

THERMAL ANALYSIS, DESIGN AND FABRICATION OF MICROFLUIDIC DEVICE WITH LOCAL TEMPERATURE CONTROLS

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ABSTRACT

This paper reports a microfluidic device with local temperature controls to stimulate bio-cells by heat. Thermal analysis on temperature distributions of microheaters as well as inside of fluidic channels was carried out. Moreover, temperature in microfluidic device was measured by on-chip resistive thermometers.

INTRODUCTION

Cell-cell interactions are key roles to construct tissues and organs in vivo. As researches on regenerative medicine and artificial organs for drug discovery increase, mechanism of cell-cell interactions get more interesting.

Recently, microfluidic devices were suggested for local stimulations and investigations of cell-cell interactions [1, 2]. These devices can control fluidic flow and stimulate cells locally by chemicals. However, it is difficult to control liquid-base stimulations because unexpected flow and diffusion can change concentrations and stimulation site.

This paper shows a microfluidic device integrated with microheater and sensors array to stimulate cells locally by joule heating. Finite element method (FEM)-based simulation on temperature distribution was done to design the device. Finally, simulation and experimental results were compared.

FEM ANALYSIS

To design the microfluidic device with microheater, we simulated temperature distribution in a micro channel using a commercially available software (COMSOL). Figure 1 shows 3D model of the microfluidic device. There are three platinum electrodes on a glass substrate. One (middle part) is a heater and the others are resistive thermometers. On the glass substrate, PDMS micro channel was bonded. The channel size is 20 mm in length, 500 μm in width and 250 μm in height. Table 1 shows material properties for FEM analysis [3-5]. Property of metal in bulk is different from one of thin-film [3]. Thermal conductivity of thin-film platinum is almost half of bulk one.

Electric resistivity of platinum was assumed to follow equation (1). Resistivity of platinum is also different between bulk and thin-film [3]. Table 2 shows electrical properties of platinum in bulk and thin-film. Both of them were used for calculations to predict heating property of platinum microheater.

Figure 2 shows simulation results of temperature distribution on a glass substrate with a micro channel and flow. 21 mA was applied for joule-heating and heating

temperature reached at 44°C around platinum heater. The value is enough to stimulate cells. Two resistive thermometers are 1 mm away from microheater in figure 2. 1 mA was applied for sensing of temperature.

$$\rho = \rho_0(1 + \alpha(T - T_0)) \quad (1)$$

FABRICATION

Based on FEM simulation, platinum electrodes and a micro channel were designed. Figure 3 shows a fabrication process flow diagram. Platinum electrodes were patterned on a glass substrate by ion beam etching after sputtering of Ti and Pt (20/200 nm). Silicon dioxide was sputtered as an insulator layer. A micro channel was fabricated by soft lithography technique using SU-8 mold and PDMS. Finally, the glass substrate and PDMS micro channel were bonded by oxygen plasma bonding.

RESULTS

Platinum electrodes were characterized by four-terminal method. Resistance-temperature curves of bulk, thin-film and fabricated device are shown in figure 4, respectively. The device property shows a good linear change. The resistivity and temperature coefficient of resistance (TCR) of the platinum microheater were calculated from the resistance-temperature curve. Table 2 compares values of bulk, thin-film and experimental results about resistivity and TCR. The resistivity of experimental results is 1.3 times higher than bulk and TCR is almost half of bulk.

Heating temperature was measured by resistance change. Experimental results and simulation were shown in Figure 5. The heating temperature of platinum microheater is between simulation data of bulk and thin-film. Experimental data was fitted by quadratic curve. It means that resistive thermometers worked well.

CONCLUSION

We analyzed temperature distribution of a microfluidic device with local temperature controls. A microfluidic device integrated with a microheater was also fabricated and characterized. Measured heating property was well consistent with FEM simulation.

For the next step, cells will be cultured in a micro channel and stimulated by heat for investigations of cell-cell interactions.

ACKNOWLEDGMENT

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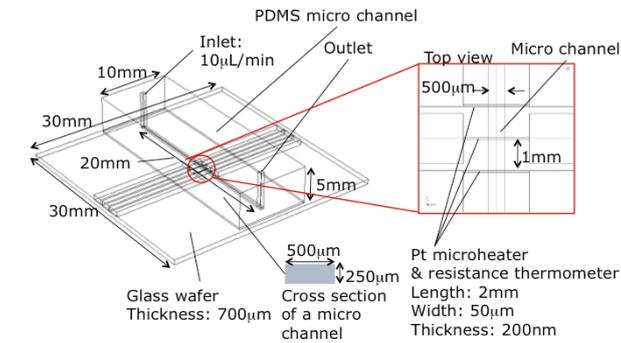


Figure 1: 3D model of the microfluidic device

Table 1: Material properties for FEM simulation [3-5]

	Thermal conductivity <i>k</i> , W/mK	Specific heat <i>C_p</i> , J/kg·K	Density <i>ρ</i> , kg/m ³
Pt (Bulk)	73	130	21450
Pt (thin film)	29.5		
Glass	1.4	835	2225
PDMS	0.18	1100	1030
Buffer	0.61	4179	1030

Table 2: Electrical properties of platinum [3,4]

	Pt bulk property	Pt thin film property	Device
Resistivity (nΩ·m)	108.6	465	137.5
TCR (1/K)	0.003927	0.0014	0.0019

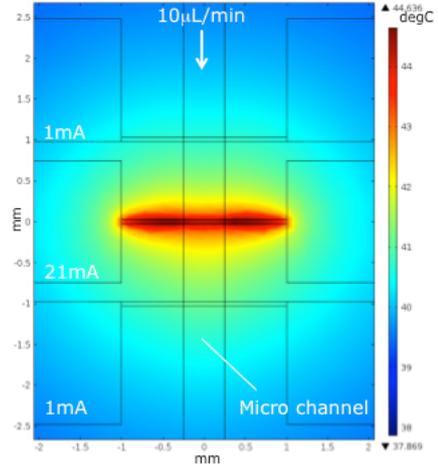


Figure 2: Temperature distribution on a glass substrate with a micro channel and flow

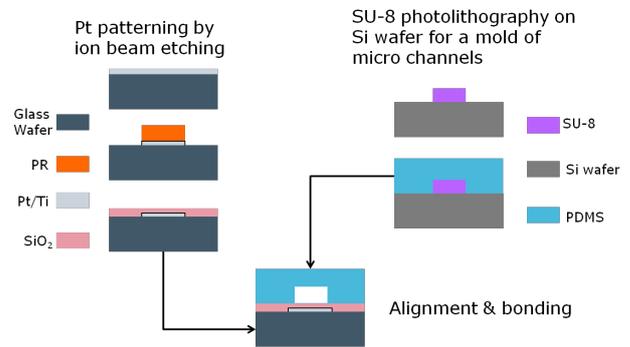


Figure 3: Fabrication process flow diagram

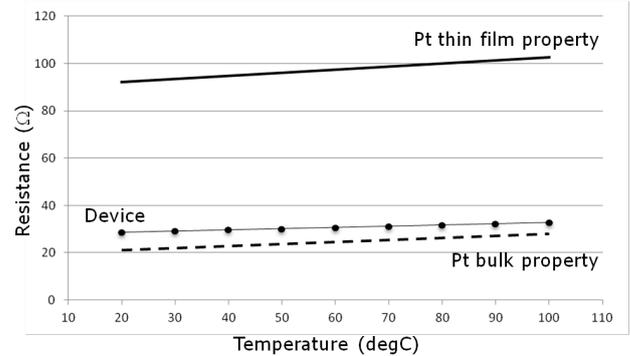


Figure 4: Resistance-temperature curve (Pt thin-film, Experimental results, Pt bulk)

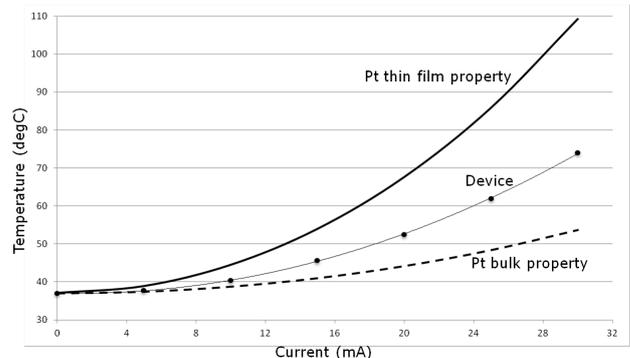


Figure 5: Temperature-current curve (Pt thin-film, Experimental results, Pt bulk)