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Hybrid Design of a Polymeric Electrothermal Actuator for Microgripper

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Abstract – Thermal micro actuators are widely used for large displacement, high accuracy and repeatability. The applications of these devices are in the fields of micro assembly, micro surgery and manipulation of micro particles. In this paper, the development of electro thermal micro actuator based on PMMA (Poly Meta Methyl Acrylate) is described. The paper presents the development of a new micro actuator for a microgripper which has a combination of asymmetric arm and bi-layer structure to completely eliminate the undesirable out of plane movement. Three models of electro thermally actuated polymeric micro actuators using low voltage of 0.1 V are designed and analyzed using COMSOL Multiphysics software. The results are discussed and compared to show the efficiency of the hybrid design. The hybrid design gives 2.5 μm of in plane gripping displacement and 0.02 μm out of plane displacement at 0.1 V.

Key words - MEMS, micro actuator, microgripper, COMSOL electrothermal actuator.

I. INTRODUCTION

Micro actuator is one of the most important parts of microgripper. The microgripper is an important component of the system to hold, pick, manipulate and assemble mechanical micro components. For example, in the case of micro robot (size of few mm) where the components are in the order of micrometers which are produced using micro mechanical or micro electric mass fabrication process have to be assembled using microgripper. The general requirement of a microgripper is that it should be able to pick up and release a component at a specified position. The positional uncertainty during assembly should be well defined and components should not be damaged during assembly. Microgripper applications include assembly of micro components in manufacturing, electronics, information technology, optics, medicine and biology areas like diagnostics, drug delivery, biopsy tissue sampling, tissue engineering and minimally invasive surgery. Thermal micro actuators are widely used for large displacement, high accuracy and repeatability. The working principle electro thermal micro actuator is based on the Joule's Law and principles of thermal expansion. The Joule's Law states that a material crossed by an electric current will get some thermal energy. This results in collision of the flowing electrons and the atoms making the material. This collision between the electrons and atoms results in vibration which excites the surrounding atoms. The large amplitude of vibration results in increase of dimensions. This phenomenon is known as thermal expansion [1].

The materials with higher co-efficient of thermal expansion result in larger gripping displacement. Polymers have the highest co-efficient of thermal expansion than metals and semi-conductors [2-5]. Due to co-efficient of thermal expansion there is an increase in dimensions in all directions. So, it is necessary to direct and amplify the thermal expansion in dimensions to obtain an efficient thermal actuation suitable for application. The amplification can be done by using asymmetric thermal arm structure, bi-layer structure and bent-beam structure. Micro actuators are broadly classified into in plane and out of plane actuators. The in plane actuators move parallel to the substrate surface, whereas out of plane actuators travel perpendicular to it [6]. Many polymeric in plane and out of plane actuators have been demonstrated using asymmetric arm [7, 8], bi-layer [6, 9] and bent beam structures [10, 11]. However asymmetric arm structured micro actuator have undesired out of plane movement. The bi-layer structure of a microgripper gives diverging movement which is undesired. To overcome the above disadvantages, combination of asymmetric and bi-layer structure hybrid design can be used.

In this paper, three models of electro thermally actuated micro actuator for a microgripper is designed using PMMA substrate and gold electrodes. The design and analysis is done using COMSOL Multiphysics software. The first model is designed using asymmetric arm. The second model is design using bi-layer structure. The third model is designed using combination of asymmetric and bi-layer structure. The

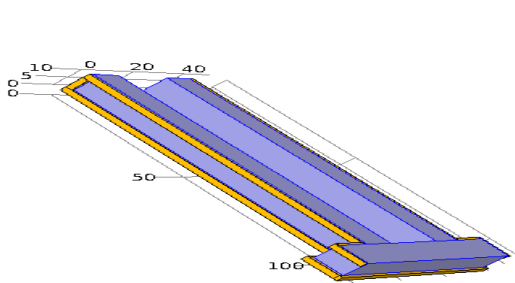


Fig. 2 : Bi-layer structure micro actuator (model 2).

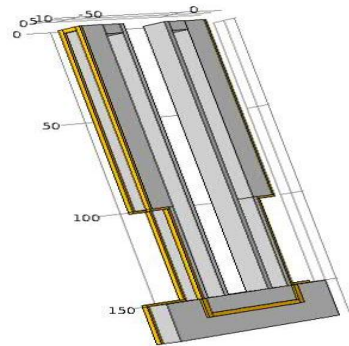


Fig. 3 : Hybrid structure micro actuator (model 3).

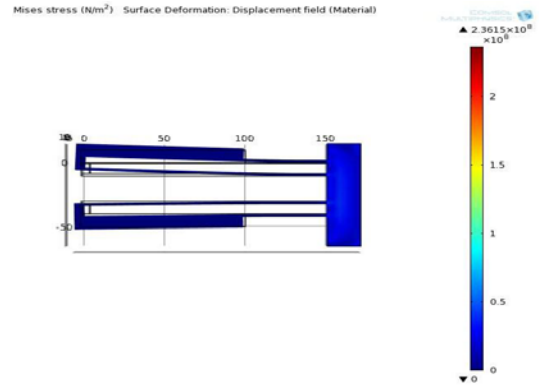


Fig. 6 : Stress distribution of model 1 at 0.1 V

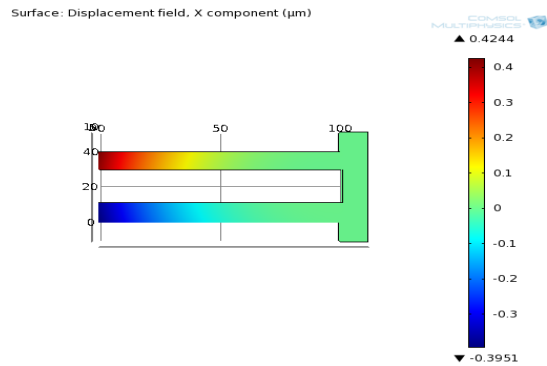


Fig. 7 : X axis displacement of model 2

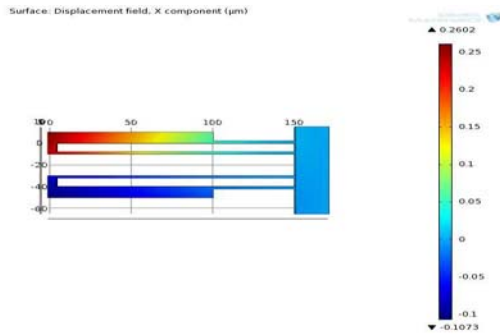


Fig. 4 : X axis displacement of model 1.

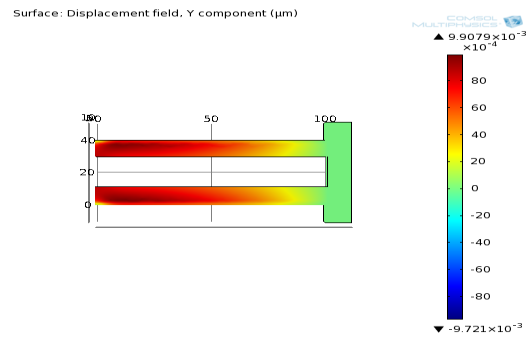


Fig. 8 : Y axis displacement of model 2

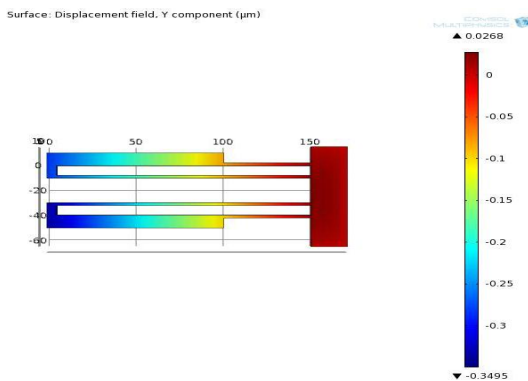


Fig. 5 : Y axis displacement of model 1.

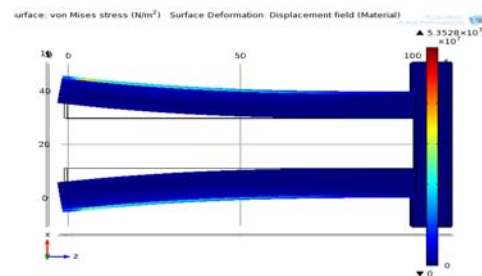


Fig. 9 : Stress distribution of model 2 at 0.1 V.

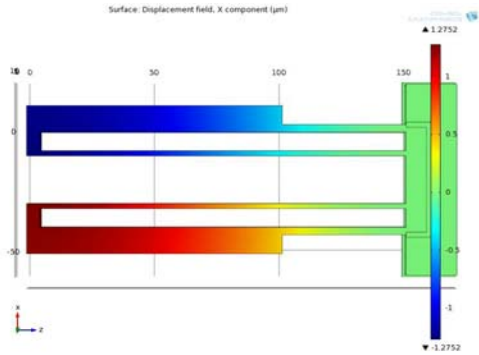


Fig. 10 : X axis displacement of model 3.

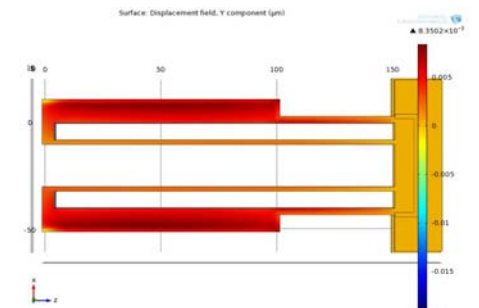


Fig. 11 : Y axis displacement of model 3.

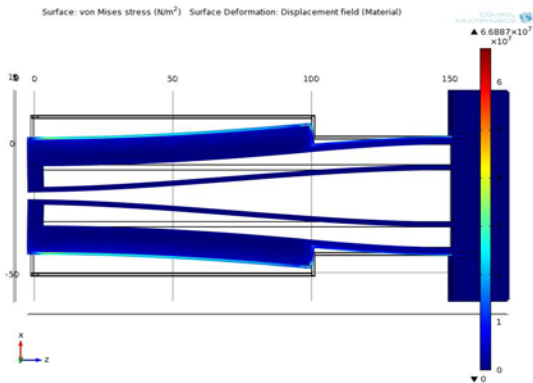


Fig. 12 : Stress distribution of model 3 at 0.1 V.

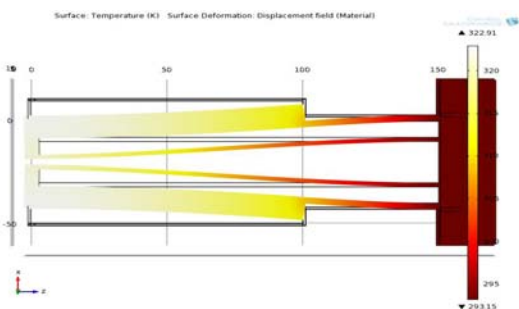


Fig 13 : Temperature distribution of model 3 at 0.1 V

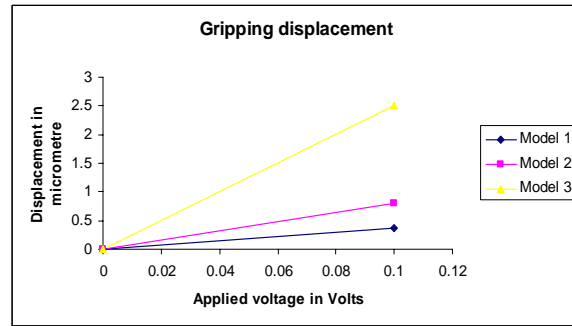


Fig. 14 : Gripping displacement of actuators arms.

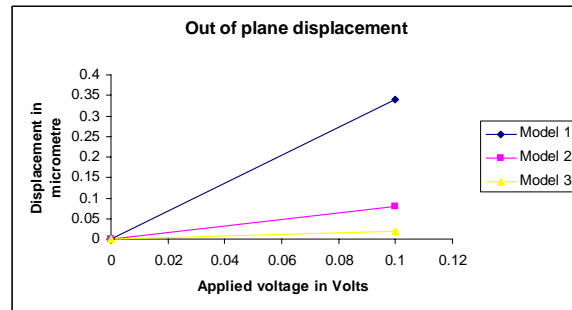


Fig. 15 : Out of plane displacement

IV. CONCLUSION

Micro actuator is an important part of microgripper. The electro thermally actuated micro actuators are designed using asymmetric arm and bi-layer structure. These structures have disadvantages such as divergent displacement and more out of plane movement. These disadvantages can be overcome by using a hybrid design structure using a combination of asymmetric arm and bi-layer structure. Three models of electro thermally actuated polymeric micro actuators have been designed using COMSOL Multiphysics software based on PMMA. The results obtained are discussed and compared. The hybrid design is found to be the optimal model which gives very good displacement of 2.5 μm at 0.1V applied voltage and minimize the out of plane movement to a large extent. Thus, this micro actuator can be used in microgripper for better accuracy and gripping of micro particles.

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