Simulation of a Tether Structure for Ultra-stretchable Monolithic Silicon Fabric

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Abstract

INTRODUCTION: The role of stretchable electronics systems allows the design of new reconfigurable macro-electronics, that extends a device capability to function as a distributed sensor network which can potentially be used for wearable electronics. At the moment such devices are primarily based on polymeric materials such as PDMS or Polyimide [1,2]. Nevertheless, silicon has been the predominant material in electronics for decades. For this reason, we selected silicon as the base material structure for a hexagonal islands network, which are connected through spiral springs to form an ultra-stretchable arrangement [3,4]. In this work we simulated a spiral tether structure for stretchable and adaptable electronic systems. The spirals interconnect several hexagonal islands as show in (Figure 1).
USE OF COMSOL MULTIPHYSICS®: The Finite Element Method (FEM) used to validate the functionality of the spiral structure. COMSOL capabilities to simulate Micro Electro Mechanical Systems (MEMS) have shown good agreement in other systems for the past years [5-10]. Therefore, our simulation was performed using COMSOL Multiphysics 5.0. The structure layout design was exported from Tanner Tools L-edit software as a DXF file, using the CAD import module of COMSOL. The 2D drawing was imported to a work-plane and then extruded to the specific thickness needed. The structure's material was Silicon (single-crystal), which was selected from the predefined materials library. The physics being used for this simulation was the Solid Mechanics module.
To deform the structure a Prescribed Displacement condition was set to the other end of the spiral structure and the value was set to a predefined parameter to be able to perform an extended study. For the mesh settings the top face of the spiral was selected to create a Free Triangular mesh, which then was used in a swept function to propagate the structure elements. The simulation was performed using a Stationary Study (including the geometric nonlinearity of the system) with an Auxiliary sweep to help the solver converge contemplating the large deformation of the structure. Finally, the Auxiliary sweep was set up using the predefined parameter and solved for a range of values from 0µm of displacement to 2mm in steps of 5µm.
RESULTS: The simulation was used to evaluate the spirals strain distribution and to identify possible weak points in the structures' design. In Figure 2 we show the simulation results of a fully extended spiral. Figure 3, shows the corresponding strain and Figure 4 shows a graph of the von Mises stress in the spiral, when is extended to different horizontal displacement of up to 675µm. The maximum stress and strain location are at the beginning of the arms. The Von Mises

stress has a maximum of 4000 MPa, which is much lower than the tensile strength of the silicon.

CONCLUSION: The spiral design seems to have some maximum stress and strain point at the beginning of the arms that could be a decreased by adding a new feature to the arms to alleviate the stresses and avoid an earlier fracture.

Reference

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Figures used in the abstract

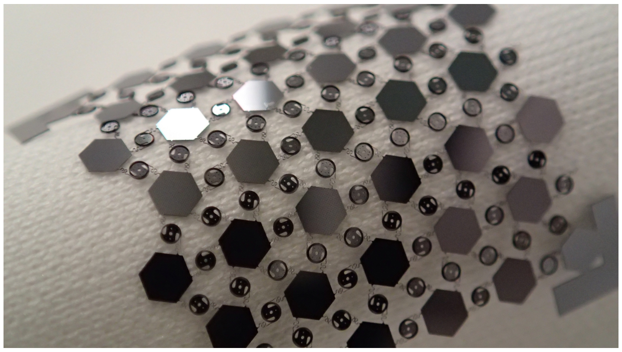

Figure 1: Digital photograph of an array of 800um-side-hexagons interconnected by single 5um-arm spirals

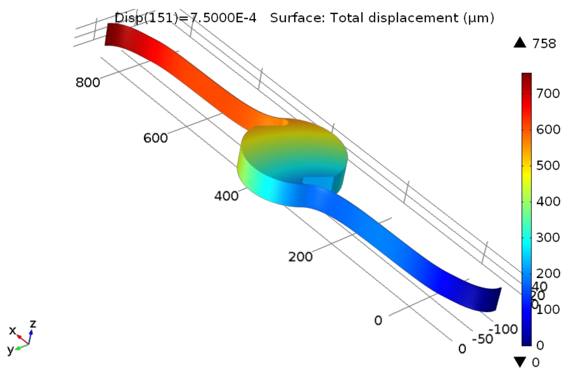

Figure 2: Simulated Displacement of the stretched spiral structure.

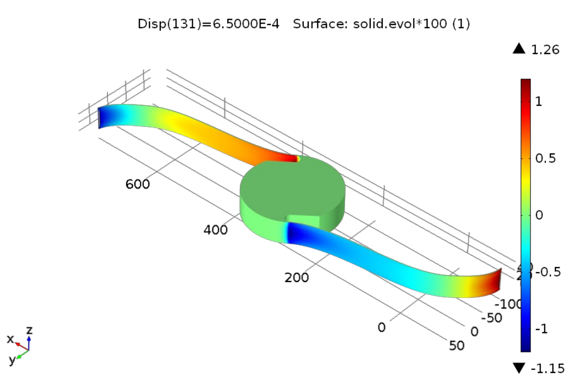

Figure 3: Expanded spiral showing the Strain across the structure.

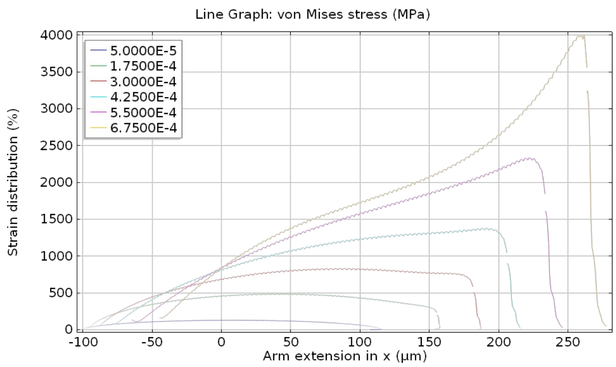

Figure 4: Expanded spiral showing the von Mises values.