Local Heating System Integrated with Platinum Micro Heater and Photopolymer Microfluidic Channel

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Local heating system composed with micro heater and microfluidic channel is designed and fabricated. Micro heater made of platinum film is formed on a slide glass by radio-frequency magnetron sputtering and lift-off processes. Microfluidic channel is designed to surround the micro heater. A SU-8 epoxy-based negative photoresist is employed as micro channel material and patterned by lithography process. The micro heater has ability to heat over 350°C at an electric power of 3.12W. Local heating property is evaluated by applying DC electric power. Heating area decreases 61.5% for micro channel filled with water by comparison with empty channel. Temperature of water in the micro channel is rise up 3.5°C and heat absorption, which is estimated about 275.3 µJ. The microfluidic channel with water is an effective method for local heating. The local heating system with integration of micro heater and channel is one candidate which can apply to various fields such as biological and biomedical tools.

Keywords : local heating system, micro heater, microfluidic channel, SU-8 photoresist

1. Introduction

There is a need of local heating by micro systems such as heat actuator, µ-TAS and so on [1-3]. In particular, heat treatment for unit cell at relatively low temperature (~40°C) is needed. For micro heating application, heat conduction control is an important subject because amount of heat is lost through heat transport path due to absorption by device material such as silicon, glass and polymer material. In order to reduce heat loss, it is an effective to localize heat generation in specific area. Therefore, the system which integrates micro heater and micro heat absorber should be required. We focus on micro channel with water path as the heat absorber. For microfluidic channel fabrication, a photoresist material is one suitable candidate because multi-laminated channel structure is more likely to fabricate [4-5].

In this study, we develop local heating system which composes with micro heater and microfluidic channel as heat absorber. Then, properties of heat localization of the local heating system are evaluated.

2. System design and Experiments

2.1. Local heating system design

Schematic diagram of the micro heater and ring channel design is shown in Fig.1(a). The micro heater provides eleven heat lines and two electrode pads made of platinum. Width, length and height of each heat line were 50 µm, 2.2mm and 60nm respectively. Space between each heat line was 150 µm. Size of electrode pad was 1.1mm × 2.2mm. The micro heater was mounted on a slide glass. The microfluidic ring channel was made of SU-8 3050 photoresist (MicroChem. Corp.) on the heater. Centers of the heater and the ring channel were piled up at the same position. The ring diameter, channel width and depth were 6mm, 50µm and 10µm, respectively. Water reservoirs were also formed on the photoresist layer. As heat absorptive material, deionized water can fill in the channel from the reservoir. Deionized water surrounded the heater acts to prevent heat conduction to outside the ring channel. Volume of deionized water was 18.8 nanoliter when the channel was filled with the water. Schematic of cross-sectional view of the
micro heater/channel system is shown in Fig.1(b).

2.2. Fabrication of micro heater and channel

For fabrication of the micro heater combined with channel, photolithography process is summarized in Table 1. The micro heater was fabricated by lift-off process on a slide glass. A novolac photoresist was formed in the heater pattern for lift-off process, then platinum film was deposited on the glass by radio-frequency magnetron sputtering. After Pt layer deposition, remaining photoresist layer was removed by dipping into acetone. Before micro channel fabrication, heating characteristic of the micro heater was evaluated. Subsequently, the micro ring channel was formed by SU-8 lithography. Hard baking was carried out in order to harden the SU-8 channel at the end of fabrication process. Photograph of the fabricated micro heater/channel system is shown in Fig.2, and components of the micro system can be confirmed. Deionized water flow in the channel ring was observed by using an optical microscope.

2.3. Method of heating experiment

Figure 3 shows schematic of electric circuit for heating and heat observation equipment. The micro heater can be heated by applying DC electric power through a pair of tungsten electrode. Resistance of the heater was determined from V-I characteristic. Temperature of the micro heater was measured by using a thermography (TH6300R, Nippon Avionics Co., Ltd.). Temperature change was measured at an interval 5s. Then, heating profile was extracted from the thermographs. Room temperature and humidity in experiment were 28.9°C and 52%, respectively.

3. Results and Discussion

3.1. Heating property of the micro heater

Input voltage-current characteristic of the micro heater without micro channel structure is shown in Fig.4. Electric resistance of the micro heater is estimated at 440Ω by V-I characteristic. Electric resistivity of the heater was 66µΩcm which was higher than one of the bulk value (9.81µΩcm). The dependency of heat temperature on the input electric power is shown in Fig.5. The micro heater can be heated over 350°C at an input power of 3.12W.
3.2. Local heating property of the micro heater/channel system

Heating area by the local heating system was evaluated, by comparing with or without water filling in the micro channel. Figures 6 show thermographs of the micro heater/channel device after 15s heating when input power was 5V/10mA. Figure 7 compares temperature distribution profiles of the micro heater/channel systems of A-A' pointed in Fig.6. The device surface temperature was about 29°C before the heating. However, the area near water reservoir was lower temperature than that of other area. When the channel was empty (a), the long and short axes of ellipse area over 29°C were 8.8mm and 6.9mm (48.0mm²). The sizes were 5.2mm and 4.4mm (18.5mm²) for the micro channel filled with water (b). The heated area decreased about 61.5%. As shown in Fig.7, gradient of heat distribution was smooth in case of the empty micro channel (a). On the other hand, temperature distribution was clearly different inside and outside the micro channel due to filling water in the micro channel as shown in Fig.7(b). It can be confirmed that the micro channel acts as heat absorber effectively.

Figure 8 provides dependence of the heater temperature on heating time at the ring channel. In case of empty micro channel (a), temperature rose up 7.4°C after heating for 180s. On the other hand, in case of water in the channel (b), the temperature rose up only 3.5°C. This result indicates that the water in micro channel acts as the heat absorber.
Table 2 Physical parameter used in calculation amount of absorbed heat.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Water</th>
<th>Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of channel</td>
<td>18.8×10^{-2}</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>1.0×10^{-3}</td>
<td>1.1×10^{-6}</td>
</tr>
<tr>
<td>Specific heat</td>
<td>4.184</td>
<td>1.006</td>
</tr>
<tr>
<td>Temperature difference</td>
<td>3.5</td>
<td>7.4</td>
</tr>
</tbody>
</table>

Table 3 Specification of the micro heater/channel system

<table>
<thead>
<tr>
<th>Property</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum temperature</td>
<td>354°C</td>
</tr>
<tr>
<td>Electric resistance</td>
<td>440Ω</td>
</tr>
<tr>
<td>Electric resistivity</td>
<td>66μΩcm</td>
</tr>
<tr>
<td>Decrease percentage of area over 29°C by filled water</td>
<td>61.5% (48.0mm^2→18.5mm^2)</td>
</tr>
<tr>
<td>Temperature rise of water by applying 5V/10mA after 180s</td>
<td>3.5°C</td>
</tr>
<tr>
<td>Amount of absorption heat in the water</td>
<td>275.3μJ</td>
</tr>
</tbody>
</table>

Then, the amount of absorption heat by water and air in micro channel is estimated by follow equation (1)

\[ Q = \rho \cdot V \cdot c \cdot \Delta T, \]

(1)

where \( \rho \), \( V \), \( c \) and \( \Delta T \) are density, volume, specific heat and temperature difference from 0s to 180s heating of water and air, respectively. Table 2 summarizes value of physical parameters for the eq. (1). As results, heat absorption \( Q \) of water and air can be estimated to be 275.3μJ and 169.3nJ, respectively. Table 3 summarizes the specification of the micro heater/channel system in this study.

4. Conclusion

The micro heater/channel system made of platinum film and a SU-8 photoresist is fabricated. The micro heater made of platinum has been successfully heated up to approximately 354°C at an input power of 3.12W. In comparing the micro channel with or without deionized water as a heat absorber, area of temperature over 29°C decreases 61.5% by filling water. Amount of absorbed heat by the water is 275.3μJ in 180s heating. In conclusion, micro channel with water filling is an effective method for local heating. The concept of local heating of the system is one promising candidates for biological and biomedical fields, such as a cell culture heater.

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References