Electrical Energy Harvesting from Body Heat: Indirect Conversion via Mechanical Vibration

Seungyong Shin, Mojtaba Hodjat-Shamami, and Farrokh Ayazi
Georgia Institute of Technology, Atlanta, GA, USA

ABSTRACT

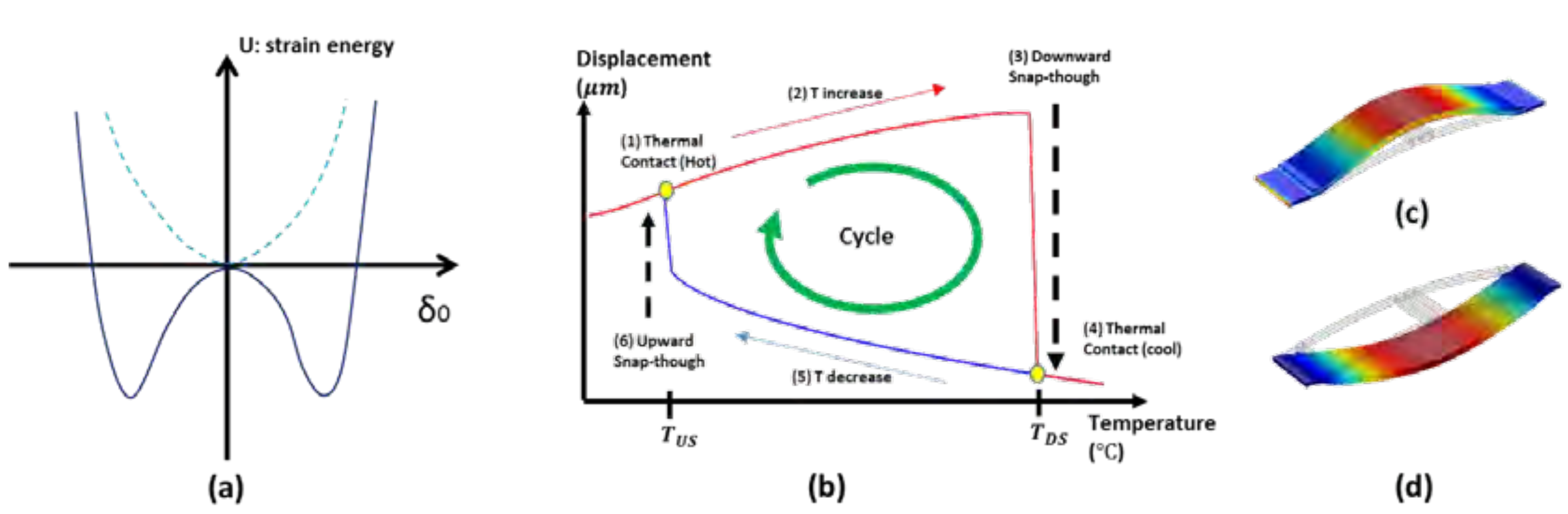
This work presents a possible structure for harvesting thermal energy of human body by converting it to mechanical vibration energy with pre-stressed biomorphic beam. The energy conversion rate can be highly increased by leveraging snap-through phenomena of bi-stable vibrational structure. The output power is estimated as $0.3mW/cm^2$. This is enough to operate typical Body Area Sensor Network (BASN). The simulation result shows that the minimum required temperature difference between body and ambient can be smaller than 10℃ which is smaller than typical temperature difference (37℃ - 20℃). That proves the feasibility of proposed human body thermal energy harvester.

INTRODUCTION

- The key requirement of BASN system is to secure a reliable energy source able to provide enough power without a need for recharging or replacing.
- Heat of a human can be abundant source of energy for BASN. The average heat energy per unit area is about $5.3mW/cm^2$.
- Draw backs in currently existing direct conversion methods.
  - ✗ High temperature gradient is required.
  - ✗ Low conversation efficiency for pyro-electric, and higher price for thermo-electric materials.
- Proposed thermo-mechanical conversion take advantage of bitable structure
  - ✓ Due to the bi-stable structure maximum displacement can be amplified.
  - ✓ Possible to operate with lower thermal gradient ΔT.

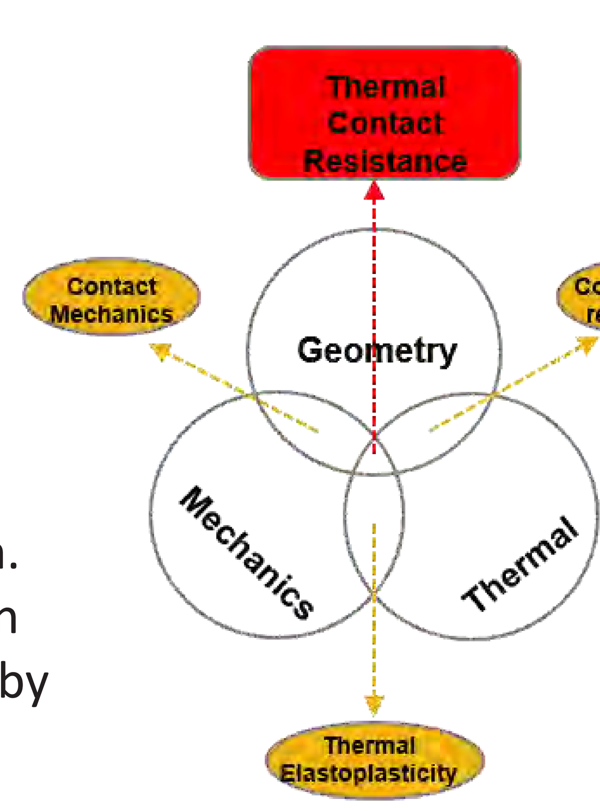
THERMO-MECHANCAL ENERGY CONVERSION

- Proposed bi-morph beam consist of two materials with different thermal expansion coefficients and the tension bar which produce initial stress on beam, or bi-stability.



Energy conversion between thermal and mechanical Energy

- Body (~37℃) contacting to the upper surface of bimorph beam increase net temperature of the beam. When temperature of bimorph beam reach T_{DS}, and make a contact with ambient temperature (~20℃) by downward snap-through buckling. Temperature starts to decrease until it reach T_{US}, and at T_{US} the beam will bend to upward by snap-though.
- This thermo-mechanical energy conversion mechanism can be simulated by COMSOL by solving Thermal Contact Resistance(TCR) Problem.



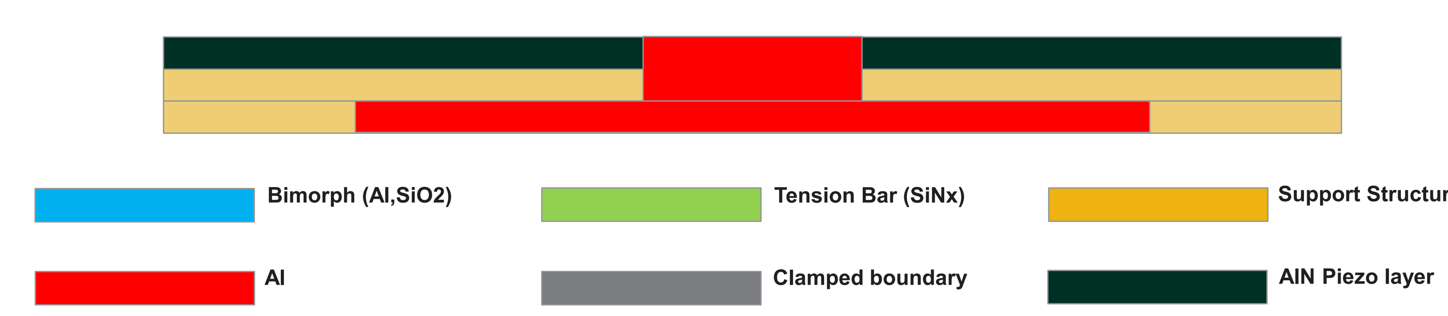
CONSIDERATION ON NUMERICAL METHOD

- Boundary conditions for transient response: Penalty method for mechanical contact and Cooper Mikic Yovanovich for thermal contact.
- Parametric stationary study : Reuse previous solution as initial condition.

CLAMPED MEMS BIMORPH STRUCTURE

- Proposed clamped-clamped MEMS bimorph structure is topologically analogous to the hairclip.

Proposed clamped bimorph beam structure with tension bar

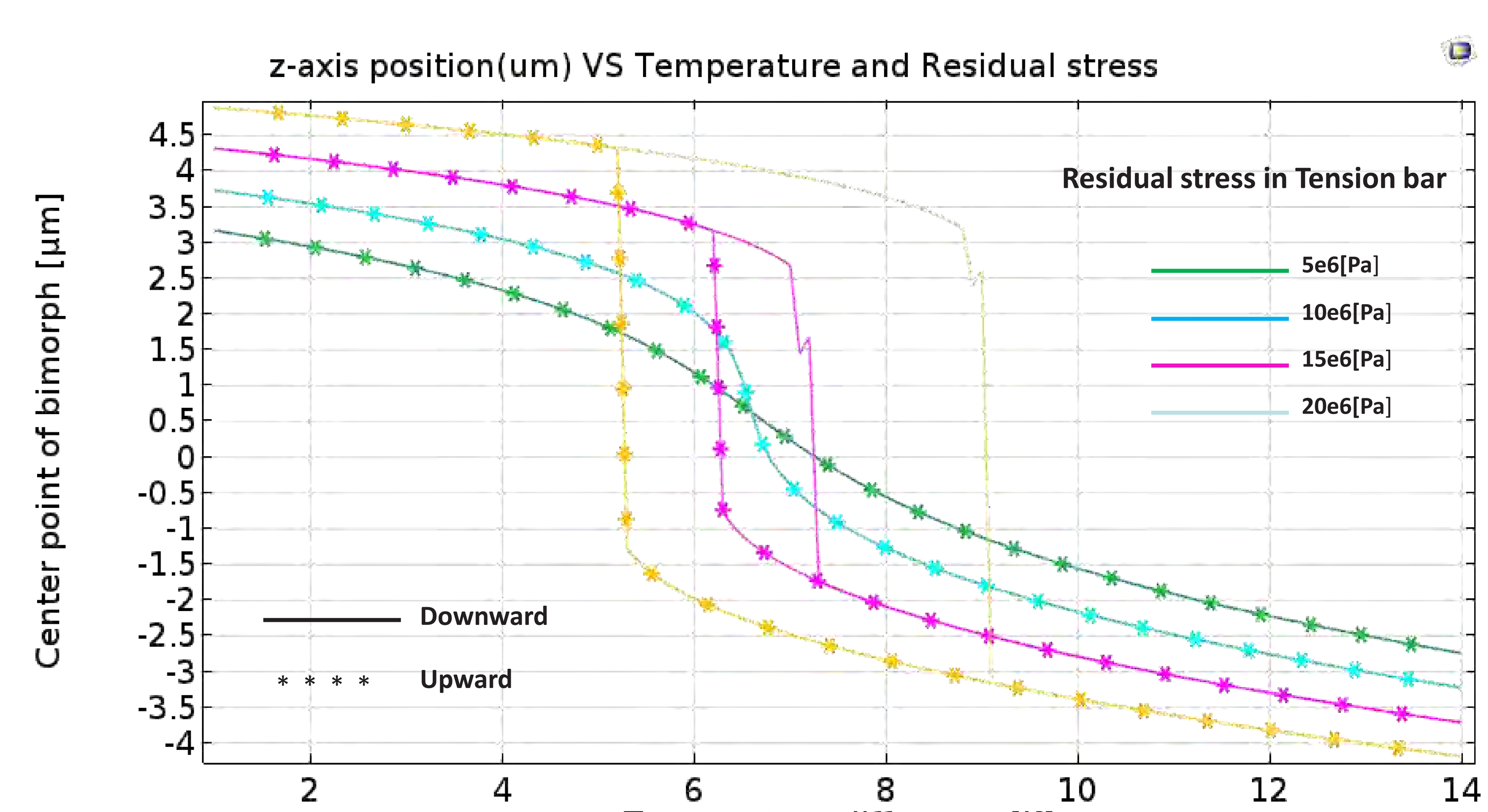


Construction of each layers

- Aluminum and SiO_2 are chosen for the bimorph material because these materials have similar Young's modulus with much different thermal expansion coefficient.
- SiN is chosen for the tension bar because of its high stiffness and controllability on residual stress.
- Converted mechanical energy can be harvested as electric energy by AlN piezo electric layer.

COMSOL SIMULATION RESULT

- COMSOL Simulation that required temperature difference for the energy conversion is below 10℃.



- $T_{DS} - T_{US}$ dependency on the residual stress in tension bar can be seen clearly.

CONCLUSIONS

- The operation of proposed thermo-mechanical energy harvester was demonstrated with FEM simulation.
- The result shows the proposed bi-morph beam convert thermal energy to mechanical energy, and it is possible to harvest heat energy of a human body.

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