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A low cost surface plasmon resonance biosensor using a laser line generator

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ABSTRACT

Due to the instrument designed by using a common surface plasmon resonance biosensor is extremely expensive, we established a portable and cost-effective surface plasmon resonance biosensing system. It is mainly composed of laser line generator, P-polarizer, customized prism, microfluidic cell, and line Charge Coupled Device (CCD) array. Microprocessor PIC24FJ128GA006 with embedded A/D converter, communication interface circuit and photoelectric signal amplifier circuit are used to obtain the weak signals from the biosensing system. Moreover, the line CCD module is checked and optimized on the number of pixels, pixels dimension, output amplifier and the timing diagram. The micro-flow cell is made of stainless steel with a high thermal conductivity, and the microprocessor based Proportional-Integral-Derivative (PID) temperature-controlled algorithm was designed to keep the constant temperature (25 °C) of the sample solutions. Correspondingly, the data algorithms designed especially to this biosensing system including amplitude-limiting filtering algorithm, data normalization and curve plotting were programmed efficiently. To validate the performance of the biosensor, ethanol solution samples at the concentrations of 5%, 7.5%, 10%, 12.5% and 15% in volumetric fractions were used, respectively. The fitting equation $\Delta RU = -752987.265 + 570237.348 \times RI$ with the R-Square of 0.97344 was established by delta response units (ΔRUs) to refractive indexes (RI). The maximum relative standard deviation (RSD) of 4.8% was obtained.

1. Introduction

Surface plasmon resonance (SPR) biosensors are designed and widely used in the detection and identification of viruses, hormones and proteins in field such as food safety, biomedical, disease diagnosis and proteomics due to their non-invasive, label-free and on-line dynamic properties of measurement [1–5]. Furthermore, it is a useful and important technology to be studied on biomolecular interactions when one of the two interactants is immobilized onto the sensor surface first, while the other is free in sample solution and also flowed over the sensor surface [6–9]. The processes of the association and dissociation were monitored by and displayed in a response curve in arbitrary unit. A surface plasmon is produced by a p-polarized laser beam which impinges on the interface between the glass (prism) and the metal film (Au film) deposited on the glass surface when the incident angle of the laser beam is larger than the angle of total internal reflection [10–15]. A typical surface plasmon wave propagating along the interface can be realized by the so-called Kretschmann configuration [16–18]. The special angle at which the surface plasmon resonance occurs is extremely sensitive to any changes in the refractive index of the medium adjacent to the metal surface, and such changes can be monitored by recording the intensity of reflected light when the sample solution is flowed through the microfluidic cell [19–21].

Although surface plasmon resonance is a powerful technique to analyze biomolecular interactions in real-time in a label free environment, at present, the cost of the instrument designed by the surface plasmon resonance technology is still extremely expensive due to the complicated configuration of optics and electronics. In practice, the portable and cost-effective surface plasmon

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resonance instruments are urgently developed and have potential for use in many fields including medicine diagnostics, drug screening and basic scientific research [22–27]. With the ongoing requirements of low cost and portable instruments, we present in this work a portable surface plasmon resonance biosensor for identifying the biomoleculars in sample solutions, which consists of the laser line generator and the line CCD array. In order to reduce the cost of this biosensor, the circuit, that is mainly composed of a line CCD array, a microprocessor PIC24FJ128, and communication interface, should be economically designed. In order to keep the temperature of the microfluidic cell and biosensor constant, the Thermal Electric Chip (TEC) with the control algorithm (PID) is applied and optimized to adjust the current flowing through the TEC according to the atmosphere temperature. A comprehensive optimization analysis on the biosensor designed by using the laser line generator to obtain the performance parameters regarding the dependence of sensitivity on optics and electronics is presented in this work.

2. Materials and methods

2.1. Materials

The laser line generator (dimension ⌀16 mm × 45 mm, wavelength 780 nm, beam divergent angle 65°) was purchased from SFOLT Co., Ltd (Shanghai, China). The high speed acquisition circuit board with line CCD array (UPD3575 module) was purchased from Tianjin Brilliance Photoelectric Technology Co., Ltd. BK7 prism with 50 nm Au film was customized in Changchun Dingxin photoelectric Co., Ltd. The optical adjustment bracket for holding the right angle prism was fabricated in Henan Nongda Xunjie Measurement and Testing Technology Co., Ltd. Ethanol and PBS were purchased from Shanghai General Chemical Reagent Factory (Shanghai, China).

2.2. Setup of the SPR biosensor

The schematic diagram for constructing the surface plasmon resonance biosensor is depicted in Fig. 1. From Fig. 1c, it is known that the evanescent wave produced from the total internal reflection acts on the prism can excite a standing charge density wave on the gold surface [17]. A surface plasmon wave will be produced by the standing charge density at the interface between the metal film and biological medium, which is a P-polarized electromagnetic wave due to P-polarized light being parallel to the incident plane while the S-polarized light being perpendicular to the incident plane.

For the biosensor constructed by a prism with the coupling method of the attenuated total reflection, the propagation constants of the incident light wave and the surface plasmon wave along the *x*-axis will be obtained in the following equations:

$$K_x^{pr} = \sqrt{\epsilon_{pr}}\frac{\omega}{C}\sin\theta_{pr} \quad (1)$$

$$K_x^{sp} = \sqrt{\frac{\tilde{\epsilon}_m \epsilon_s}{\tilde{\epsilon}_m + \epsilon_s}}\frac{\omega}{C} \quad (2)$$

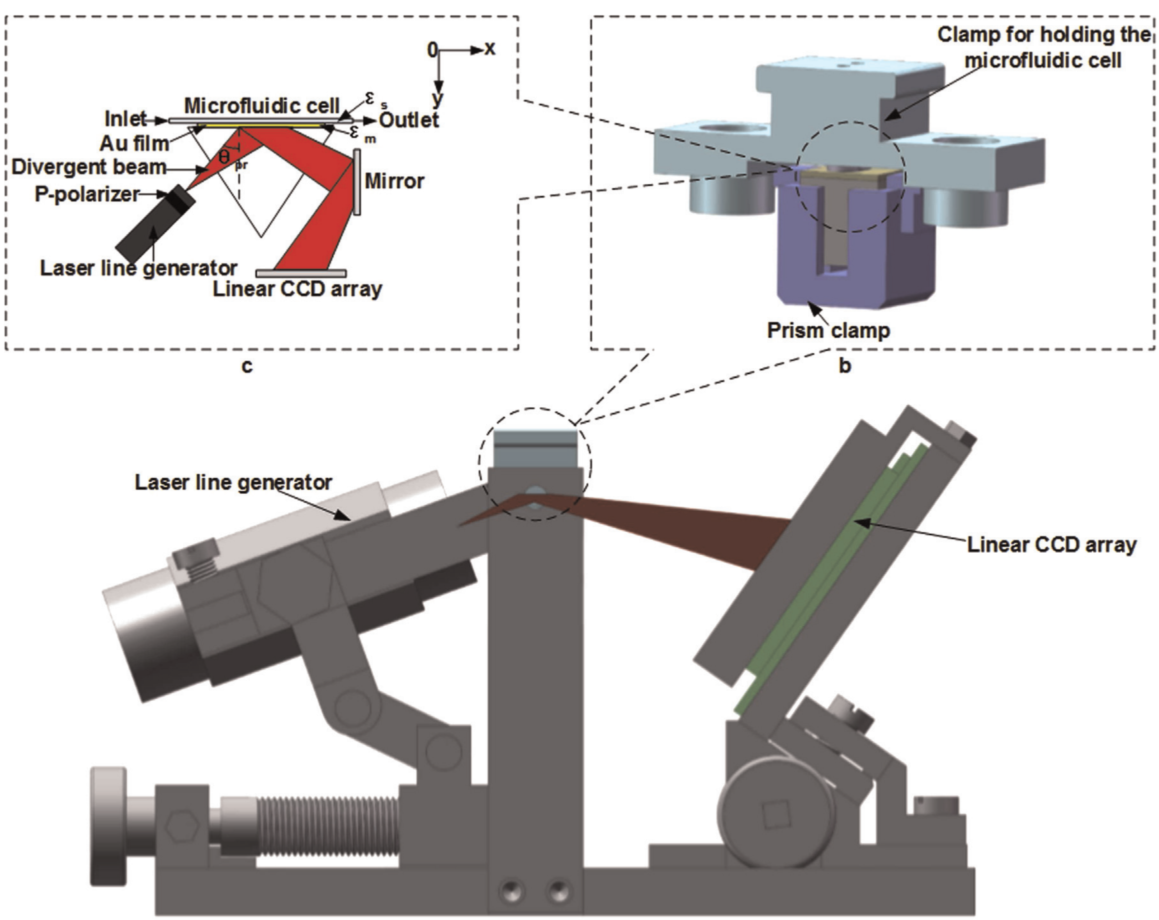

Fig. 1. Schematic of the surface plasmon resonance biosensor using the laser line generator and a linear CCD.