Simulation of a Thermoelectric Spiral Structure

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Introduction

Energy efficiency and harvest, speed and performance, flexibility and portability are key elements for innovation in the current consumer electronics markets.

- Thermoelectric Generators can convert energy from heat gradients into electricity. Every source of heat from an electronics device can potentially be used as a source of energy.
- These generators have the advantage of: being silent, compact, simple and scalable fabrication, can power small devices like wristwatches.

Our thermoelectric generators are conceived in a flexible polymer substrate, that has been coated with Bismuth Telluride layer.
The spiral design allows for an expandable generator that can see a larger heat gradient when it is elongated away from the heat source.
Parallelization of many thermoelectric spirals is used to generate relevant power.

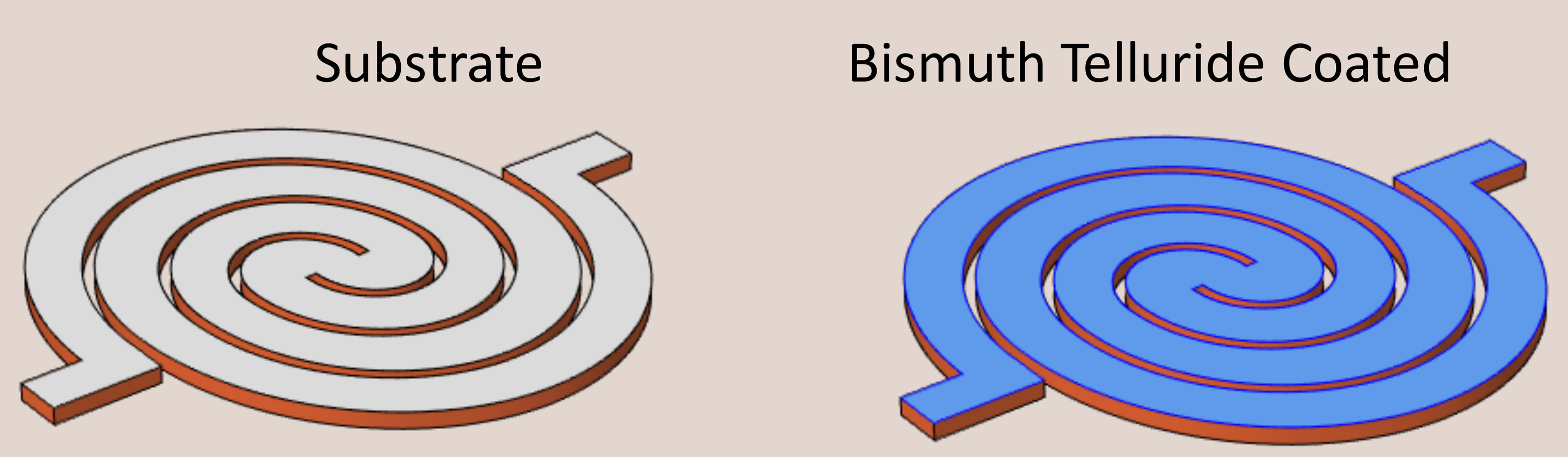


Figure 1: Thermoelectric generator spiral. The device is laser-cut from a polyimide film and the a thing film of thermoelectric material is sputtered (1um)

Design and Simulation

We use COMSOL Multiphysics to model our solid-state thermoelectric using the structural mechanics, heat transfer, and electric currents physics modules.

- The structural mechanics study gives us relevant information about the shape of desired deformation
- The second physics integrated (heat transfer) is used to visualize the heat distribution across the thermoelectric spiral
- Finally the third physics provided us with significant information about the power produced for a fixed temperature difference.

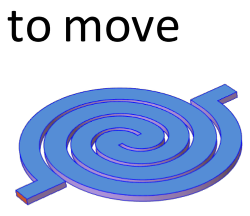
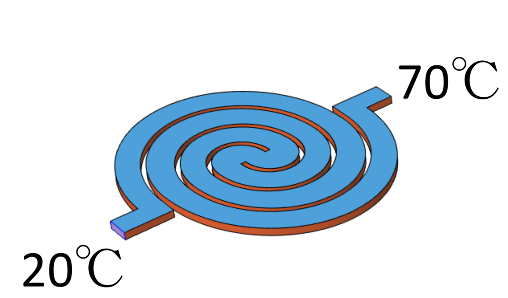
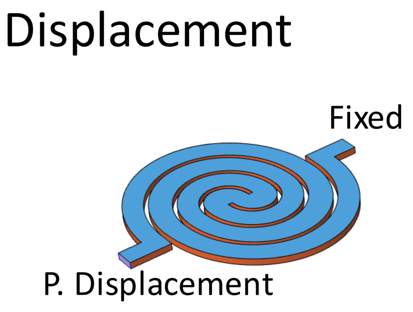
Solid Mechanics	Heat Transfer in Solids	Electric Currents
Linear Elastic Material	Heat Transfer in Solids	Current Conservation
$\sigma = \sigma_{ex} + C : \varepsilon_{el} = \sigma_{ex} + C : (\varepsilon - \varepsilon_{incl})$	$\rho C_p \frac{\partial T}{\partial t} + \rho C_p \mathbf{u} \cdot \nabla T + \nabla \cdot \mathbf{q} = Q$	$\nabla \cdot J = Q_j$ $J = \sigma E + J_E$ $E = -\nabla V$
Free to move	Temperature Gradient	
		
Fix constrain- Prescribed Displacement		
		

Figure 2 User Interfaces used and Boundary conditions

Results

We performed a solid mechanics simulations to evaluate the reliability and durability of the thermoelectric generators when they are elongated.

The prescribed displacement condition allowed us to graphically visualized the deformation and to spot regions of stress concentration.

Thermal simulation provided a good description of the heat distribution across the generators. This distribution is important because it is directly related with the energy conversion:

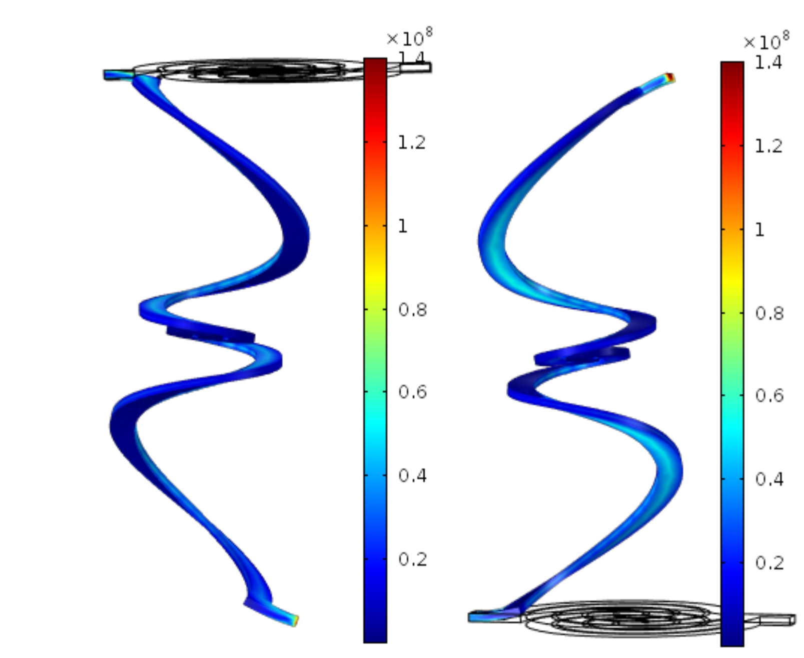


Figure 3 Von Misses Stress, higher stress concentration on the polyimide side

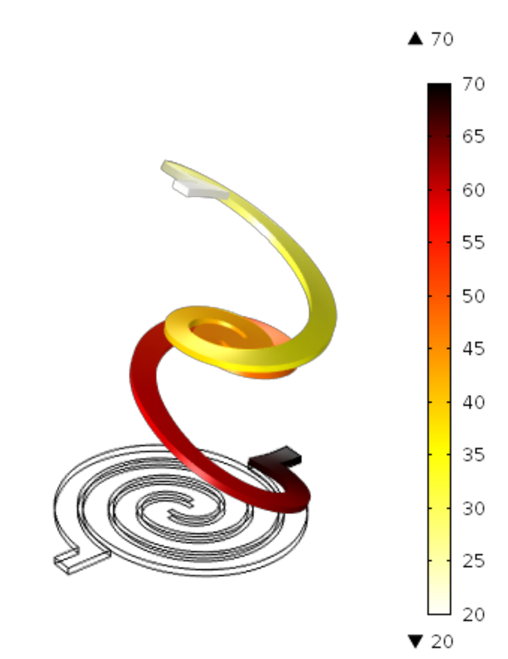


Figure 4:Temperature Gradient

We have also been able to calculate the total power generated by the thermoelectric material under steady state conditions. By parallelizing many spiral thermoelectric generators, we can add the electric contribution generated by each one and obtained a significant electric power.

Conclusions

We have successfully simulated a flexible polymer-based thermoelectric generator using the Multiphysic capabilities provided by COMSOL. We observed not only the temperature gradient but also de deformation and the power generated by our design.

This device can potentially energize low power consumptions devices or batteries from heat sources that can be found in every consumer electronic device.

References

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