Design of Mechanical Structure of Th-Vi PiEHs and Electronic Interface of Hybrid Energy Harvesters

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Motivation and Concept

Target

The aim is to harvest energy from ambient vibration and ambient temperature in order to power sensors in an extreme environment such as nearby thermal engines in cars. Piezoelectric, pyroelectric and thermal expansion effects are the principle of energy conversion. The energy harvested from ambient temperature is considered in our work as additional to the energy harvested from ambient vibration, and not as the principal source.

Challenges

While vibrational energy harvesting through piezoelectric materials raised numerous works in the literature, harvesting thermal energy poses great challenges when the ambient temperature is constant or is varying slowly. To deal when in this case, we are exploring the combination of gas expansion and the above effects, with a harvester structure that is composed of the piezoelectric transducers themselves placed in closed-structure with ideal gas

Approach

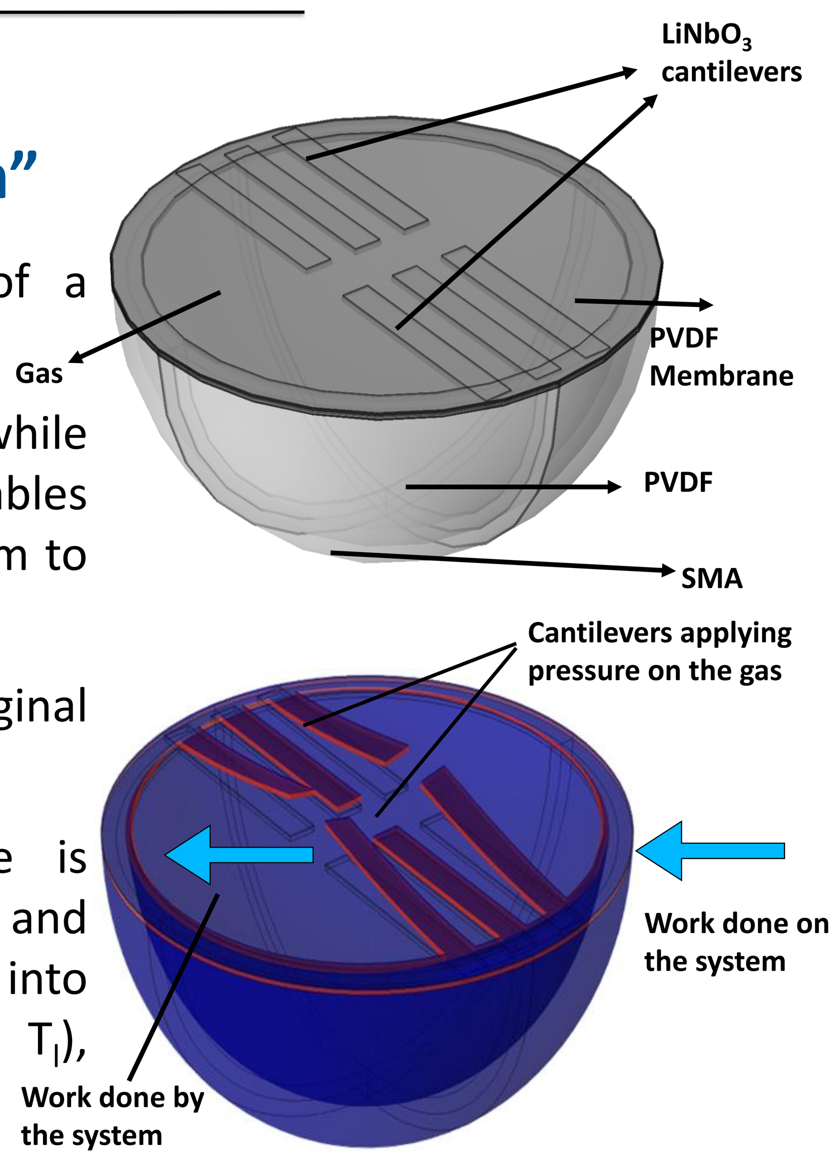
"Closed system"

Thermodynamic cycle consists of a linked sequence of a thermodynamic process that involves

- transfer of heat and work into and out of the system while varying temperature, pressure and other state variables within the system, and that eventually return the system to its initial state.

During a closed cycle, the system returns to its original thermodynamic state of temperature and pressure

For the hybrid transducer, the thermodynamic cycle is converting mechanical work to increase the temperature and vice versa (decrease in temperature will get converted into mechanical work). The system has 2 isotherms (T_h and T_l), which will help pyroelectric material to harvest Energy

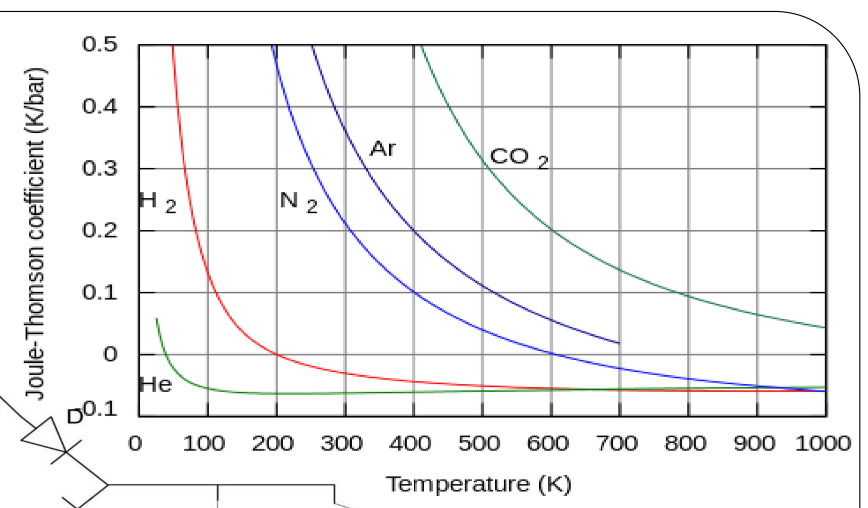


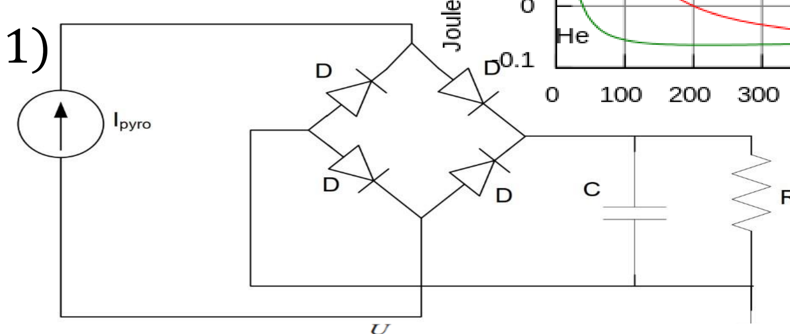
Modeling

Mathematical Modeling

Joule-Thompson Effect

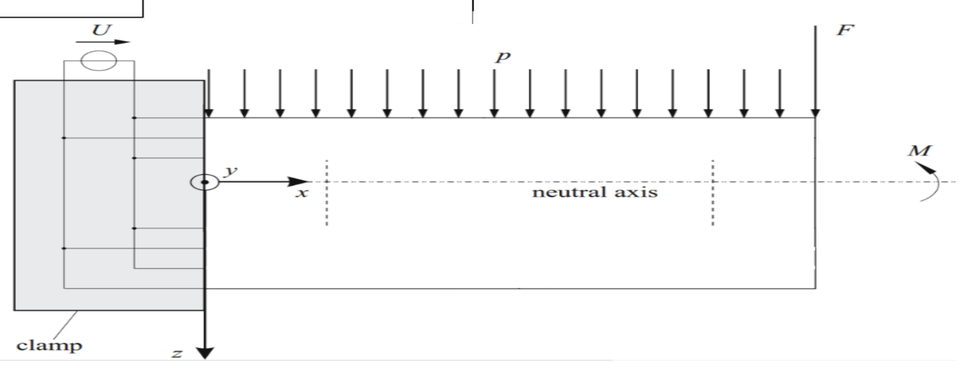
$$\mu_T = \left(\frac{\delta T}{\delta P}\right)_H = \frac{V}{C_P}(\alpha T - 1)$$





Pyroelectric Energy

$$E_{Py} = \frac{1}{2}\frac{p*^2}{\varepsilon}A.d.dT^2$$



Piezoelectric Energy

$$E_{pi} = \int_0^l \frac{1}{2C'_{Piezo}}\left(\frac{\partial Q_q}{\partial x}\right)^2 dx + \int_0^l \frac{M^2}{2C} dx + \int_0^l \frac{M\, m_{Piezo}}{C\, C'_{Piezo}}\left(\frac{\partial Q_q}{\partial x}\right) dx$$

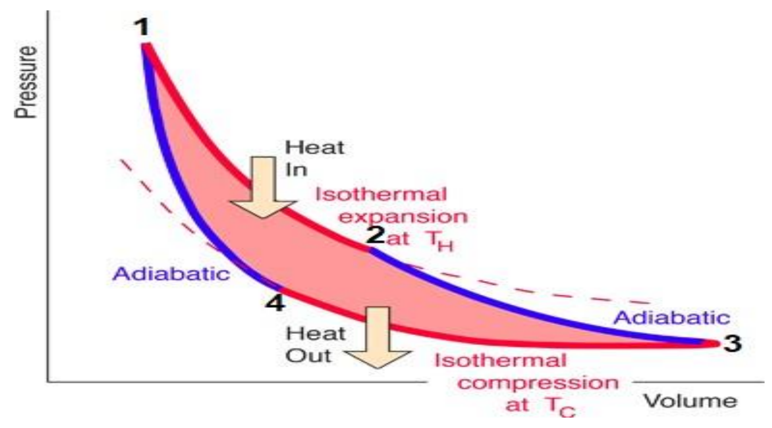
Thermodynamics

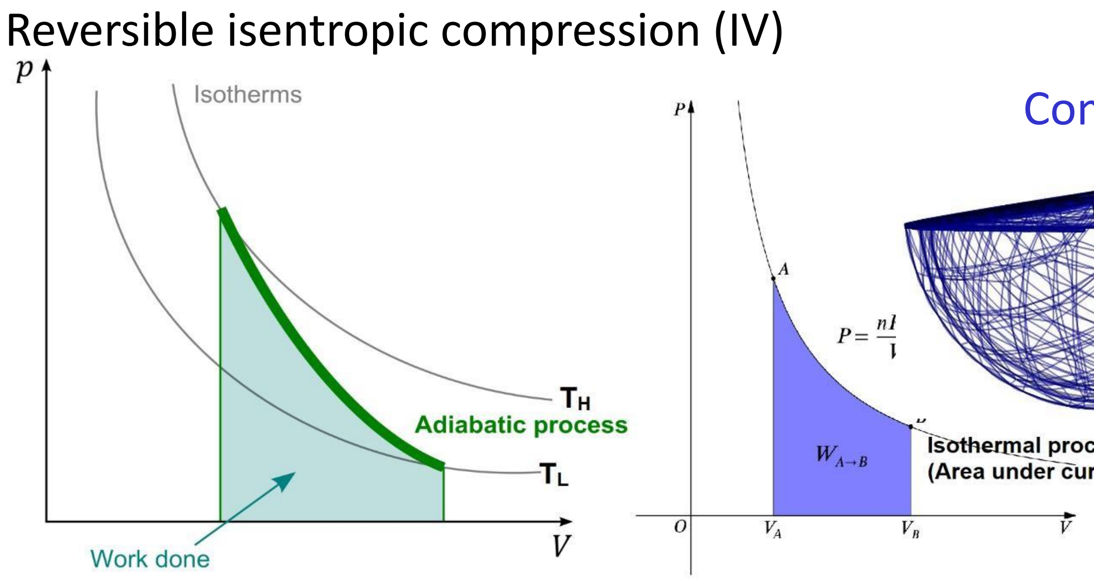
Work done during expansion of a gas

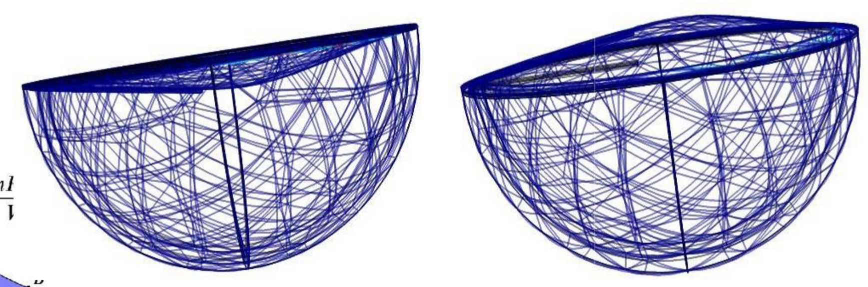
- ❑ Reversible isothermal expansion (I)
- ❑ Reversible isentropic expansion (II)

Work done during contraction of a gas

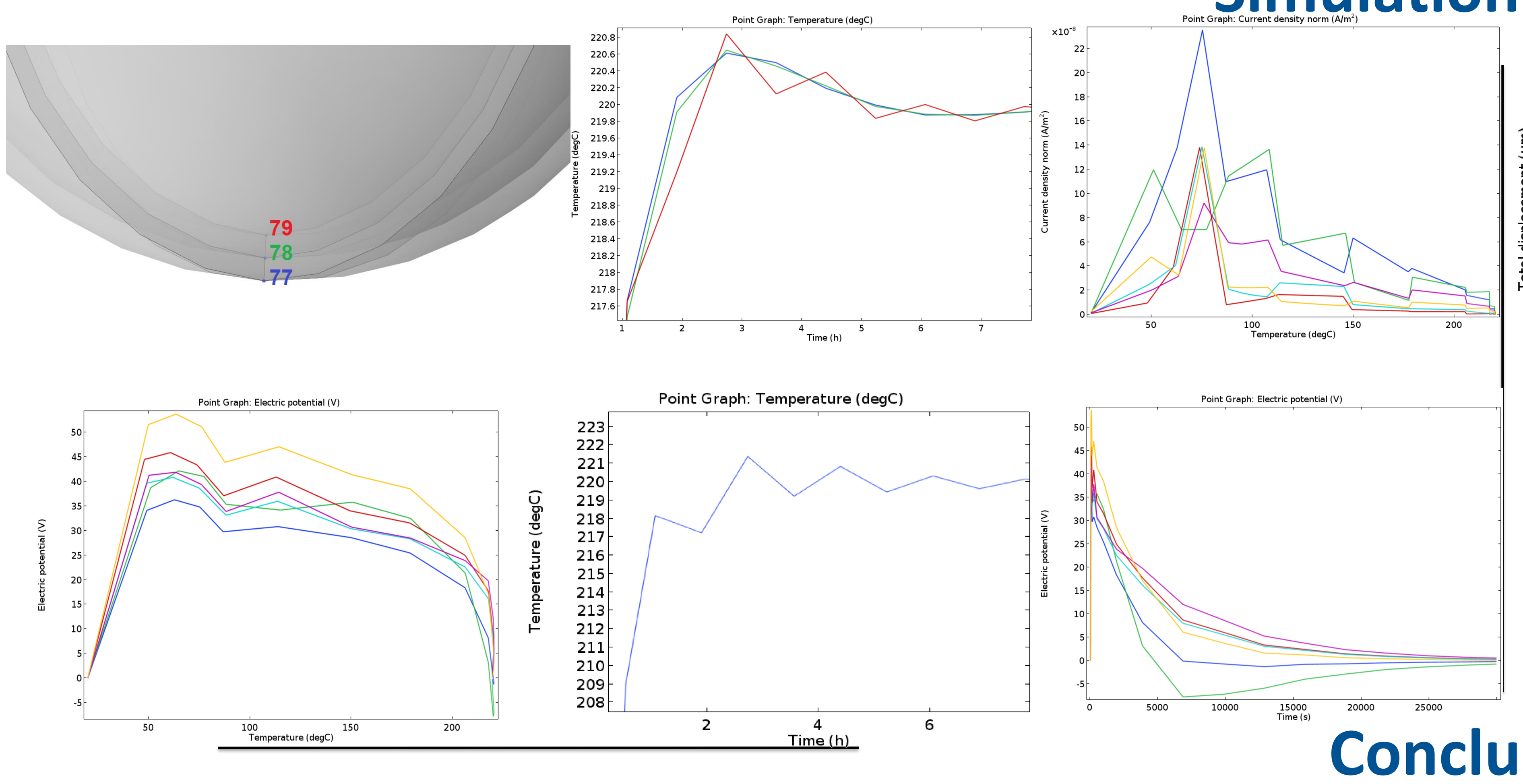
- ❑ Reversible isothermal compression (III)
- ❑ Reversible isentropic compression (IV)

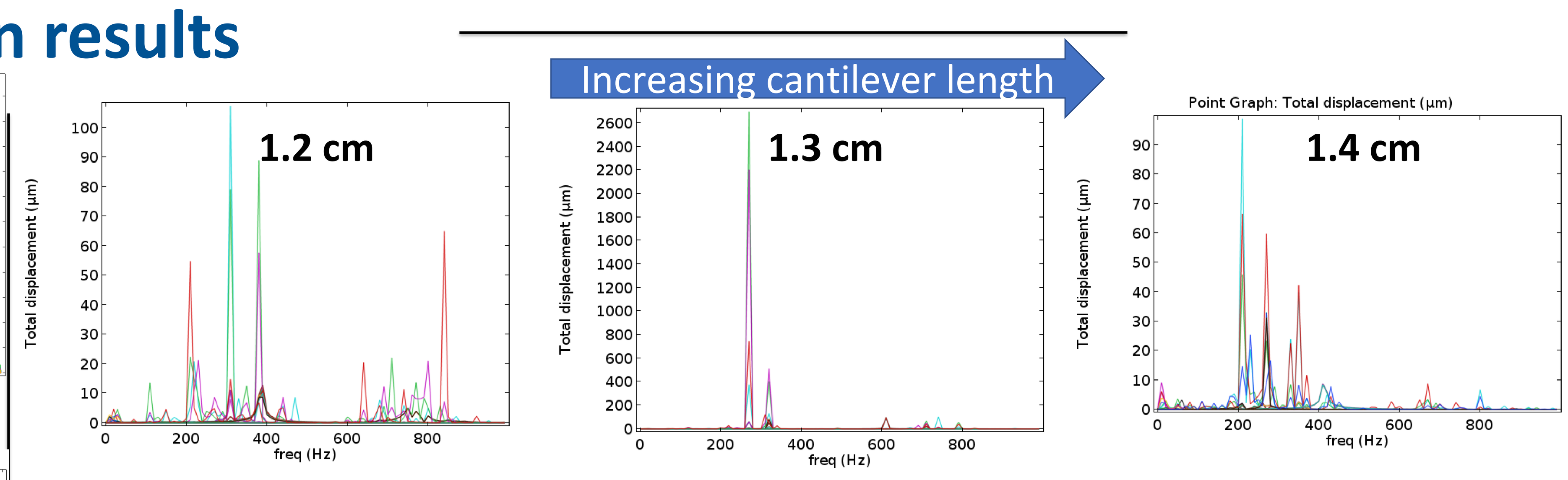






Simulation results





	E_{piezo}	E_{pyro}	E_{total} (open)	E_{total} (closed)
Total Energy (220 °C)	0.0003 µW	3.1622 µW	3.1625 µW	3.1638 µW
Total Energy (120 °C)	0.0003 µW	3.1622 µW	3.1625 µW	4.3823 µW

Conclusion

- With the help of this new closed system concept we will always be able to harvest energy even at constant temperature, as the gas inside give rise to temerature fluctuation because of joules thompson effect therefore the pyroelectric part will be able to harvest energy with the combination of piezoelectric part and this will lead to better electrical ouput.

References

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2.B. Gusarov, E. Gusarova, B. Viala, L. Gimeno, S. Boisseau, O. Cugat, E. Vandelle, B. Louison, Thermal energy harvesting by piezoelectric PVDF polymer coupled with shape memory alloy, Sensors & Actuators: A. Physical, submitted (2015). for energy harvesting applications, in Proc. PowerMEMS London, Journal of Physics.

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