GEOMETRIC OPTIMIZATION OF A THIN FILM ITO HEATER TO GENERATE A UNIFORM TEMPERATURE DISTRIBUTION

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Abstract

The shape of thin film ITO heater was designed and optimized to create a uniform temperature distribution across a specified area. COMSOL^{TM} script language was used to solve the electrothermal problem and find the minimum temperature deviation for each variable (Gap size (g), center width (W_1) and reduction ratio of width ($R=W_{i+1}/W_i$)). Gap size and width did not strongly affect the temperature distribution, but reduction ratio was highly related with temperature distribution. At R=0.8, the standard deviation of temperature was found to be minimized at ±0.21ºC. Through this research, highly uniform temperature distributions for microsystems are made available.

Keywords: Optimization, thin film ITO, uniform temperature, Reduction ratio

1. Introduction

Biomedical microdevices that require precise temperature control, such as cell culture chips, PCR (Polymer Chain Reaction) chips and gas sensors need a microheater that has a uniform temperature distribution over a relatively large area. [1-3] Another typical requirement for these heating systems is transparency to allow optical detection of the reactions above the microheater system.[3-4] For this work, the microheater was designed to heat an array of PCR wells simultaneously in a consistent and reproducible manner. To implement the heaters, ITO was deposited on to a glass microscope slide. A uniform coating of ITO was found to not generate a uniform temperature distribution. To overcome this difficulty, a spiral type heater was designed and optimized with FEMLAB and MATLAB programming tools.

2. Simulation and Experiment

The geometric optimization for the microheater was performed by simulating a wide-range of possible geometries using COMSOL^{TM}, a commercial FEA (finite element analysis) package, and MATLAB^{TM} programming. The desired function of the microheater was to minimize the standard deviation of temperature across an area 1 cm^2 where a PCR array would be located. The design variables are gap size (g), center width (W_1) and reduction ratio of width ($R=W_{i+1}/W_i$) as indicated in Figure 1. Using a numerical method, the global minimum point of standard deviation was found among the results of a series FEA experiments. Using the optimal design from these analyses, the thin film ITO heater was fabricated by sputter depositing ITO through a shadow mask. To crystallize the ITO, it was annealed at 380 ºC. Transparency of the ITO heater was measured with an Ocean Optics spectrometer after completion of the fabrication process. To compare the simulation result with experimental result, an IR (infrared) camera was used to measure the temperature across the heating surface.

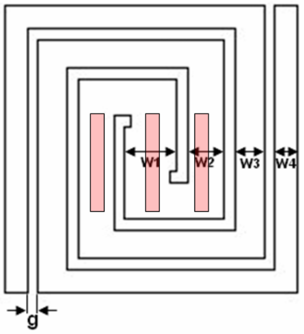

Figure 1. Geometry of thin film ITO Heater (3 variables (g, W1 and $R=W_{i+1}/W_i$) was used to acquire the uniform temperature distribution at specific areas (shaded)

3. Result and Discussion

The optimum geometry of a thin film ITO (Indium Tin Oxide) heater to be used for an array of PCR and DNA melting wells was determined using numerical analyses and compared to experimental data. The IR camera image and step response of ITO heater were compared with simulation data. The comparison showed very good agreement, and the step response of the system indicated that PCR should be able to be performed rapidly. (Data not shown) The transparency of the ITO heater was 82% between 450nm and 550nm, the wavelengths that are usually used for fluorescent dyes. At the minimum point, the standard deviation of temperature was ±0.21ºC and gap size, width and reduction ratio were g=2mm, W1=2.8mm and R=0.8 respectively. The reduction ratio, which controls the resistance, was more sensitive than the other variables. The W1 and g variables were highly correlated with the heat generation capacity of the ITO heater.

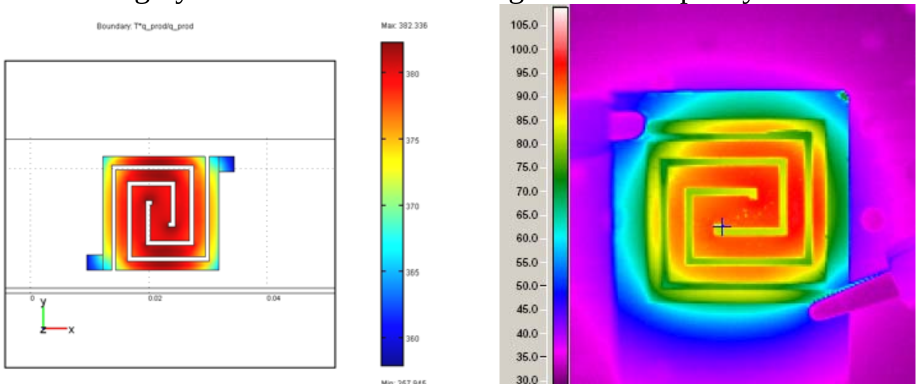

Figure 2. Validation of heater (Left: Simulation, Right: IR camera)

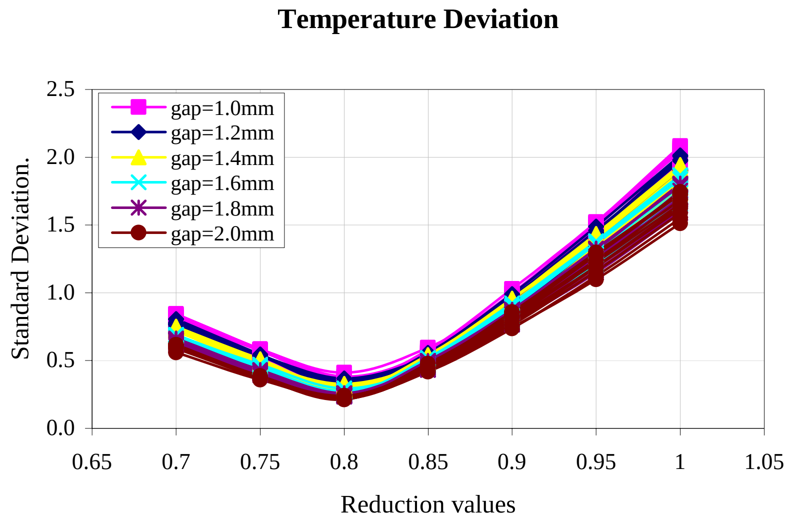

Figure 3. Temperature deviation of ITO heater with each case.

4. Conclusion

Shape optimization of a thin film ITO heater was completed to achieve a uniform temperature distribution. Three design variables were used to find the optimal geometry and among these variables, the reduction value was found to highly affect the temperature distribution. At Reduction value=0.8, the standard deviation of temperature profile was minimized at ±0.21ºC. Based on these results and concepts, we are able to make a uniform, small scale heater. If we change the scale of thin film ITO heater, the design values might change, but the trends should follow these results. This method has the potential to be applied to various electrothermal systems that involve the need for a uniform temperature.

Reference

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