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Design and Simulation of Electrothermally Activated Bidirectional Microtweezer Using PMMA for Biomedical Applications

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--ABSTRACT--
The design and simulation of PMMA (Polymethylmethacrylate) microtweezer that can be used for the manipulation of biological species in solution with minimal desired interactions is done using COMSOL Multiphysics 4.2a. The electro thermally activated polymer bimorph microtweezer consists of two "hot-and-cold-arm" actuators with gold (Au) layer of 1 um thick on both sides of the actuator to provide bidirectional operation i.e. capable of producing displacement in two directions as a single device. It provides the total inward displacement of 11.38 µm and total outward displacement of 8.06 µm with applied potential of 1 volt.

KEYWORDS: *MEMS electrothermal actuation, bidirectional microtweezer, polymethylmethacrylate, gold*

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I. INTRODUCTION

In MEMS, microtweezers have great importance because of their vast application area. Applications of microtweezer ranges from micro manipulation i.e. manipulation of micro components to cell manipulation. There are different kinds of microtweezers depending upon the principle of actuation used such as piezoelectric, electrostatic, electrothermal and electromagnetic[1]. Thermal actuation is mostly used as compared to other actuation mechanism because it provides larger forces and easier control. Thermal actuators are based on the principle of joule heating and thermal expansion [2, 3].The substance that has higher coefficient of thermal expansion (CTE) provides larger displacement. CTE of polymers is larger as compare to semiconductors and metals[4]. So, polymers provide larger displacement than semiconductors and metals. There are some other advantages of polymers over semiconductors and metals. These are lower stiffness, transparency, better biocompatibility, lower material cost and easier fabrication by mass replication technology[5]. Like SU-8, PMMA is also a non conducting polymer. For making electrothermal devices it must be electrically conducting. This can be done by depositing a metal layer on its surface[6].Microtweezers developed using polymers provide larger displacement and gentle handling force that is ideally suitable for biological applications[1]. PMMA (polymethyl methacrylate) is sustainable, environment friendly, has small Young' modulus and high thermal expansion coefficient which makes it suitable for electrothermal application. Electrothermal actuators using PMMA requires less power for producing same displacement as compared to polysilicon electrothermal actuator[4].

II. DESIGN AND SIMULATION

In this paper a polymeric microtweezer designed using PMMA that can provide in-plane bidirectional operation. This design is based on two lateral thermal bimorph actuators[7] with total length of microtweezer is 250 µm and initial tip opening of 30 µm. A gold layer of 1 µm thick is considered on inner side of narrow arm and outer side of wide arm that acts as heaters. The properties of PMMA and gold are listed in Table 1.

Table 1 Properties of PMMA and Gold

Properties	**PMMA**	**Gold**
Co-efficient of thermal expansion	$70x10^{-6}$ per K	$14.2x10^{-6}$ per K
Thermal conductivity	0.19W/mK	317 W/mK
Heat capacity	1420 J/Kg K	129 J/Kg K
Density	1190 Kg/ m^3	19300 Kg/m^3
Young's modulus	$3x10^9$Pa	$70x10^9$Pa
Electrical conductivity	$1x10^{-19}$ s/m	$4.6x10^6$ s/m
Poisson ratio	0.4	0.44
Relative permittivity	3	---

It has four anchors out of which anchor A1 and A4 are connected to outer layer of gold while anchor A2 and A3 are connected to inner layer. Any one from anchors A1 and A2 is supplied with potential of 1 volt depending upon the direction of operation either inward or outward and A4 and A3 are connected to ground. Structure of microtweezer is shown in Figure 1. The design is simulated in MEMS module of COMSOL Multiphysics 4.2a.

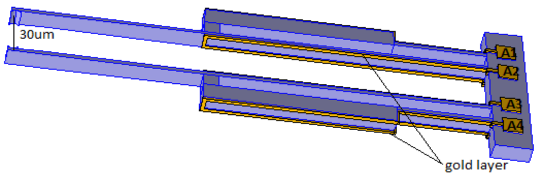

Figure 1 Geometrical representation electrothermal microtweezer

III. RESULTS AND DISCUSSIONS

This microrweezer provides bidirectional operation as single device depending upon the potential applied to either anchor A1 or anchor A2. When potential is applied to anchor A1, microtweezer gives converging displacement of 11.38 µm as shown in Figure.2. Figures 3 and 4 show the stress and temperature distribution for inward displacement of microtweezer, respectively.

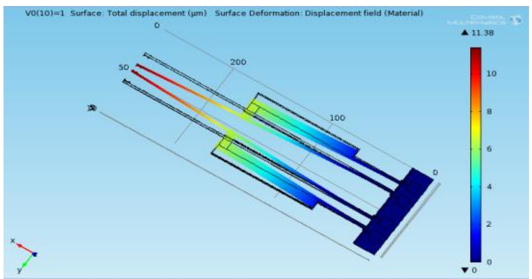

Figure 2 Total inward displacement in microtweezer

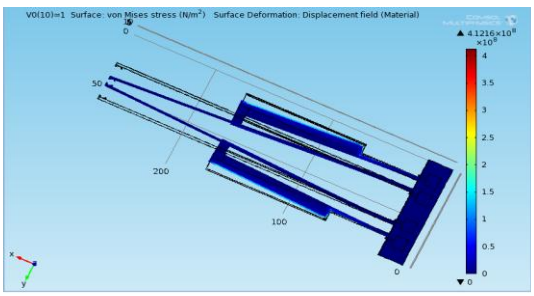

Figure 3 Stress distributions for inward deflection of microtweezer

When the potential of 1 volt is applied at anchor A2 then, the microtweezer provides diverging displacement of 8.0613 µm as shown in Figure 5. The stress and temperature distributions for outward deflection of microtweezer are shown in Figures 6 and 7, respectively.

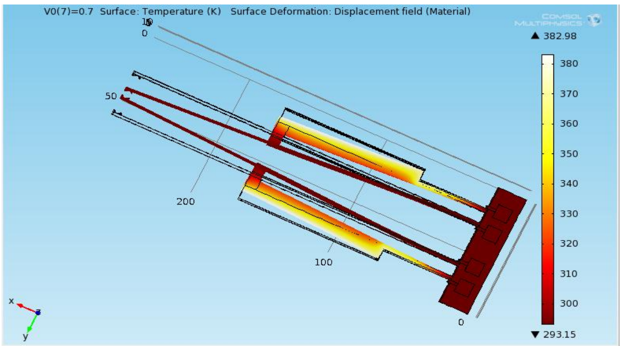

Figure 4 Temperature distributions for inward deflection of microtweezer

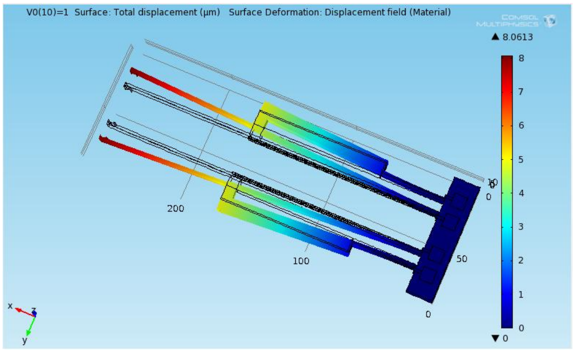

Figure 5 Total outward displacement in microtweezer

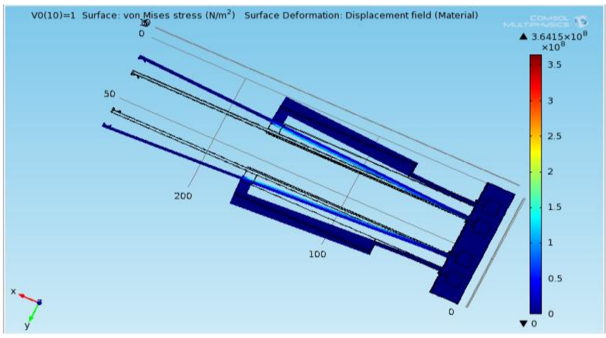

Figure 6 Stress distribution for diverging displacement

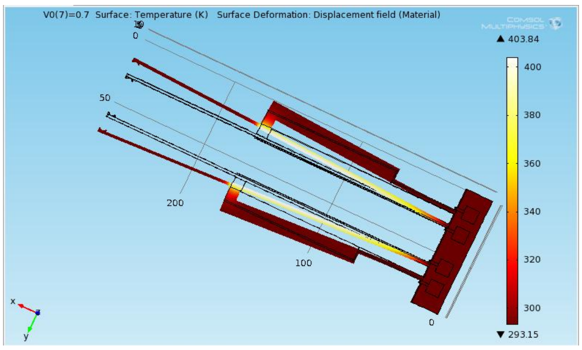

Figure 7 Temperature distributions for diverging displacement

The variations in inward and outward displacement of microtweezer with applied potential are graphically shown in igure 8.

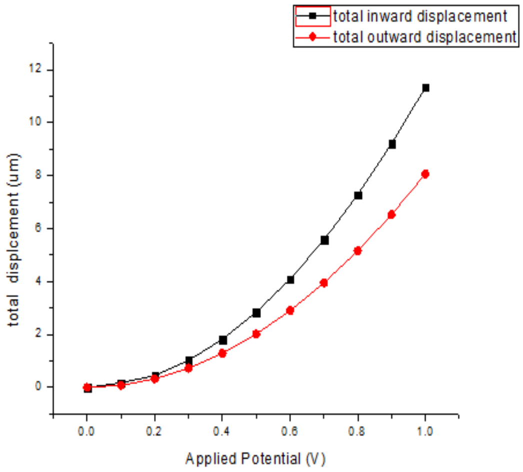

Figure 8 Inward and outward displacement with applied potential

IV. CONCLUSIONS

Most of microtweezers provide either converging displacement or diverging displacement but the device designed in this paper provides both i.e converging as well as diverging displacement which increases range of its deflection up to 46 µm. It can be used as a microtweezer for handling biological samples as PMMA being a biocompatible material.

V. ACKNOWLEDGEMENT

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