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A Thermocouple Device Fabricated on Trench Sidewall for Measuring Accurate Temperature of Microfluid

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Abstract

A thermocouple was fabricated on a trench sidewall by using photoresist spray-coating and angled exposure techniques. The thermocouple fabricated on the trench sidewall is ideal for measuring accurate temperature of microfluid in the channel. The trench structures and thermocouples were fabricated in a Si substrate. Without microfluid in the channel, thermocouples fabricated on trench sidewall and top-surface the Si substrate showed the same temperature. However, under the air-flow condition, the thermocouples on the sidewall showed lower temperature, which indicated that local temperature measurement is needed to precisely maintain the solution conditions in the microfluidics experiment.

1. Introduction

Microfluidics devices are widely used to analyze cells and protein molecules. During the analysis, the activities of cells and protein molecules should be maintained. Keeping the solution conditions is essential to precisely analyze the characteristics of cells and protein molecules. Temperature is one of the important factors of solution condition. Making temperature sensor in the vicinity of the microchannel gives information of local temperature. However, due to the restriction of microfabrication, temperature sensor has hardly incorporated *inside* the microchannels.

In the present study, the temperature sensor is fabricated on the sidewall surface by using photoresist spray coating technique. A microfluidics device with the thermocouples fabricated on the trench sidewall was demonstrated for accurate temperature measurement of microfluidic (Fig.1).

2. Photoresist spray coating and angled exposure

Conventional photoresist spin-coating can not be applied to a sample with three-dimensional surface structure. Photoresist is easily accumulated at the concave structures while the striations occur behind the protruded structures. Photoresist spray coating has been developed to make uniformly deposited resist films on the surface with three-dimensional structure [Fig.2(a)] [1-3]. Photoresist is atomized by mixing with N_2 gas. Controlling the spray flow is indispensable to achieve the uniform resist deposition. The gas flow was numerically analyzed to reveal the physics of photoresist spray coating [3,4]. The photoresist was spray-coated under the improved conditions. The angled exposure technique was conducted to pattern the spray-coated photoresist film on the side wall. [Fig.2(b)]. Considering the trench dimensions, the sample was inclined enough not to be doubly exposed by the UV light reflected at the bottom. Uniformly spray-coated and patterned photoresist film was obtained [Fig.2(c)].

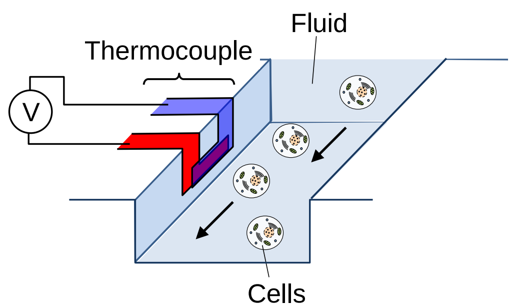

Fig.1: Schematic drawing of temperature monitoring of microfluid.

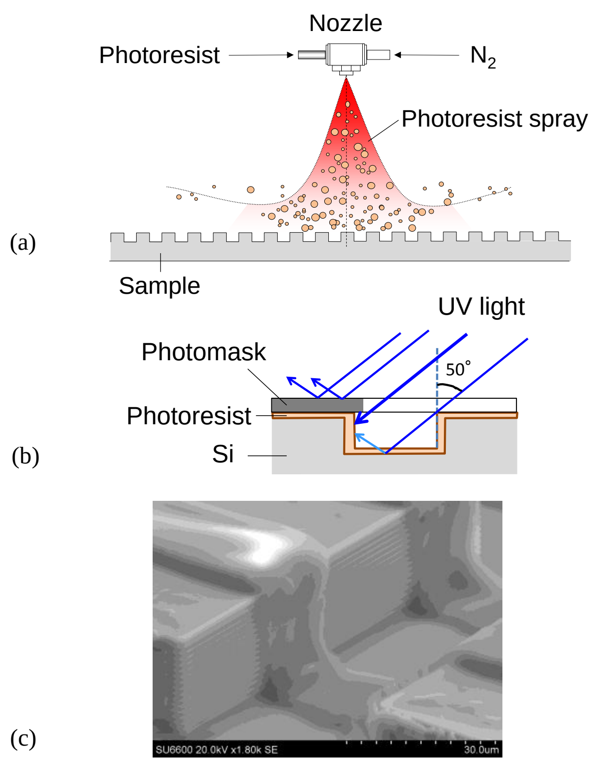

Fig.2: Schematic drawings of (a) photoresist spray coating and (b) angled exposure. (c) Line and space patterns of the spray-coated photoresist films.

3. Fabrication of thermocouples on trench sidewall

Trench structures (w: 200μm, d: 100μm) are fabricated in the Si substrate by Deep-RIE. The Si substrate was thermally oxidized to obtain insulator layer (SiO_2 thickness: 2μm). Cr film was deposited on the Si substrate (Cr thickness: 600nm), and photoresist was spray-coated. Patterns of thermocouple were patterned onto the trench sidewall surface by angled exposure [Fig.3] [6]. The Cr film was wet-etched. Thermocouple patterns of Al (Al thickness: 600nm) were fabricated following the same procedures. The Al/Cr thermocouples were fabricated on the sidewall surface (Fig.4). The thermocouples were also fabricated on the top surface of the Si substrate for reference. A lid of PDMS was placed on the Si trench substrate with the thermocouples thereby forming microchannels. The device with the thermocouples was set on a hot plate and heated. With increasing the hot plate temperature (20-140°C), thermoelectric voltage was monitored.

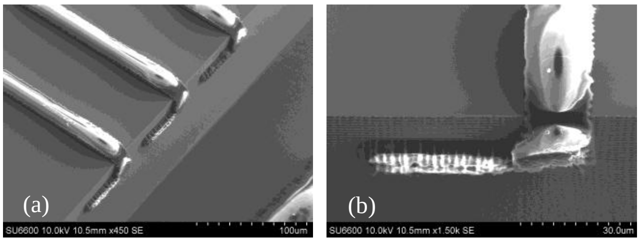

Fig.3: (a) Thermocouple pattern of photoresist. (b) Magnified image of the pattern on the sidewall.

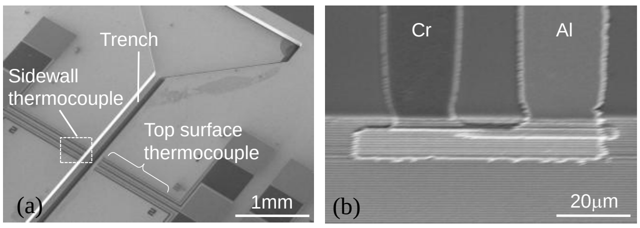

Fig.4: (a) Fabricated microfluidics device with thermocouples. (b) A thermocouple fabricated on trench sidewall. Magnified image of the enclosed in (a).

4. Results and discussion

Open voltages of the thermocouples were increased by increasing the hot plate temperature, which indicated that the fabricated thermocouples successfully detected the temperature increase. Using a syringe pump, air-flow was supplied into the microchannel. Open voltages were measured under the air flow conditions. Calibration lines were obtained by least square fitting. The calibration lines were plotted with the measured open voltages (Fig.5). The calibration lines were obtained for the open voltages measured by sidewall thermocouple without air-flow; top-surface thermocouple with air flow; sidewall thermocouple with air-flow. Calibration lines for "sidewall without air-flow" and "top-surface with air-flow" agreed well each other. This was reasonably recognized by that Si is a good thermal conductor. However, calibration line obtained for "sidewall with air-flow" located at the lowest position among the three measurements. Local temperature at the sidewall was indeed different from the temperature measured at the top-surface.

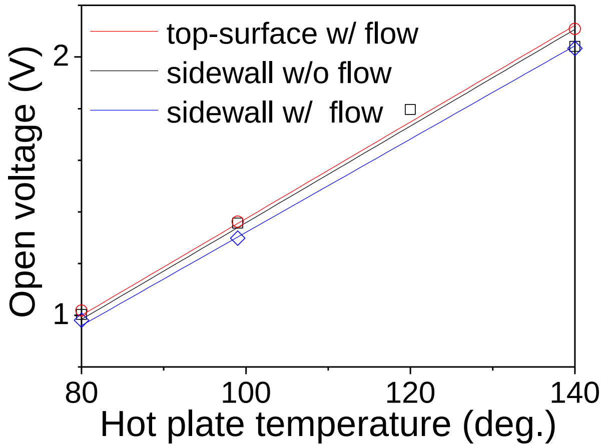

Fig.5: Open voltages of thermocouples as a function of hot plate temperature for the three conditions; measured by top-surface thermocouple with air-flow; sidewall thermocouple without air-flow; sidewall thermocouples with air-flow.

4. Conclusions

Thermocouples were fabricated on the trench sidewall of the microfluidics device by using photoresist spray-coating and angled exposure techniques. The thermocouples fabricated on the trench sidewall were suited to measure local temperature of the fluid in the channel. Next step for keeping the solution temperature is making *sidewall heater*. Combining the sidewall thermocouples with "sidewall microheaters" are indispensable for the precise analysis of cells and protein molecules.

Acknowledgements

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