MEMS Based Gecko Foot for Micro Robotics

A. Pasumarthy[1], H. Sinha[1], A. Islam[1]

[1]Birla Institute of Technology, Mesra, Ranchi, Jharkhand, India

Abstract

This paper presents a 3D MEMS model of an electro thermally actuated Gecko foot. Micro hairs on the gecko foot are an intricate biological structure with hierarchical nano-sections and micro-sections. A gecko has billions of nanoscale hairs on its feet that are in contact with surfaces while it climbs. This model explores the advantages provided by electrothermal actuation by reducing the complexity in the structure. The nanohairs are complex structures, and are responsible for dry adhesion i.e. Vander Waals forces. The model shown in Figure 1 is a standard electrothermal actuator design inspired by reference [3]. It acts as a single microhair (stalks) of the gecko foot and the nanohairs (spatula stalks) are attached on its tip. The material used is polysilicon which achieves the design goal while providing the minimum required adhesion. The same design with greater number of nanohairs is simulated without the actuation and the results are compared.

The actuator operation involves three coupled physics mainly Solid mechanics, Heat transfer in solids and Electric currents. The standard model given in the MEMS library has been used for comparing the performance of the proposed model. The micro hair structure is electro thermally actuated to counterbalance the forces acting on it and the nano hairs adhere to the surface. Using COMSOL Multiphysics® we compare the two designs of the gecko foot, one with electrothermal actuation and one without. The results of the comparison have been tabulated. The COMSOL software has also facilitated in performing the modal analysis of the structure which is crucial in analyzing the dynamic response when subjected to varying frequencies.

In the no actuation model the Stress and Strain values are 1.08e6 N/m2 and 8.85e-3 respectively. Whereas in the actuation model the Stress and Strain values are 5.85e5 N/m2 and 6.87e-7. Based on the obtained simulation results one can conclude that the actuation model has a superior performance. This results in the requirement of a reduced number of nanohairs which reduces the structural complexity and this simplifies the fabrication process manifold.

Reference

1.G. Shah and I. Lee, “Finite Element Analysis of Gecko Foot Hairs for Dry Adhesive Design and Fabrication,” Dept. of Mechanical Engineering—NanoRobotics Lab, Carnegie Mellon Univ., Pittsburgh.
2.M. Sitti and R.S. Fearing, “Synthetic Gecko Foot-Hair Micro/Nano-Structures for Future Wall-Climbing Robots,” Proc. IEEE Robotics and Automation Conf., Sept.2003.
3. A.R. Kalairasi and Dr. S.Hosimin Thilagar, “Design and Finite Element Analysis of Electrothermal Compliant Microactuators,”Anna University, Chennai.
4. S. M. Karbosi, M. Shamshrisar, M. Naraghi and M. Manoufi, “Optimal design analysis of electro thermally driven micro-actuators”, Microsystem. Technol, pp. 1065-1071, (2010).
5.K. Autumn, et al., Evidence for van der Waals attachment by Gecko foothair inspires design of synthetic adhesive, Proc. of the National Academy of Science, 2002.

Figures used in the abstract

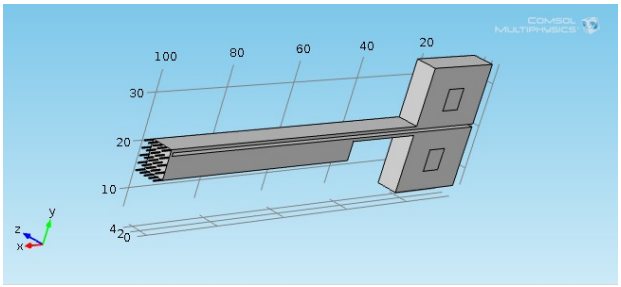

Figure 1: 3-D Structure of the proposed gecko foot microhair.

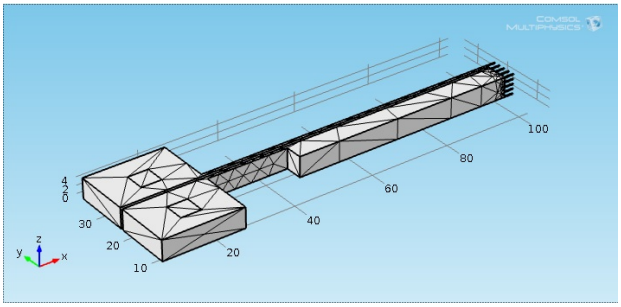

Figure 2: Finite Element Analysis using user defined mesh.

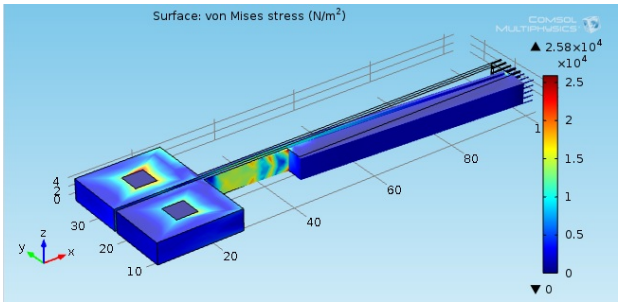

Figure 3: Stress Analysis of the micro hair structure.

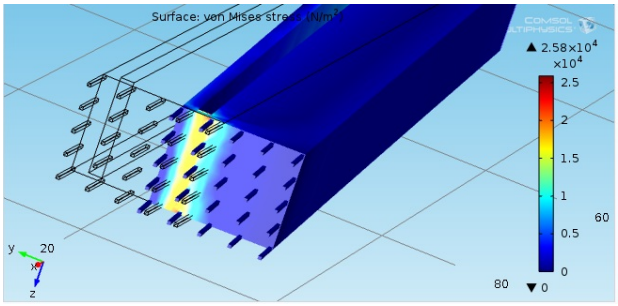

Figure 4: Displacement of the nano hairs after actuation.