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Graphene-based biological sensors
グラフェンデバイスのバイオセンサ応用

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Chemical and biological molecules were detected with high sensitivity using graphene field-effect transistors (FETs). The ambipolar characteristic was clearly obtained against reference electrodes in a buffer solution and the transconductances were estimated to be 100 times higher than those in vacuum. The detection limit for pH resolution was determined as 0.025. To selectively detect targets such as ions or protein, receptors were modified on graphene channels. The target concentration dependence of the drain currents revealed that graphene FETs effectively detected targets with concentration from several pM to several hundred nM. Therefore, the graphene FET will be useful for hand-held chemical and biological sensors for home medical care.

1. Introduction

Label-free electrical monitoring of biorecognition events provides a promising platform, which is simpler, less expensive and requires less energy. Rapid testing of different proteins is required in various applications, including clinical diagnostics, environmental testing, food analysis, bioterrorism detection technologies, etc.

Graphene, a single honeycomb-like sheet of carbon atoms, have been intensively investigated in most recent due to its extraordinary high mobility even at room temperature [1]. Since graphene has a perfect two-dimensional structure, electrical characteristics in graphene FETs are very sensitive for modulation of surface potentials in graphene channels [2].

In this study, we have demonstrated highly sensitive electrical detection of chemical and biological molecules based on graphene FETs.

2. Experimental

A monolayer graphene was obtained by microme-chanical cleavage of graphite on SiO_2 films. Graphene FETs were fabricated by conventional e-beam lithography and lift-off method [Fig.1(a)]. Figure 1(b) shows an experimental setup for detection of molecules in a solution. A silicone rubber was placed on the graphene FET so that the graphene channel was immersed in a buffer solution [3]. An Ag/AgCl reference electrode was used as the top-gated electrode to minimize environmental effects.

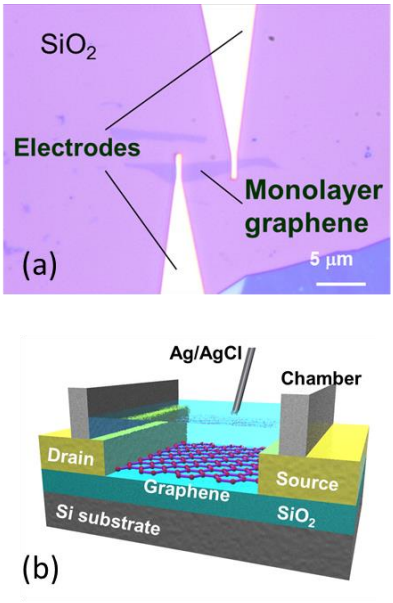

Fig. 1. (a) Graphene FET and (b) measurement system of a graphene FET for sensors.

3. Results and discussion

Solution-gated graphene FETs showed ambipolar characteristics against reference electrodes in a buffer solution and the transconductances were estimated to be 100 times higher than those in vacuum [4]. With increasing pH, the Dirac point shifted to positive direction. The detection limit (S/N = 3) for pH resolution was determined as 0.025 (Fig. 2).

To selectively detect targets such as ions or protein, receptors were modified on graphene channels [5-9]. Atomic force microscopy images

revealed that receptors were successfully immobilized on the graphene channel. The receptor-modified graphene FET showed selective electrical detection of targets. The target concentration dependence of the drain currents revealed that graphene FETs effectively detected targets with concentration from several pM to several hundred nM (Fig.3).

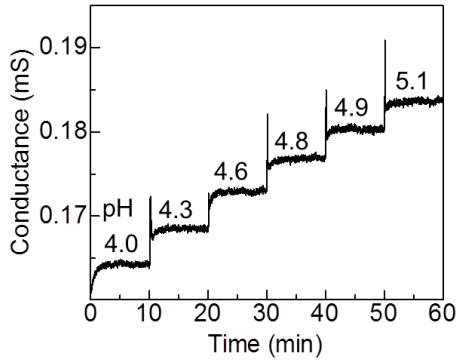

Fig. 2. pH dependence.

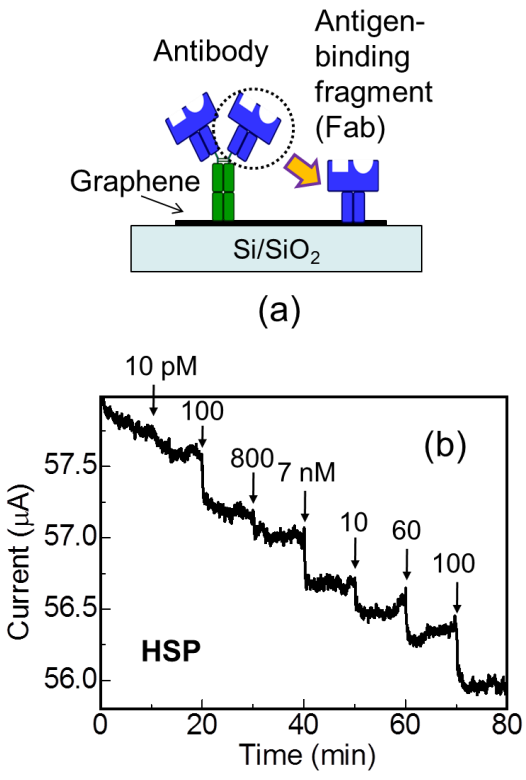

Fig. 3. (a) Fab modified on graphene, (b) target protein concentration dependence.

3. Conclusions

The chemical and biological molecules were detected with high sensitivity based on graphene FETs. When a different kind of receptor is functionalized on each graphene channel in the graphene FET array, many kinds of biomolecules can be electrically detected simultaneously. Therefore, the graphene FET array can be useful for the fabrication of multiplex hand-held chemical and biological sensors for home medical care.

Acknowledgments

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