nano-tera.ch
swiss scientific initiative in health / security / environment systems

BodyPoweredSenSE RTD 2013

FNSNF

TRIBOELECTRIC GENERATORS FOR HARVESTING ENERGY FROM BODY MOVEMENTS

Rubaiyet Iftekharul Haque[1,2], Etienne Lemaire[1], Christopher J. Borsa[2], Pierre-André Farine[2], Danick Briand[1]

1. *Microsystems for Space Technologies laboratory (LMTS), Ecole Polytechnique Fédérale de Lausanne (EPFL), Rue de la Maladière 71b, CH- 2000 Neuchâtel, Switzerland.*
2. *Electronics and Signal Processing Laboratory (ESPLAB), Ecole Polytechnique Fédérale de Lausanne (EPFL), Rue de la Maladière 71b, CH- 2000 Neuchâtel, Switzerland.*

EPFL

MOTIVATIONS

Objectives: The goal of this research is to harvest energy from the human movement using triboelectric effect.

Requirement:

- Work at low frequency vibration.
- Flexible and/or stretchable harvester to harness energy from human body movement.

Challenges:

- Efficient detection of mechanical deformation, such as pressure and flexion due to human motions.
- Large area fabrication of the device.

INTRODUCTION

Triboelectric effect refers to the generating electricity based on contact electrification effect and electrostatic induction. This effect can be used to harvest energy from kinetic energy. To date, power density of 500 W/m^2 is achieved [1].

Basic principle:

When contact or friction between two materials having opposite charge affinity take place

- ❑ Electrons transfer from material:
  - Low work function → High work function.
  - Contact potential difference: $V_c = \frac{W_1 - W_2}{e}$
- ❑ Equalization of Fermi level.

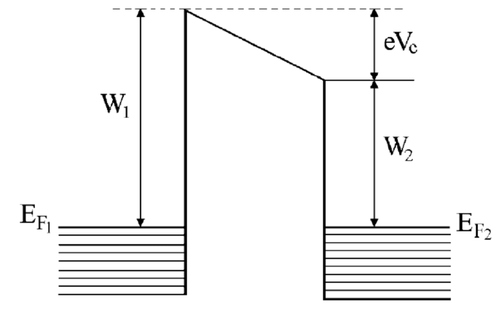


Fig 1: *Material to materials contact [2]*

TRIBOELECTRIC GENERATOR

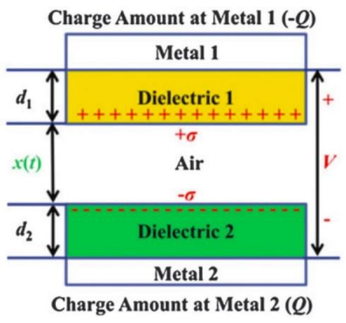
Working principle:

- ❑ Contact electrification
  - Charge transfer
  - Creation of a voltage drop
- ❑ Electrostatic induction
  - Electron flow
  - Balance of potential

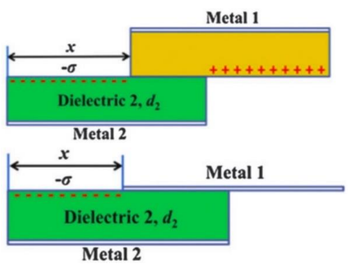
Table: *List of materials for triboelectric application [3]*

	Materials	Charge affinity [nC/J]
Positive	Nylon	+30
	Glass (soda)	+25
	Paper	**+10**
	Nitrile rubber	**+3**
	Steel	0
	PET	**-40**
Negative	Polystyrene	-70
	Polyimide (PI)	-70
	Silicones	**-72**
	Latex rubber	**-105**
	PTFE/Teflon	**-190**

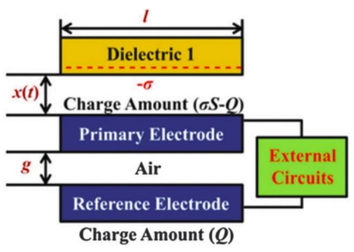
Four fundamental modes of triboelectric generator [1]:



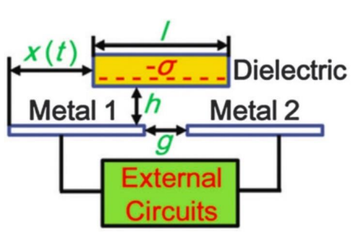
(a) *Vertical contact separation mode*



(b) *Lateral sliding mode*

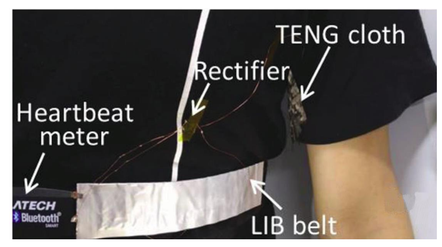


(c) *Single-electrode mode*



(d) *Freestanding triboelectric layer mode*

Possible energy harvesting applications from body movements:



Chest belt [4]

Knee brace [6]

Shoe sole [5]

PROCESSING

Use of flexible/stretchable substrates

↓

Deposition of electrodes

↓

Deposition of triboelectric materials having different electron affinity

↓

Assembly of the layers

Fig 2: *Fabrication process*

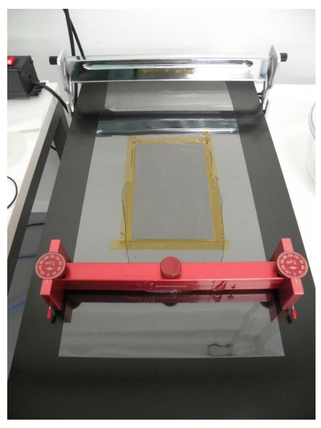


Fig 3: *Film applicator (PDMS casted on stretchable conductive fabric)*

PROOF OF CONCEPTS

Flexible vertical contact separation triboelectric generator:

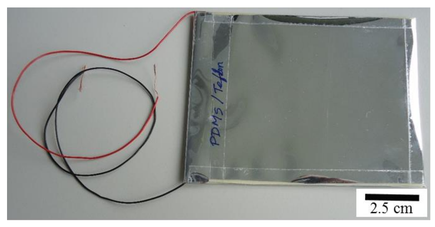
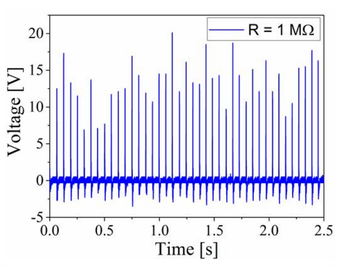


Fig 4: *Vertical contact-separation based triboelectric generator*



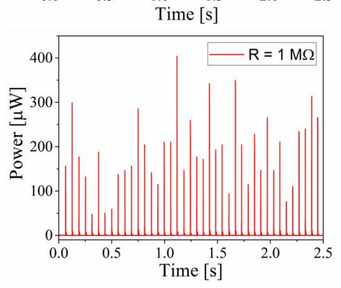


Fig 6: *Output of triboelectric generator.*

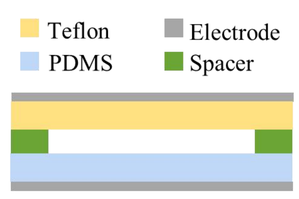


Fig 5: *Schematic diagram of Triboelectric generator*

Stretchable triboelectric generator:

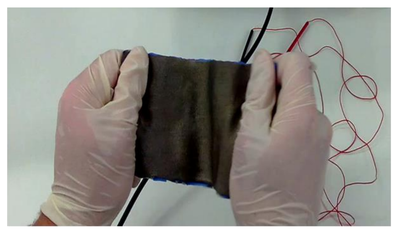
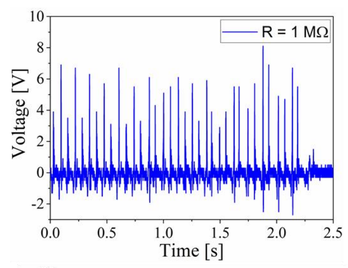


Fig 7: *Stretchable triboelectric generator*



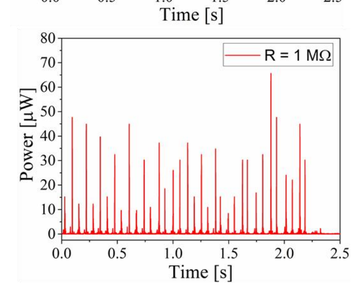


Fig 9: *Output of stretchable triboelectric generator.*

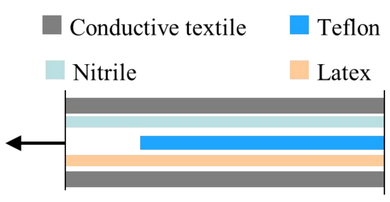


Fig 8: *Schematic diagram of stretchable triboelectric generator*

CONCLUSIONS

- ❑ Triboelectric generator (TEG) is capable of harnessing kinetic energy.
- ❑ Different combination of flexible & stretchable materials, namely, PET, PI, Teflon, PDMS, Paper, Nitrile and Latex rubber have been tested to develop flexible and stretchable TEGs.
- ❑ Developed TEGs provides output voltage of 10 - 20 V & current of 5-20 μA.

REFERENCES

[1] Z.L. Wang et al., Energy Environ. Sci., 2015, 8, 2250.
[2] M. Lungu, Minerals Engineering, 2004, 17, 69.
[3] https://www.trifield.com/content/tribo-electric-series/
[4] X. Pu et al., Adv. Mater., 2015, 27, 2472.
[5] I. Patel, 2011, Ceramic Based Intelligent Piezoelectric Energy Harvesting Device, Advances in Ceramics -Electric and Magnetic Ceramics, Bioceramics, Ceramics and Environment, Prof. C. Sikalidis (Ed.), 133-154.
[6] R. Riemer, et al., Journal of NeuroEngineering and Rehabitation, 2011, 8(22).

Contact: rubaiyet.haque@epfl.ch, http://lmts.epfl.ch/EnviroMEMS