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The enhancement method of optical fiber biosensor based on surface plasmon resonance with cold plasma modification

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ABSTRACT

Cold plasma modification on optical fiber biosensor based on surface plasmon resonance (SPR) is proposed to enhance the SPR effect on biosensing. A side-polished multimode fiber sensor based on surface plasmon resonance as the transducing element with a halogen light source is carried out for the measurement of the BSA for the sensitivity analysis. The comparison with detection surface was fabricated by binding chemically to self-assembly monolayer (SAM) of 11-mercaptoundecanoic acid (MUA) and cold plasma modification method on gold (Au) surface of optical fiber, and then was activated by EDC/NHS for BSA. The pretreatment of cold plasma modification using isopropanol (IPA) to deposited carboxyl group on side-polished surface of optical fiber biosensor, and there are easily to combine biomolecule by EDC/NHS modification. The results of the comparison between traditional surface modification and cold plasma modification with the measurement for 5 ng BSA is observed on OSA and shifted obviously in wavelength. The side-polished fiber sensor based on surface plasmon resonance can provide the SPR response on spectrum, and the IPA plasma treatment can increase the sensitivity of the SPR dip shifted with 10–40 nm under the 10 min treatment time of the surface modification.

1. Introduction

Over the past decade, surface plasmon resonance (SPR) has been used in a wide range of chemical and biological sensing applications. SPR is a charge density oscillation that may exist at the interface of two media with dielectric constants of opposite sign, for instance, a metal and a dielectric. The excitation of a surface plasmon wave leads to the appearance of a dip in the measurement results, and the intensity of the reflected light is considered in determining the sensitivity of the SPR sensing. The first use of SPR for prism coupling was proposed in 1968 by Kretschmann [1]. Since Jorgenson and Yee proposed using optical fibers for SPR sensing in 1993 [2], many types of optical fiber sensor have been proposed, including single-mode dip fibers [3], single-mode D-type fiber [4], and D-shaped fibers [5]. In recent years, studies of SPR sensing systems have been focused on the attenuated-total-reflection geometry obtained by use of prism-coupling optics and the systems of optical fiber sensors that need some bulky structures or complicated signal processing to improve their high sensitivity. Therefore, the side-polished multimode fiber sensor provides the simple structure and system for chemical and biological sensing with high sensitivity in wavelength interrogation [6,7], and it also proves the high detect limited on biomolecular [7,8]. Surface modifications of materials have become an important object to study because of they can maintain bulk's properties but just change their surface structure [9].

In this study, cold plasma modification on optical fiber biosensor based on surface plasmon resonance (SPR) is proposed to enhance the SPR effect on biosensing. The comparison with detection surface was fabricated by binding chemically to self-assembly monolayer (SAM) of 11-mercaptoundecanoic acid (MUA) and cold plasma modification method on gold (Au) surface of optical fiber, and then was activated by EDC/NHS for protein BSA. The pretreatment of cold plasma modification using isopropanol (IPA) to deposited carboxyl group on side-polished surface of optical fiber biosensor, and there are easily to combine biomolecule by EDC/NHS modification. The results of the comparison between traditional surface modification and cold plasma modification with the measurement in wavelength for BSA is observed on OSA and changed obviously.

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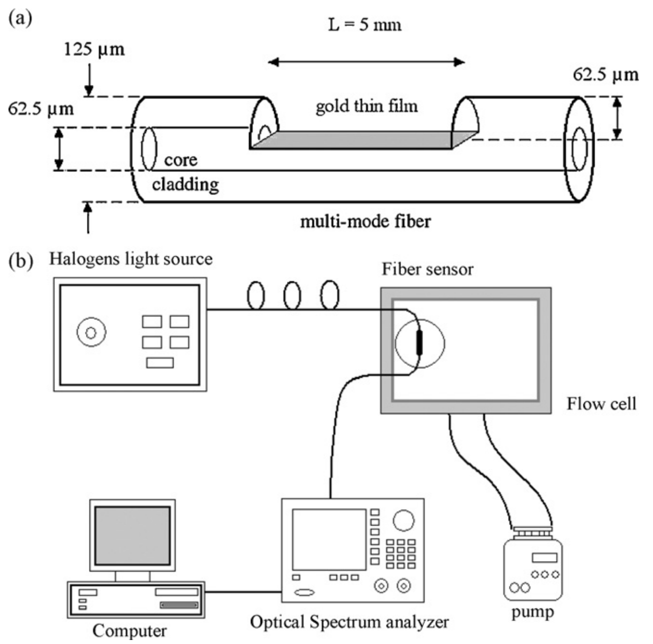

Fig. 1. (a) A single SPR fiber biosensor with the lengths of sensing area of 5 mm and (b) The measurement system diagram of SPR fiber biosensor.

2. Fabrication of SPR fiber sensors

All fiber used for this paper are the (POFC) graded-index multimode fiber (MMF-625) with 62.5 μm in core diameter and 125 μm in cladding diameter, and have the small insertion losses (<0.05 dB). The single side-polished fiber configuration with gold layer is illustrated in Fig. 1(b). The graded-index multimode fiber with 62.5 μm core diameter and a 125 μm cladding diameter fabricated by Prime Optical Fiber Corporation (POFC) was used in the experiment. For a high yield rate polishing processes, a silicon V-groove must be fabricated and be used to hold bare fibers for polishing. We take 4 inches silicon (1 0 0) wafer to grow up oxides layer and process the photolithography to etch SiO_2 channel by HF 25%. The V-groove channel is etched by KOH 45.3%, and the channel length and width is 5 mm and 125 μm, respectively. The multimode fiber mounted on the V-groove holder with photoresist and monitored by optical microscopy. After the photoresist had become hard, we polished fibers embedded in wafer using polishing diamond films with the grain size of 6 μm, 1 μm and 0.1 μm in turn. In order to increase the sensitivity of the SPR measurements, the polished surface set the length of 5 mm and the depth of 62.5 μm down to the fundamental mode region. The polished breadth of 125 μm is confirmed by optical microscope. The side-polished fiber established total reflective structure and combined the gold thin film in order to integrate the SPR fiber sensor.

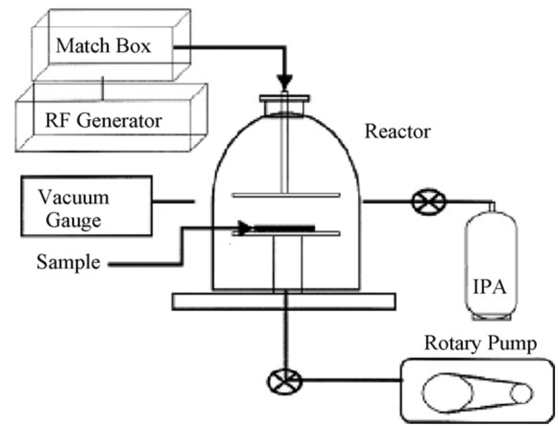

Fig. 2. Schematic diagram of plasma CVD system equipped with a bell-jar reaction chamber.

The gold thin film was deposited by dc sputter system (ULVAC Co., Japan). The gold thin layer was coated by a sputtering method on the polishing surface. During the deposition the vacuum chamber was evacuated 4×10^{-2} Torr, the background pressure was 2×10^{-5} Torr.

3. Experiment system

The schematic diagram of the optical system is shown in Fig. 1(b). The sensing system consists of a halogens light source, a side-polished sensing fiber with flow cell, peristaltic pump, and an optical spectrum analyzer (OSA). A halogen white light source (Ando Electric Co., Ltd. AQ4303B) and an OSA (optical spectrum analyzer, Ando Electric Co., Ltd. AQ6315A) are setup, as sketched in Fig. 4, for SPR sensing measurement. The light source covers the band of 400–1800 nm and provides highly stable optical outputs with a deviation of ±0.05 dB. The peristaltic pump (CZ-77120-42, Cole-Parmer Instrument Co., USA) is a variable-speed tubing pumps. The Pump System can accommodate two tubes simultaneously for the 6 rpm and 60 rpm systems at controlled

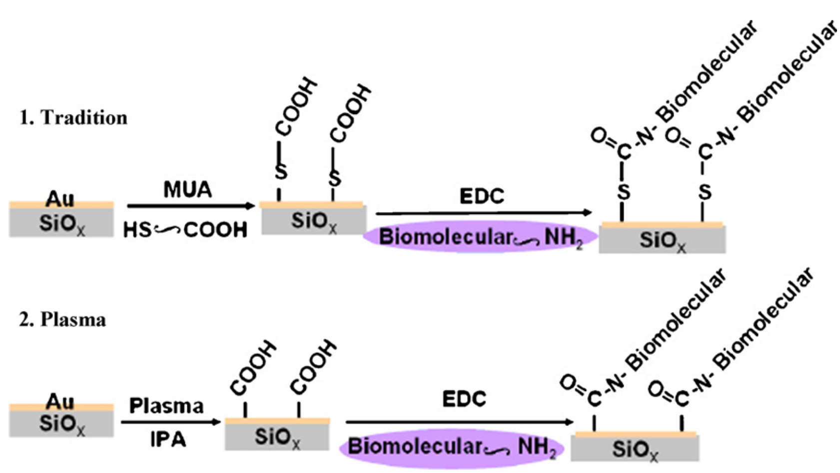

Fig. 3. The sketch map of the surface modification with the traditional surface modification and cold plasma modified.