Biosensors and Bioelectronics 94 (2017) 200–206

Contents lists available at ScienceDirect

Biosensors and Bioelectronics

journal homepage: www.elsevier.com/locate/bios

Graphene oxide functionalized long period grating for ultrasensitive label-free immunosensing

Chen Liu[a], Qi Cai[a,b], Baojian Xu[b], Weidong Zhu[c], Lin Zhang[d], Jianlong Zhao[b,*], Xianfeng Chen[a,*]

[a] School of Electronic Engineering, Bangor University, Bangor LL57 1UT, United Kingdom
[b] State Key Laboratory of Transducer Technology, Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences, Shanghai 200050, China
[c] Department of Applied Science and Technology, Saint Peter's University, NJ 07306, USA
[d] Aston Institute of Photonic Technologies, Aston University, Birmingham B4 7ET, United Kingdom

ARTICLE INFO

Keywords:
Graphene oxide
Biosensor
Antibody-antigen
Long period grating
Label-free
Immunosensor

ABSTRACT

We explore graphene oxide (GO) nanosheets functionalized dual-peak long period grating (dLPG) based biosensor for ultrasensitive label-free antibody-antigen immunosensing. The GO linking layer provides a remarkable analytical platform for bioaffinity binding interface due to its favorable combination of exceptionally high surface-to-volume ratio and excellent optical and biochemical properties. A new GO deposition technique based on chemical-bonding in conjunction with physical-adsorption was proposed to offer the advantages of a strong bonding between GO and fiber device surface and a homogeneous GO overlay with desirable stability, repeatability and durability. The surface morphology of GO overlay was characterized by Atomic force microscopy, Scanning electron microscope, and Raman spectroscopy. By depositing the GO with a thickness of 49.2 nm, the sensitivity in refractive index (RI) of dLPG was increased to 2538 nm/RIU, 200% that of non-coated dLPG, in low RI region (1.333–1.347) where bioassays and biological events were usually carried out. The IgG was covalently immobilized on GO-dLPG via EDC/NHS heterobifunctional cross-linking chemistry leaving the binding sites free for target analyte recognition. The performance of immunosensing was evaluated by monitoring the kinetic bioaffinity binding between IgG and specific anti-IgG in real-time. The GO-dLPG based biosensor demonstrates an ultrahigh sensitivity with limit of detection of 7 ng/mL, which is 10-fold better than non-coated dLPG biosensor and 100-fold greater than LPG-based immunosensor. Moreover, the reusability of GO-dLPG biosensor has been facilitated by a simple regeneration procedure based on stripping off bound anti-IgG treatment. The proposed ultrasensitive biosensor can be further adapted as biophotonic platform opening up the potential for food safety, environmental monitoring, clinical diagnostics and medical applications.

1. Introduction

The development of biosensor is extremely important for the healthcare, clinical analysis, drug discovery, and environmental and security sectors (Marks et al., 2007; Estevez et al., 2014). To overcome the drawback of traditional biosensor which is usually time consuming, complicated, labeling required and hazardous, fiber optic sensing technology has been proposed by employing fiber Bragg gratings (FBGs), long period gratings (LPGs), and tilted fiber gratings (TFGs) with the advantages of label-free, real-time, multiplex and in-line determination (Wang and Wolfbeis, 2013; James and Tatam, 2003; Albert et al., 2013; Cusano et al., 2014; Zhou et al., 2004). However, the major challenge in fiber sensor field is the lack of sensitivity for applications with small biomolecules and low concentration of analyte (Fan and White, 2011; Canning, 2009). To improve the biosensing performance, techniques have been developed to accelerate the device sensitivity, for instance by cladding etching, side polishing and fiber tapering (Chen et al., 2005; Jang et al., 2009; Zhao et al., 2004; Ding et al., 2005). Instead of sacrificing of mechanical integrity, more elegant approaches have been investigated either by novel design of grating structures or by the deposition of thin overlay. The dual-peak LPG (dLPG) operating near the dispersion turning point owns intrinsic high sensitivity to the change of surrounding-medium refractive index (SRI) (Shu et al., 2002; Chen et al., 2007). The coating of thin film induces strong changes on the LPG transmission properties (Marques et al., 2016; Villar et al., 2005; Cusano et al., 2006; Pilla et al., 2012).

* Corresponding authors.
E-mail addresses: jlzhao@mail.sim.ac.cn (J. Zhao), x.chen@bangor.ac.uk (X. Chen).

http://dx.doi.org/10.1016/j.bios.2017.03.004
Received 28 December 2016; Received in revised form 28 February 2017; Accepted 5 March 2017
0956-5663/ © 2017 Elsevier B.V. All rights reserved.

Various fiber optic biosensors have been produced for the detection of protein (Lepinay et al., 2014), bioaffinity of antibody-antigen (Chiavaioli et al., 2014; DeLisa et al., 2000; He et al., 2011), DNA hybridization (Chen et al., 2007; Yin et al., 2013), cellular behavior (Shevchenko et al., 2014), enzyme-glucose binding (Deep et al., 2012; Luo et al., 2014), biotin-streptavidin (Voisin et al., 2014) and bacteria (Brzozowska et al., 2015).

To date, the advancement of nanotechnology plays an essential role in the exploration of multidisciplinary fields including physics, chemistry, materials, medicine and biotechnology. Biosensing benefited by nanotechnology is based on advanced materials and nanostructures as transducer elements or reporters. Graphene has attracted great excitement since its discovery (Novoselov et al., 2004; Geim, 2009). The extraordinary mechanical, electrical, chemical and optical properties make graphene a very promising carbon-based nanomaterial for widespread applications such as field-effect transistor, ultracapacitor, energy storage, sensor and ultrafast laser (Zhou et al., 2017; Bonaccorso et al., 2010, Bao et al., 2009; Bao et al., 2010). Moreover, graphene oxide (GO) displays advantageous characteristics for biosensing due to its excellent capabilities in biocompatibility, solubility and selectivity (Morales-Narváez and Merkoç, 2012; Wang et al., 2011; Loh et al., 2010). GO contains both sp^2- and sp^3-hybridized carbon atoms as well as different oxygen-containing functional groups such as hydroxyl, epoxy, carboxyl on its basal plane and sheet edges, which can be used for immobilization of biomolecules (Dreyer et al., 2010; Chen et al., 2012). The enriched functional groups can interact in an ionic, covalent or non-covalent manner, so that in principle they provide the highest extraction efficiency of biomolecules per unit area (Loh et al., 2010). In recent years, the functionalized GO has been exploited to fabricate biosensors for drug delivery (Liu et al., 2008; Zhang et al., 2010a), bioimaging in living cells (Wang et al., 2010; Sun et al., 2008), the detection of cancer cell (Tao et al., 2013), glucose (Song et al., 2010), DNA (Liu et al., 2010a; Gao et al., 2014), enzyme (Zhang et al., 2010b), protein (Liu et al., 2010b), peptides (Han et al., 2010), and cellulose and lignin (Yang et al., 2010).

We report an ultrasensitive fiber optic biosensor utilizing GO layer coated on fiber grating device as the linking interface for label-free immunoassay detection. In this work, for the first time, we propose a new GO deposition method based on the chemical-bonding in conjunction with physical-adsorption. As the schematic illustration in Fig. 1, the dLPG coupled the light from fiber core to cladding serving as an optical transducer. The GO layer was coated over the dLPG surface and then immobilized by bioreceptor IgG leaving the binding sites free for specific anti-IgG recognition. The kinetic binding between antibody and antigen altered the dLPG transmission spectrum and was monitored in real-time as a change in local refractive index (RI), thereby eliminating the need of analyte labeling. The GO-dLPG based biosensor with extremely enhanced sensitivity can detect the optical signal change due to biochemical, bioaffinity, immunogenic interactions occurring within the evanescent field.

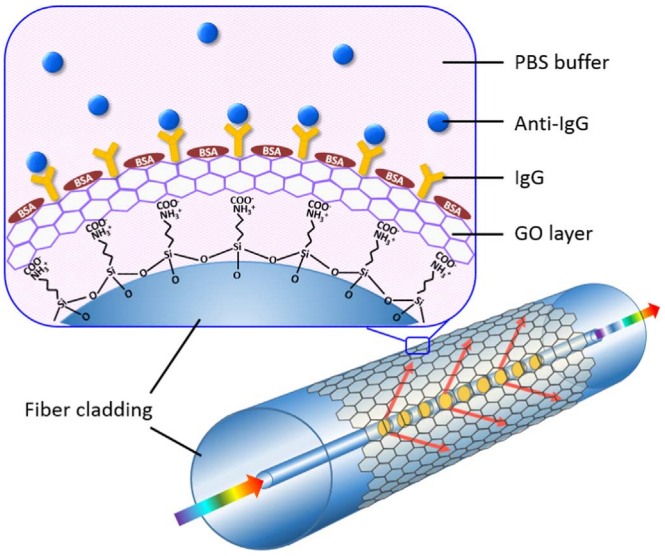

Fig. 1. Schematic diagram of fiber optic biosensor comprising the dLPG coated with the graphene oxide linking layer, which provides a remarkable analytical platform for bioaffinity binding between pre-immobilized IgG and target anti-IgG.

2. Materials and methods

2.1. Materials

The aqueous dispersion of graphene oxide (2 mg/mL), Sodium hydroxide (NaOH), (3-Aminopropyl)triethoxysilane (APTES), N-(3-Dimethylaminopropyl)-N′-ethylcarbodiimide hydrochloride (EDC), N-Hydroxysuccinimide (NHS), Bovine serum albumin (BSA), Rabbit IgG, Goat Anti-Rabbit IgG and phosphate buffered saline (1×PBS, pH 7.4) were purchased from Sigma-Aldrich (United Kingdom). Hydrochloric acid (HCl), methanol, ethanol, acetone, and deionized (DI) water were purchased from Thermo Fisher Scientific Inc. (United Kingdom).

All chemical and biochemical reagents were of analytical grade and were used as received without further purification. All aqueous solutions were prepared with DI water.

The silica single-mode fiber (SMF-28, cladding diameter 125 μm) was purchased from Corning.

2.2. Fabrication of dual-peak long period grating

The dLPG with period of 162 μm and length of 30 mm was inscribed in a hydrogenated single-mode fiber by a CW frequency-doubled Ar laser at 244 nm wavelength. The point-by-point method over multiple iterations was employed to achieve the dual-peak feature. After UV fabrication, the dLPG was annealed at 80 °C for 48 h to remove the residual hydrogen and to stabilize the optical properties.

2.3. Functionalization of GO-dLPG sensor

Deposition of graphene and its derivatives on fiber surface could enhance the performance of optical fiber devices (Wu et al., 2014; Sridevi et al., 2016). However, the lack of efficient transfer techniques limited the usage of graphene and GO for fiber device with cylindrical shape and small diameter.

In this work, we develop the GO deposition on the optical fiber surface by APTES as cross-linking agent followed by physical adsorption. Immobilization of biomolecule plays a crucial role in generating a biosensor with high sensitivity, stability and durability. The device surface must be modified to introduce functional groups, which can immobilize bioreceptor on the surface serving as an analytical platform for biological events.

2.3.1. Surface silanization and GO deposition

Fig. 2 plots the schematic scheme of the functionalization of a GO-dLPG as a label-free biosensor. The section of silica fiber over the dLPG region was cleaned by the use of acetone solution for 30 min to remove the organic contaminant, rinsed with DI water thoroughly and dried. Then the fiber device was immersed in 1.0 M NaOH solution for 1 h at room temperature to enrich the number of silanol (Si-OH) groups on the surface and washed with ethanol and DI water for three times respectively (Fig. 2a).

For the silanization, the alkaline-treated fiber was firstly incubated into a freshly-prepared 5% (v/v) APTES ethanol solution for 1 h, which mainly reacted with hydroxyl groups to form Si-O-Si bonding, followed by washing with ethanol to remove unbound monomers and baked in an oven at 70 °C for 30 min to enhance the stability of APTES monolayer (Fig. 2b).

Download English Version:

https://daneshyari.com/en/article/5031045

Download Persian Version:

https://daneshyari.com/article/5031045

Daneshyari.com