Optimization of piezoelectric-triboelectric hybrid generator design

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INTRODUCTION:

Devices which scavenge mechanical energy and convert them to usable electricity are in high demand. They can harvest energy from sources such as human body movement and ocean waves.

Triboelectric generators (TEGs) consist of two dissimilar dielectrics sandwiched between two electrodes and separated by a gap. Charge is induced when the dielectrics are forced into contact. When they are separated, a voltage is induced in the electrodes. This voltage can be used to drive an external load.

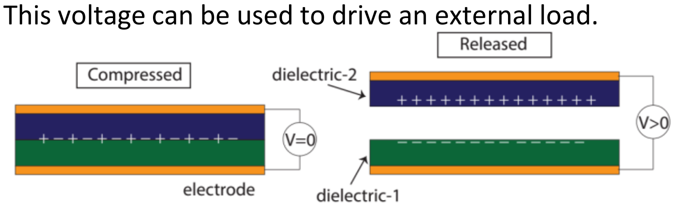

Figure 1. Mechanism for voltage generation in a TEG.

In a traditional design, when the device is compressed, the output voltage is zero. To generate voltage when compressed, researchers have incorporated piezoelectrics [1], materials which generate voltages under stress.

COMPUTATIONAL METHODS:

We use the MEMS module in COMSOL to study the effect of piezoelectric inclusions in a triboelectric generator. We used *piezoelectric effect* multiphysics which combined *electrostatics* and *solid mechanics*. A *stationary* study was conducted.

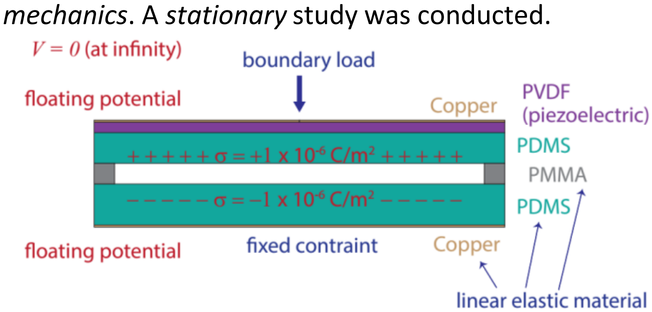

Figure 2. Boundary conditions and material choices. PVDF is the piezoelectric polymer. PMMA is used as a spacer while PDMS is the dielectric. We use a surface charge layer to simulate the triboelectric effect [in a real device, top and bottom dielectrics would be dissimilar].

Study 1: We compare two device geometries: (a) *layered structure* where PVDF (piezo) forms a complete layer and (b) *embedded inclusions* where PVDF is inside the PDMS (dielectric) matrix.

Study 2: We compare two kinds of electrode materials: (a) *hard* materials such as copper and (b) *soft* materials such as polymers. [PS: the words *hard* and *soft* are used as general terms]

REFERENCES:

[1] W.-S. Jung *et al., High Output Piezo/Triboelectric Hybrid Generator, Scientific Reports 5, 9309 (2015)*

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RESULTS:

Study 1: For the same deformation, the *layered* structure produces more voltage than *inclusions*. We attribute this to differences in the stress distribution in the PVDF layer. As shown in fig.3, we find that the layered structure is most effective in generating high levels of positive x-stress.

Geometry*	Load (N/m)	displ. at center (cm)	V_{top} (V)	V_{bot} (V)	$\Delta V = V_{top} - V_{bot}$ (V)
Layered	-13100	0.051	+111	-100	211
Embedded	-5250	0.051	+36	-27	63

* Volume ratio of PVDF : PDMS is the same in both cases

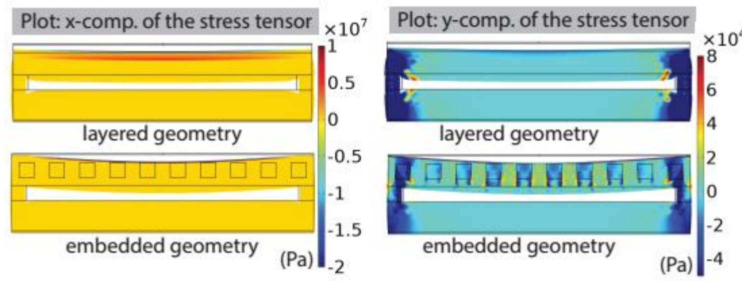

Figure 3. Table summarizes the comparison between layered and embedded geometries. Plots show stress distribution in both cases.

Study2: When we use *hard* materials such as copper for the electrode, we find that the x-stress in PVDF is positive throughout. However, when we use *soft* materials, such as polymers, the PDVF layer experiences both positive and negative stresses, thereby reducing the voltage produced.

Electrode	Young's modulus (Pa)	Load (N/m)	displacement at center (cm)	V_{top} (V)	V_{bottom} (V)	ΔV (V)
Copper	1.1×10^{11}	-16000	0.068	+126	-113	239
PMMA*	3×10^{9}	-12250	0.068	+76	-53	129
PDMS*	7.5×10^{5}	-9350	0.068	+31	-9	40

* Non-conducting polymers are used due to the unavailability of conducting polymers in *materials*. The equipotential boundary conditions ensure that they still act as electrodes (terminals).

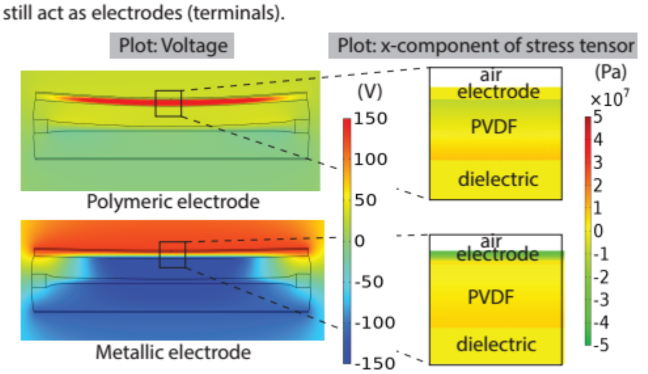

Figure 4. Table summarizes the effect of mechanical properties of the electrode materials on output voltage. The plot shows voltage distribution across the layers and the corresponding x-stresses.

CONCLUSIONS:

This study highlights the interplay between electrical and mechanical properties in determining the output of a hybrid generator. These simulations can be combined with experimental constraints to formulate viable device designs.

In the future, we would like to do a time-dependent study which simulates the entire compress-release cycle with the device connected to a load. We would like to monitor power generation as a function of time.