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RESEARCH PAPER

A Cantilever Array Sensor Platform Guided by Optical Fibers and Its Sensing Application

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Abstract: A cantilever array sensor platform was developed based on the optical lever method, and the cantilever array chip was also fabricated to introduce its applications on biochemical detection. Optical fibers coupled to lasers were used as the scanning light source. This sensor system had good stability, and the noise of the detection signal was about 2 nm. Meanwhile, the cantilevers of the fabricated chip had good straightness and were consistent to temperature response, and the deviations of the response sensitivity for cantilevers' temperature change were no more than 5.0%. This sensing system was used to detect Hg^{2+} in aqueous solution within a concentration range of 1–200 ng mL^{-1}. The deflections of one array chip were close in the same concentration, and the average deviation was less than 15%. The samples with the concentrations of 1.0 and 0.2 ng mL^{-1} Hg^{2+} were detected separately by the fabricated chip and a foreign commercial chip on the sensor platform. The result showed that it was difficult for the fabricated chip to achieve a higher detection sensitivity and necessary to improve the cantilever array production process.

Key Words: Biochemical sensor; Optical fiber; Cantilever array; Mercury (II); Quantitative detection

1 Introduction

Cantilever sensor technology shows broad prospects of development in the field of biochemistry detection sensor. The design and use of cantilever sensors originated from atomic force microscope probe technique[1]. The molecular recognition process was transformed into identifiable and recordable mechanical signal by the cantilever sensor. This technique had many advantages such as label free, high sensitivity, real time and in situ, also it was applied in detection of chemical molecules and ions[2–4], recognition of biological molecules such as protein[5] and nucleic acids[6], and monitoring of cell growth[7,8] and microorganisms[9].

Recent years, cantilever chip manufacturing technology is more and more mature with the development of the micro-fabrication technology. Cantilever array chip containing multiple cantilevers has already been produced, easily achieving high throughput detection and setting parallel control experiment. Therefore, it is the foundation and key of the cantilever array sensor application to make cantilever array chips with uniform and consistent mechanical performance and set up stable and reliable sensor platform. There are already many reports to realize the detections by cantilever array at the present. Vertical cavity surface emitting laser (VCSEL) was firstly used as sequential scanning light source of the cantilever array sensor[10]. However, it was not convenient to control the temperature of VCSEL, which induced noise from instable laser output. Martinez *et al*[11] used a scanning laser to realize detection of a two-dimensional cantilever arrays, but this method could not avoid noise caused by displacement error. Wu *et al*[12] used a piezoelectric ceramic tube and convex lens fixed in the tube to control the position of the laser beam and realize detection of cantilever chip with two cantilevers. However, there was noise caused by displacement error of piezoelectric

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ceramic tube, and the displacement of convex lens would affect the laser spot shape, which caused different noise between different cantilevers and influence the accuracy.

In this study, a cantilever sensor platform based on optical level method was built by using eight optical fibers coupled respectively to eight lasers as the light source, and a cantilever array chip containing eight cantilevers was also fabricated. Preliminary experiment was taken to test the flatness and temperature response of the cantilevers. The sensor platform and cantilever array chip were applied for quantitative detection of Hg^{2+} in aqueous solution. Meanwhile Hg^{2+} of very low concentration was detected by different kinds of cantilever array chips to compare their performance in low concentration detection.

2 Experimental

2.1 Fabrication of cantilever array

Cantilever array is one of the most important parts of the detection process and easy to be damaged, thus it is necessary to fabricate cantilever arrays with economic price, high sensitivity and consistent performance. As shown in Fig.1a, the fabrication steps of cantilever array chip are as follows[13]:

(1) A 1-μm thick silicon nitride film (SiNx) was deposited on both sides of the washed silicon wafer (Nanoshift LLC. USA) by low pressure chemical vapor deposition (LPCVD). (2) Standard photolithography process and reactive ion etching (RIE) were carried out to define the cantilever patterns on the front side of the wafer. (3) A 3-μm thick oxide layer was deposited on the front side by plasma enhanced chemical vapor deposition (PECVD) as a protect layer. (4) The sidewall of the chip and the connecting part between the chip and the frame were etched in this process. Firstly, the patterns for etching were defined by photolithography process and RIE of the oxide, and then the wafer was etched 300 μm by deep reactive ion etching (DRIE). At last, the oxide left was wiped off by wet etching. (5) Thermal growth was carried out to form a 1-μm oxide layer on the front side. (6) Photolithography process and RIE was carried out to define the cantilever patterns on the back side. (7) The chip was revealed by anisotropic etch process, and the oxide layer on the front side was removed by wet etching. (8) A 3-nm thick Ti layer and a 20-nm thick Au layer were deposited in sequence by evaporation.

Figure 1b shows the photograph of a fabricated cantilever array chip. Every chip contained eight cantilevers. The dimension of each cantilever was 500 μm long, 100 μm wide and 1 μm thick, with a pitch of 250 μm.

2.2 Sensor platform

The schematic of cantilever array sensor is shown in Fig.2. Deflection signal of the cantilever array was detected by optical lever method, and collected by position sensitive detector (PSD). The light source of the cantilever array was eight optical fibers coupled to eight single mode lasers (650 nm, Beijing HYST Ltd., China), while the ends of the fibers converged into eight V-grooves fabricated by silicon etching process. The pitch of the grooves was 250 μm to keep one to one correspondence between the laser beam and cantilever. Real-time signal read out of cantilevers was realized by sequential control of the lasers. Each laser was settled on a peltier element. The temperature was set at 25.0 °C to ensure that the lasers work at a constant temperature to maintain the output of lasers stable. The cantilever array chip was placed in a 200-μL liquid cell. The flow rate was set at 1 μL s^{-1} during the experiment. A temperature controller with an accuracy of ±0.05 ºC (MAP6A, SHIMAX) was settled under the liquid cell, there was 2 mm gap between the temperature controller and the chip. The sensor platform was placed on an optical isolation stage in a constant temperature chamber.

3 Results and discussion

3.1 Performance analysis of cantilever array

A micrcocantilever chip that could be applied for detection

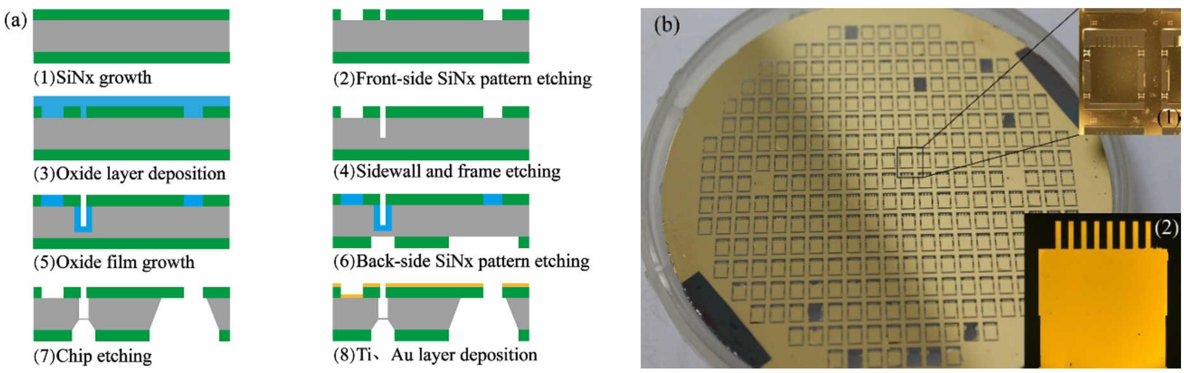

Fig.1 (a) Fabrication process flow diagram of cantilever array, and (b) Photograph of the fabricated cantilever arrays, partial enlarged drawing (1) and micrograph of one chip (2)