM measurements were carried out using a commercially available instrument (SPI, Seiko Instruments) in the contact mode at applied load of 10^{-9} N in air. This conductive probe atomic force microscopy was used to examine electrical transport path through only the surface of the conjugated polymerization. A point of variable length of an electric path could be constructed using a microfabricated Au probe electrode contacting one electric path. Current-voltage (I-V) measurements are made in air as a function of the probe position by applying positive voltages to the Pt electrode while keeping the probe tip on the ground.

3. Results and Discussion

3.1 Measurement of the I–V traces between two Pt electrodes using two probes

The first time a current-voltage (I–V) trace measurement was carried out using a method of two-probes before using the AFM technique. The I–V measurements were measured by applying some different DC voltages between the two parallel Pt electrodes at room temperature in an ambient and a reduced pressure of 1.2×10^{-2} Pa. In principle, the method of four-probes is more appropriate for precise measurement of the conductivity of the electric path, but it was hard to attach four probes to the electric path directly, because the electric paths of the micron width size were too small to the naked eye.

The I–V trace measurements were obtained by the results of a sample before and after the polymerization. Pt plots were measured a patterned line of the same 200 μm length with two-probe method as the reference data. Before polymerization, current was almost zero, as shown in Fig.1. After polymerization, the I–V curves measured at an ambient air and in a vacuum of 1.2×10^{2} Pa were almost identical to each other. The currents was increased linearly with the applied voltage in the air and vacuum, indicating that the sample and circuits are ohmic, and the effects of absorbed water on the surface in the ambient air may be a neglected quantity. Thus, it is easy to calculate the electrical resistance between two electrodes of the sample. However, we did not know that why current flowed between two electrodes, and how shape the current paths were, because monomolecular layer was a super and a transparent thin film. Therefore we tried to confirm the widths of path and how current flowed between two electrodes with a conductive AFM.

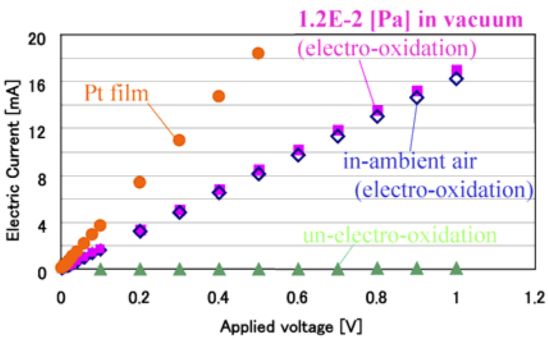

Fig. 1