Graphene oxide linking layers: a versatile platform for biosensing

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Graphene oxide is opening up many new opportunities for biosensing applications. The honeycomb structure of carbon atoms makes possible its interaction with wide range of biological substances via stacking interaction with benzene rings. In addition, graphene oxide possesses different oxygen-containing functional groups, which allows the immobilization of biomolecules through strong covalent bonds. Covalent immobilization could be easily realized using existing biochemical immobilization protocols. Moreover, reduction of graphene oxide can finely tune chemical, electrical and optical properties of carbon material for specific biosensing applications. The main advantage of graphene oxide is the extremely high surface area of different structures made from this material, which provides high immobilization efficiency for wide range of biologically significant substances such as DNAs, RNAs, proteins, including antibodies and membrane proteins, viruses, and bacteria. Furthermore, graphene oxide can be easily produced in the form of water-dissolved flakes, which in turn can be used for scalable production of biosensors components.

Here, we describe a novel type of graphene oxide linking layers for highly sensitive biosensing based on surface plasmon resonance (SPR) [1]. During the last three decades, researchers have used only two technologies of linking layers for SPR biosensors, which are based on self-assembled monolayers of thiol molecules and on hydrogel layers. Using graphene oxide, we developed biosensor chips for existing commercial biosensors, whose sensitivity is higher than for commercial sensor chips available on the market [2] (Fig. 1). Graphene oxide sensor chips show three times higher sensitivity comparing to the sensitive commercial chips based on carboxymethylated dextran when using in the standard biosensing protocol based on streptavidin-biotin interaction. Moreover, the developed sensor chips are bioselective and can be used multiple times with a simple procedure of regeneration. The biosensing protocols based on streptavidin are widely used for the investigation of biochemical reactions with wide range of biological substances without the necessity to attach radiological or fluorescent labels to investigated objects. At present moment, SPR-based label-free biosensing has application in pharmaceutical industry, and it is included in the guidelines of the US Food and Drug Administration and of the European Medicines Agency for the testing of biotechnology-derived pharmaceuticals. Biopharmaceuticals have high molecular masses and reactions with them can be easily investigated by SPR providing many advantages over other methods. However, most of developing drugs are based on low-molecular-weight substances, such as those acting on G-protein coupled receptors (GPCRs), which serve as targets for 40 percent of drugs on the market. At present moment, the investigation of drugs acting on GPCRs by SPR is not conducted due to insufficient sensitivity of SPR biosensors. Therefore, the implementation of graphene oxide linking layers in SPR biosensor chips could broaden the area of pharmaceutical applications of biosensors to all developing drugs and change the whole process of drug discovery and development.

[1] Y.V. Stebunov, O.A. Aftenieva, A.V. Arsenin, V.S. Volkov, ACS Appl. Mat. Interfaces 7 (2015), 21727-21734.
[2] A.V. Arsenin, Yu.V. Stebunov. RU Patent Application No. 2527699 (Feb 2013); US Patent Application No. 20150301039 (Oct 2015).

Figure 1. Biosensor chips based on monolayer graphene, graphene oxide, and carboxyl graphene linking layers designed for use with a commercial SPR instrument.