Fabrication of BioFET sensor for simultaneous detection of protein and DNA

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There have been various researches into detecting biological molecules, such as protein, RNA, and DNA, which are central to biological processes. Generally, there are optical, spectrometric, electrochemical, and SPR measurement as the method to analyze biological molecules. However, all these methods involve time-consuming, and multi-stage processes that are expensive and unsuitable for on-line monitoring.[1]

To overcome these disadvantages, recently some papers proposed the field effect transistor (FET) type biosensor that was fabricated by using standard semiconductor-processing technology.[2-5] In case of using the FET type sensor for application as a biosensor, it is likely to get standardization, miniaturization, and mass production because its configuration effectively integrates both a sensor and a measurement circuit. Then, it can be easily expected to extend its application scope, in such fields as medical diagnostics, biological research, environmental protection, and food analysis.

In this research, we try to fabricate FET type biosensor, so called BioFET, which is able to detect both protein and DNA simultaneously. It is possible because protein and DNA have a positive charge and a negative charge, respectively. In the operation of a FET, the channel current characteristics are controlled based on the electric field established by applying a voltage between the gate and the body of the semiconductor.[6] Likewise the response of FET type biosensors can be obtained by the electric field on the gate which is established by bio molecules, such as protein and DNA with a charege.

Up to now to get the response for bio molecules, the FET type biosensor generally adopt the amperometric method that obtains the current variation as the response.[4,5] Although we have tried to obtain the response using the amperometric method, it is not easy to take the stable response. For that reason we will try to take another method, so called potentiometry, which is able to get the voltage variations as the response. In the FET type sensor, advantages of the potentiometric method are related to their miniaturization, to their capability of measuring different species on the same silicon chip, and finally to the large-scale production capabilities of the microelectronic industry. Especially, it is able to directly convert the charge variations caused by bio molecules on the gate surface to the response that is recognized as bio molecules. The schematic diagram of the measurement circuit adopting the potentiometric method is shown in Fig. 1. As shown in Fig. 1, the voltage variations as the response are achieved by using a feedback circuit which varies the V_{RS} (voltage between reference electrode and substrate) to maintain the drain current as the charge caused by bio molecules on the gate are changed. Therefore, it is possible that the measurement of the voltage variations of FET can be used as the response of protein and DNA.

The most important step in the fabrication of the FET type protein and DNA sensor is the immobilization of the bio sensing material on the gate surface to capture proteins and DNA. Thus, to capture proteins and DNA effectively, we used the gold gate that is chemically modified by immobilized molecular receptors, so called self-assembly mono-layer (SAM), which is able to combine with protein and DNA specifically. In addition, this is very useful because the SAM is favorably formed on the FET's gate (Au) based on the attachment of a thiol group. In this research, we will use two different kinds of SAMs, such as 11-Mercaptoundernoic acide and 3-mercaptopropionic acid which are able to capture protein and DNA, respectively. Generally, the drain current of a conventional MOSFET is varied by the gate potential. As such, in the case of using the circuit in Fig. 1, it is expected that the charge variations, caused by protein and DNA attached to the gate, will be shown by voltage variations because of the protein and the DNA having the positive and the negative charge, respectively. The fabricated FET which will be used for detecting protein and DNA after forming the SAM on the gate surface is shown in Fig. 2.

In the future, this research will focus on the fabrication of BioFET sensor for simultaneous detection of protein and DNA, and then use the amperometric measurement circuit to obtain the response as a biosensor.

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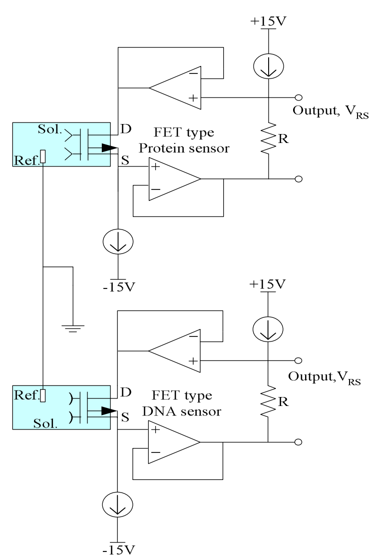

Fig. 1. Schematic diagram of the measurement circuit.

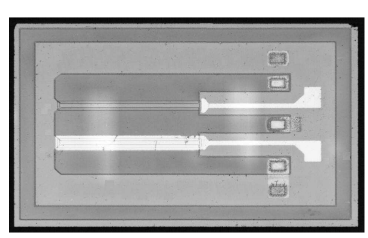

Fig. 2. Photograph of the fabricated FET.