A Fiber Optic Biosensor Detecting System of Laser-Processed Micro Channels

Zhong-chen Bai, Shui-jie Qin, Xin Zhang, Zimi Zhang

Key Laboratory for Photoelectric Technology and Application Guizhou university Guiyang 550025 China yufengvc@163.com; sjqin@mail.gzest.gov.cn; Ie.xzhang@gzu.edu.cn; zzm.malone@gmail.com

ABSTRACT

With the development of micromachining technology, smart micro sensors have been a very potential technology. A novel fiber optic biosensor and it's detecting system are designed in the paper. Micro-flow patch of the fiber optic biosensor is fabricated by high power laser on PMMA material. The probe of cone surface is fabricated by chemical etching method on mutilmode fiber. The probe of molecular recognition is engraved by high power laser on the probe of cone surface. ZnSe nano crystal cluster marking with glucose molecules is used for verifying feasibility of the fiber optic biosensor. It is shown that Tapered angle of the probe of fluorescence received affected the experimental results. Tapered angle of the probe of fluorescence received depends on chemical etching time. Microchannels can solve center aim of the two the probe of molecular recognition and fluorescence received. When concentration of detecting sample is brought down, fluorescence of individualistic cluster will become remarkable in 80 μm microchannels.

Keywords: *Fiber optic biosensors; Micro channels; Laser-processing; Tapered angle*

1 INTRODUCTION

With the development of micromachining technology, smart micro sensors have been a very potential technology[1-4]. Especially，with the development of laser processing technology, the method of fabricating smart devices becomes more and more feasible, and products can be easily modified and secondary operated. Other methods are difficulty to solve it. Some microchanels products based on micromachining technology have been put into market, such as inkjet tube of laser printer. Laser micromachining technology has a lot of merits, such as 3D sample fabricated by high power laser, hard material that can not be processed by IC technology[5].

The fiber optic biosensor have been a rising and applied widely technology[6-7]. The fiber optic biosensor can realize long distance and real time detection, particularly, detecting disadvantage environment of human health has a lot of individual advantages. Presently, the fiber optic biosensor was researched by many institutions all over the world. Many results have been equipped with army and put into the market. General, many fiber optic biosensors have all many defect, such as weak signal of receiving fluorescence, mismatch mode between optic fiber and signal light etc. A novel fiber optic biosensor is designed in the paper. Microchannels which diameter is micron were used as detecting sample room[8-9], which not only can cut down sample consumption but also can realize center leveling between probe of molecular recognition and the probe of fluorescence received.

2 FIBER OPTIC BIOSENSOR DETECTING SYSTEM

The detecting system of the fiber optic biosensor includes four parts(figure1), the light source, the fiber optic biosensor, the signal receiver, the real time observation. Light source is selected by characteristic of fluorescent molecules spectrum. ZnSe nano crystal cluster[10] which the wavelength width is from 260nm to 420nm is used for marking fluorescent molecules in the paper. The signal receiver is constitutes of band pass filter, light sensitive CCD and photon counter. The real time observation is composed by optical microscope, control computer and image software.

Firstly, the light from the light source gets into the fiber optic biosensor. Mix signal from the fiber optic biosensor goes through band pass filter. Noise signal is filtered. Secondly, signal light is received by light sensitive CCD and is amplified by photon counter. The data is obtained by photon counter. At the same time, the real time process of the fiber optic biosensor passes through microscope. The control computer is used for recording it.

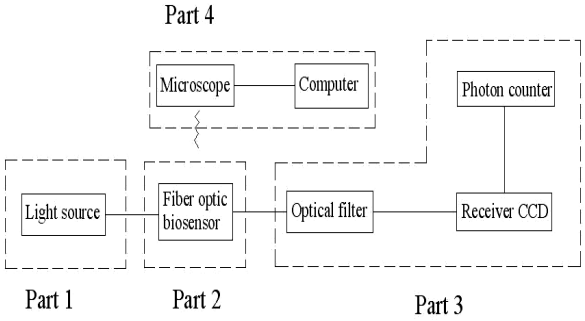

Figure 1 The detecting system of the fiber optic biosensor

2.1 Structural design of the fiber optic biosensor

The construction of the fiber optic biosensor is a very important part and it influences the results of the system. The construction of the fiber optic biosensor is figure.2.

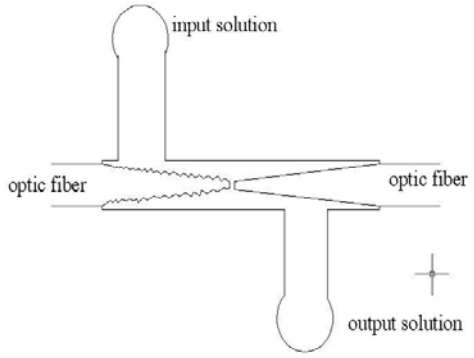

Figure 2 Schematic of the fiber optic biosensor

Many fiber optic biosensors all have the problem that the probe centre of molecular recognition and fluorescentce received can not aim. Microchannles are used for confining moving width of optic fiber, which realized easily centre aim of the two optical fibers. The construction of the fiber optic biosensor consists of the probe of molecular recognition, the probe of fluorescence received, sample entrance and liquid waste vent.

2.1.1 Laser processing microchannels

Nd:YAG high power laser(wavelength 1064nm) is used for fabricating microchanels on PMMA material. Microchannels which diameter is microns are fabricated on PMMA material by adjusting pulse width of laser, scanning speed and power of laser. Micro-flow patch of the fiber optic biosensor is fabricated by forth part: microchannels of detecting sample, liquid storage container, microchannels of sample and liquid waste. Micro-flow patch of the fiber optic biosensor fabricated by laser is cleaned by ultrasonic cleaner.

2.1.2 Fabrication of the optical fiber probe

The two multimode optical fibers are selected. Sheath and lading of optic fiber is divested in the width of 300 μm at the end; then, Absolute alcohol is used for cleaning optic fiber, which put into HF solution. The probe is etched cone surface by HF solution(Figure3). The size of cone surface depends on etching time. One of the two optic fibers is used for the probe of molecular recognition. The probe surface of molecular recognition is engraved scraggly cone surface by high power Laser (wavelength 1.06 μm) and cleaned by deionized water, then SDBS is used for cleaning it. Another of the two optical fibers is used for the probe of fluorescence received.

The fiber optic biosensor can be assembled by Micro-flow patch of the fiber optic biosensor, the probe of molecular recognition and fluorescence received, cove plate. Firstly, the probe of molecular recognition and fluorescence received are fixed respectively one side the microchannel of entrance and exit of sample. At the same time, the two optic fibers is centre aim. Then, a cove plate is coved on micro-flow patch of the fiber optic biosensor, and is sealed up. Thus, the fiber optic biosensor is assembled completely.

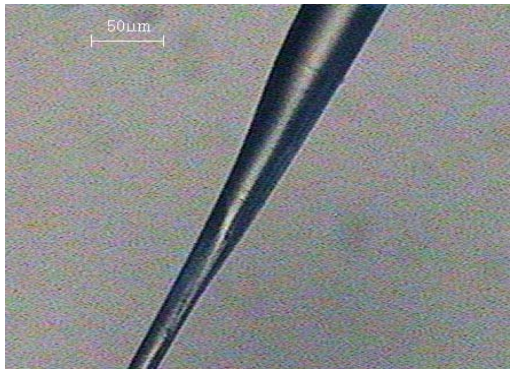

Figure 3 Cone surface fiber by chemical etching

2.2 Relation between minimum fluorescent receiving angle θ_1 and optic fiber tapered angle β of the probe of fluorescent receiving

The fluorescent receiving probe is indicated in figure4. As fluorescence is not loss and can be transmitted long distance in the optic fiber, the incident angle must greater than or equal with critical angle θ_3 for total reflection. n_1, n_2 denote respectively relative refractive index of the optic fiber core for detecting solution and cladding. under relation can be get from law of refraction:

$$\frac{\sin\theta_1}{\sin\theta_2} = n_1 \quad (1)$$

When the receiving fluorescence can nicely happen total reflection, one can get

$$\sin\theta_3 = \frac{1}{n_2} \quad (2)$$

Geometric relation from figure 4 can get formula (3):

$$\sin(\beta + \theta_2) = \sin\theta_3 \quad (3)$$

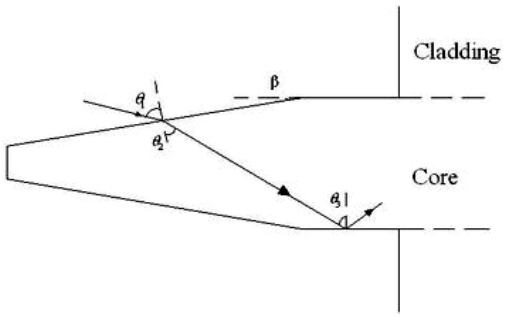

Figure4 Profile of the probe of fluorescence received

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By (1),(2),(3), we can get formula (4)

$$\sin\beta\sqrt{n_1^2-\sin\theta_1^2}+\cos\beta\sin\theta_1=\frac{n_1}{n_2} \qquad (4)$$

Form formula (4), we know when optic fiber is selected, n_2 is certain, so θ_1 depends on β. β can affect what the fluorescence received light is.

3 EXPERIMENT

3.1 Experiment sample preparation

Se(selenium) and Na_2SO_3(sodium carbonate) are dissolved in water of 90 degree and magnetic stirring four hours, which can gain Na_2SeSO_3 solution-(1); $Zn(AC)_2$(zinc acetate) is dissolved in water and add to $C_2H_4O_2S$（mercapto-acid）, next, add NaoH (sodium hydroxide), and adjust PH=8, which add to (1) solution by N_2 protected and magnetic stirring nine hours at 90 degree, which can synthesize ZnSe nano crystalline cluster of shell-core structure. Concentration of 0.04mmol/ml solution is prepared.

Glucose solution is prepared by concentration of 0.04mmol/ml solution is 2ml. Glucose solution and ZnSe solution are mixed in test tube. Mixture solution is stood 10 minute at 30 centigrade degree. Detecting sample solution is prepared.

3.2 Let in sample

Detecting samples is injected into liquid storage container of entrance of the fiber optic biosensor, which is let in micro-flow patch of the fiber optic biosensor by capillary force. The fiber optic biosensor is observed by microscope. When detecting sample solution is full of microchannels, microcahnnels is bright. Or, the microchannels is black. Owing to detecting solution is full of microchannels, refractive index is highlighted. So microchannels is bright.

4 RESULTS AND ANALYSIS

4.1 The result on microscope

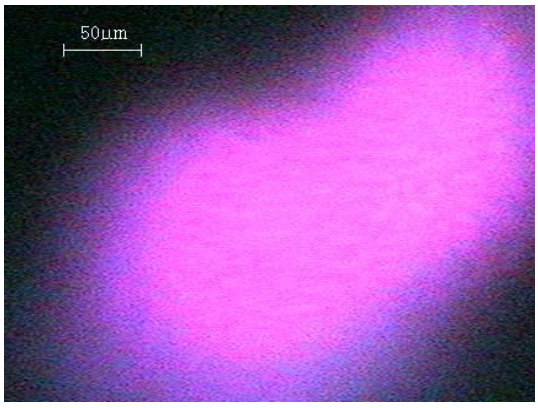

Figure 5 (a) The fluorescence of the probe of molecular recognition.

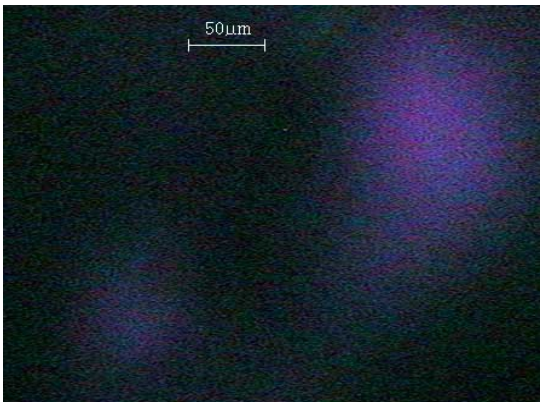

Figure 5 (b) The receiving fluorescence of the probe of fluorescence received.

The round fluorescence of the probe of molecular recognition and fluorescence received is observed from control computer(figure5a and figure5b). The fluorescent intensity of the two probes is different from figure5a and figure5b.

4.2 Efficiency of fluorescence received affected by the several factor

When between the probes center of molecular recognition and fluorescence received can not aim in the experiment, fluorescence received is markedly reduced. When the two optic fibers center deviates more, fluorescence received is very weak or hardly is seen. When the two optic fibers center can not aim, fluorescence can not get into the probe of fluorescence received. Even if some fluorescence can get into the probe of fluorescence received, according to formula (4), total reflection can not happen and loss in optic fiber.

Fluorescence received is affected by adjusting tapered angle of the probe of fluorescence received. By equation $\sin\beta\sqrt{n_1^2-\sin\theta_1^2}+\cos\beta\sin\theta_1=\frac{n_1}{n_2}$, if adjusting rationally β, θ_1 can be changed accordingly. The efficiency and intensity of fluorescence received is also changed.

4.3 Results affected by concentration of detecting sample

In cases of 80 μm microchannels, adjusting concentration of detecting sample, fluorescence received by photon counter is changed accordingly. Owing to bring down concentration of detecting sample, fluorescence of individualistic cluster will become remarkable.

5 CONCLUSION

Construction of the fiber optic biosensor based on laser processing microchannels technology is designed, which can reduce sample consumption and solve the problem of centre aiming of the probe of molecular recognition and fluorescence received. Such construction can also rise the efficiency of fluorescence received. The probe of cone surface optic fiber is fabricated successfully by chemical etching method. The probe of molecular recognition of the fiber optic biosensor is craved scraggly cone surface by high power Laser (wavelength 1.06 μm) and is cleaned by deionized water. The factor of fluorescence received efficiency is analyzed. The result is shown in photon counter: with increasing of counter time, output fluorescent photon counter will become stability. When concentration of detecting sample is brought down, fluorescence of individualistic cluster will become remarkable.

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