

Potential Behavior of Bio-Chemically Modified Electrode for Extended Gate Field Effect Transistor

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1. Introduction

We have proposed potentiometric detection of bio-molecules based on field effect devices. An extended gate field effect transistor (EGFET) is known as a solid-state ion sensor in which an ion-selective membrane is deposited on an extended metal gate electrode such as silver/silver chloride [1]. The EGFET is composed of two parts, one is a sensing electrode which generates a signal of selective molecular recognition and another is a FET structure which transduces the molecular recognition events into electrical signals. The extended-gate configuration is useful to develop disposable biosensors for clinical applications such as a DNA chip.

In the present study, a gold electrode is used as an extended gate of EGFET for potentiometric detection of bio-molecules. Effect of surface modification with different functional groups on the potential behavior of the gold electrode is investigated, and oligonucleotide hybridization detection is also discussed using a genetic EGFET.

2 Materials and Methods

2.1 Device structure and fabrication

A gold thin film was deposited by sputtering or vacuum evaporation on the glass substrate. The chip was mounted on a printed circuit board and is wire-bonded. The chip was encapsulated with an epoxy resin except for the sensing area.

2.2 Measurement of electrical signal of EGFET

The FETs are n channel depletion type with a gold electrode as extended gate. The extended gate separated with FET was immersed in a phosphate buffer solution (pH 6.86) together with an Ag/AgCl reference electrode with a saturated KCl solution, as shown in **Fig. 1**. The electrical characteristic of the FET was measured using a semiconductor parameter analyzer.

2.3 Materials

Four types of alkanethiol molecules were used for investigation of potential behavior of bio-chemically modified gold electrode. The alkanethiol molecules with functional groups such as amino group, carboxyl group, hydroxyl group and oligonucleotide were used to investigate the potential behavior, respectively. They were introduced to the surface of gold electrodes at a concentration of 20 mM, though that of oligonucleotide probe was 20 μ M.

Synthesized oligonucleotide probes were used for DNA hybridization and 5'-end of the probe was modified with a thiol group for attachment to the gold electrode. The base sequence of the probe was

5'-CCACTACCAGGGCACGT-3' (17mer), and that of complementary target DNA was 5'-ACGTGCCCTGGTAGTGG-3' (17mer).

For hybridization, the sample solution containing target oligonucleotides (100 μ M) was introduced to the gold electrode with immobilized oligonucleotide probes. Hybridization was performed at room temperature.

3. Results and Discussion

A gold thin film was deposited by sputtering or vacuum evaporation. The surface roughness of the evaporated film was bigger than that of the sputtered film, as shown in **Fig. 2**. The interface potential of the gold thin film was measured with a Ag/AgCl reference electrode in a phosphate buffer solution (pH 6.86). The stability of the potential was characterized for a shift and a drift after changing the pH of the buffer solution. The potential drift of the sputtered gold film was smaller than that of the evaporated gold film. The stability of the interface potential was considered to be dependent on the surface roughness of the gold film, because rapid diffusion of charged species between the surface of the film and an aqueous solution is affected by the surface morphology.

We introduced artificial dissociation sites at the surface of the gold film. The surface of the gold film was coated with self-assembled monolayers (SAM) of various types of alkane thiol [2,3]. The end of the alkyl chain was chemically modified with functional groups such as amino group, carboxyl group, hydroxyl group and oligonucleotide. **Figure 3** shows the time course of interface potential after the introduction of alkane thiol molecules. In all alkane thiol molecules, the interface potential decreased drastically just after the introduction of each molecules, because the thiol group is negatively charged in aqueous solutions. After the adsorption of alkane thiol molecules with gold surface, the charges on the gold electrode depend on the surface functional groups. This is considered to be due to the difference of dissociation characteristics of the surface functional groups. Moreover, the complementary target DNA has been introduced to the gold electrode modified with oligonucleotide probes and hybridized with them. The interface potential shifted in the negative direction, because DNA molecules have negative charges in an aqueous solution, as shown in **Fig. 4**. Thus, the charge density change due to DNA hybridization on the gold electrode could be successfully detected using EGFET. The proposed EGFET for

detection of oligonucleotide hybridization is useful for realizing a miniaturized and cost effective system for SNP analysis.

4. Conclusions

We proposed potentiometric detection of bio-molecules using extended-gate field effect transistor (EGFET) and investigated potential behavior of gold electrode as extended gate. The stability of the interface potential depended on the surface roughness of the gold electrode. The charge density change due to DNA hybridization as well as the adsorption of thiol molecules on the gold electrode could be successfully detected using EGFET.

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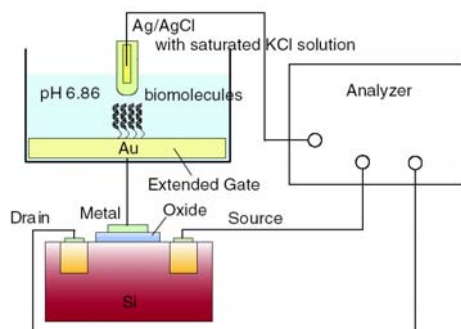


Figure 1 Schematic diagram for measurements of electrical characteristics of extended gate field effect transistor. A gold electrode was used as an extended gate.

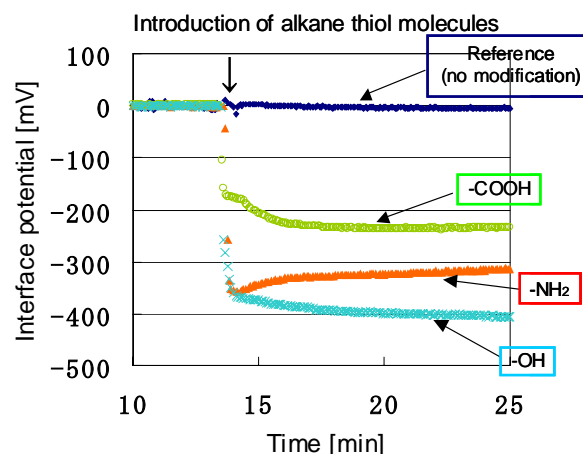


Figure 3 Time course of interface potential after the introduction of alkane thiol molecules for extended gate field effect transistor.

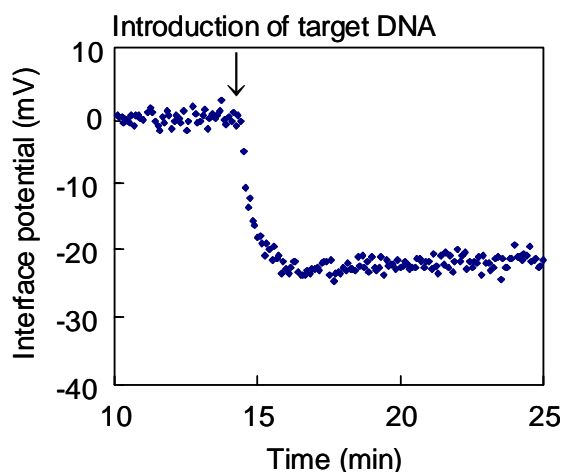
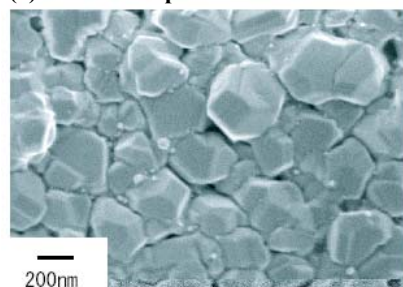


Figure 4 Time course of interface potential after hybridization with target DNA for extended gate field effect transistor.

(a) vacuum evaporation



(b) sputtering

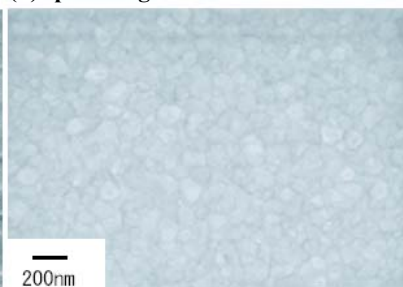


Figure 2 Microstructure of gold film electrode.