Performance Comparison between Different Materials and Operation Modes of Triboelectric Nanogenerator

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Motivation

1) **Alternative energy source**
   - renewable, clean and zero emission
   - large and small scale harvesting

2) **Excellent properties and performance**
   - flexible, light and biocompatible
   - various choices of materials
   - versatility and applicability
   - high power density and efficiency (record high: 500 W/m^2, 85% [1])

3) **Uncomplex fabrication process**
   - industrial roll-to-roll process
   - lamination and screen printing process
   - standard microfabrication process

Device structure

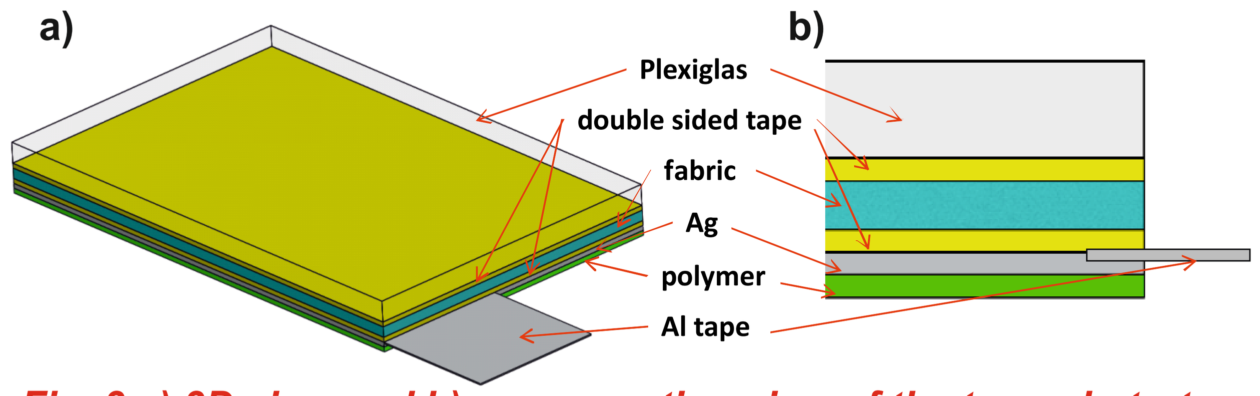

Fig. 3 a) 3D view and b) cross-section view of the top substrate.

The top substrate consists of a stack of plexiglass, double sided tapes, fabric, Al tape and Ag electrode screen-printed on polymer (Fig.3). The bottom substrate comprises Al tape attached on a plexiglass.

Objective

The Objective of this project is to investigate the implementation feasibility of triboelectric nanogenerator (TENG) in textile. The generator should possess a potential to scavenge energy from human movements and to deliver sufficient power for self-powered systems and transducers. The first step of the project is to research and compare the performance of TENGs with different triboelectric materials and operation modes including other factors, such as frequency and contact force.

Background

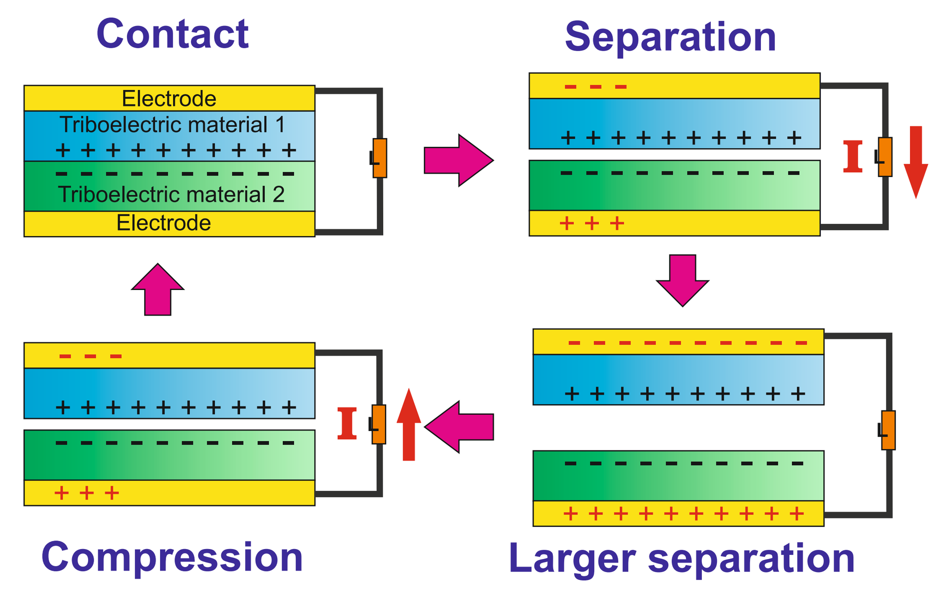

Fig. 1 Operation principle of TENG

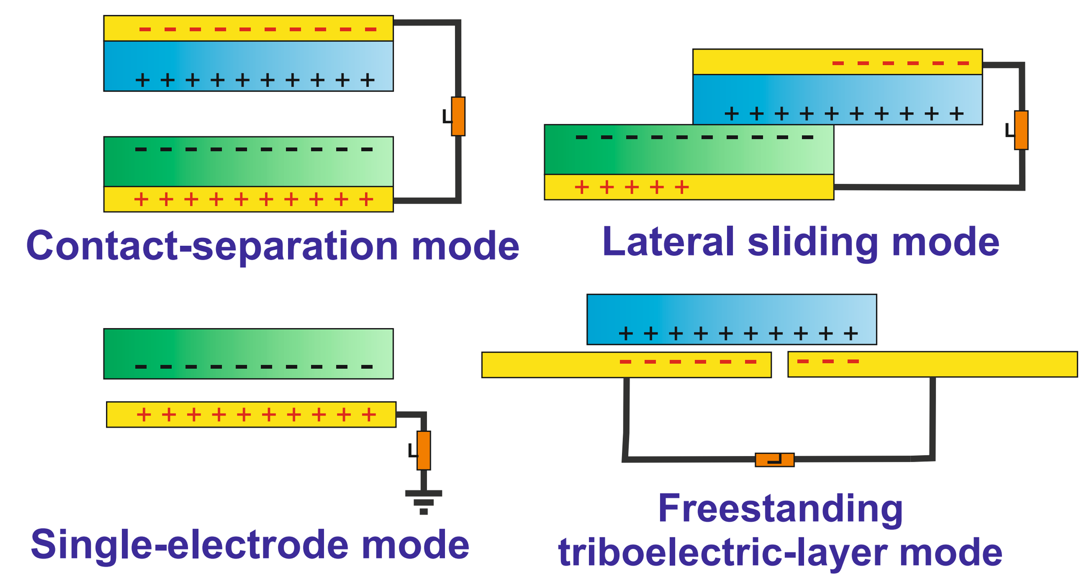

Fig. 2 Four fundamental operation modes of TENG

The operation principle of TENG is based on contact electrification and electrostatic induction. A periodic relative movement between the substrates causes a potential difference between the electrodes resulting in an alternate current through the load. (Fig. 1)

Four fundamental operation modes of TENG are designated depending on different configurations of the electrodes and/or different moving manners of the triboelectric materials [2]. The four mode are vertical contact-separation mode (CS-mode), lateral sliding mode (LS-mode), single-electrode mode (SE-mode) and freestanding triboelectric-layer mode (FT-mode) (Fig. 2).

Results

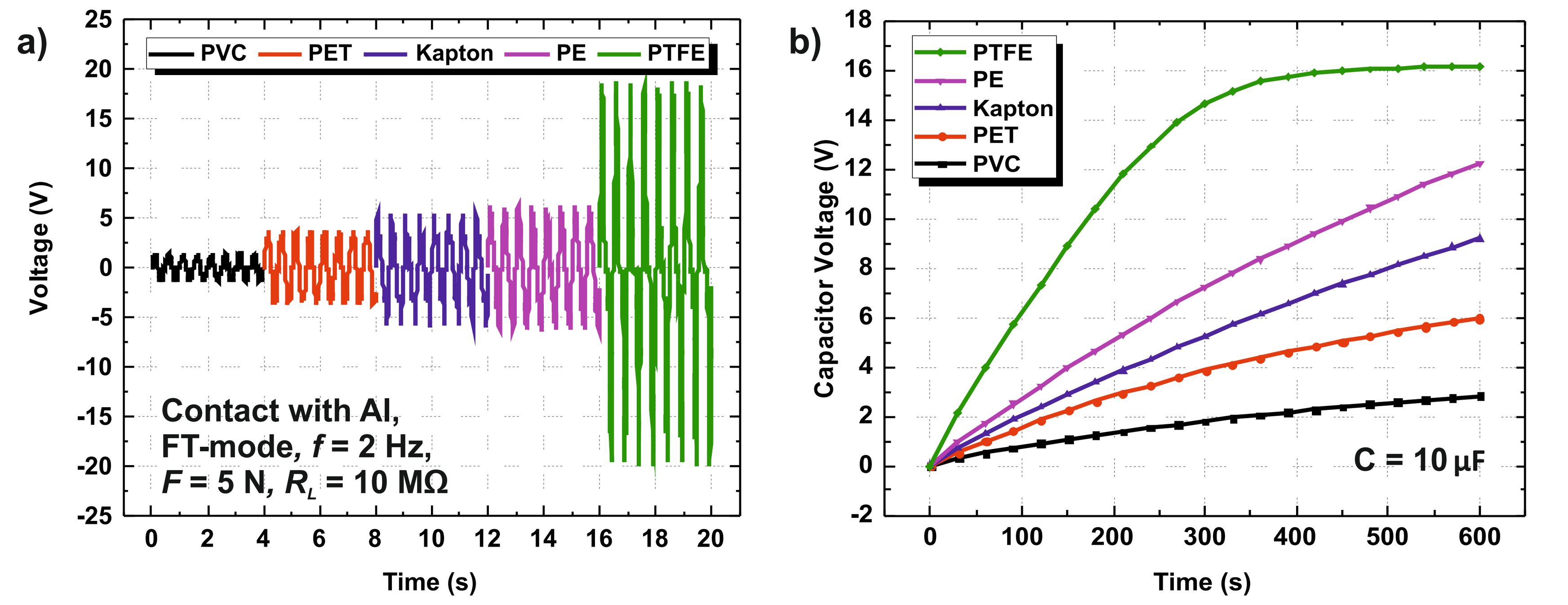

Fig. 4 a) Output voltage and b) capacitor charging voltage of TENGs with different materials

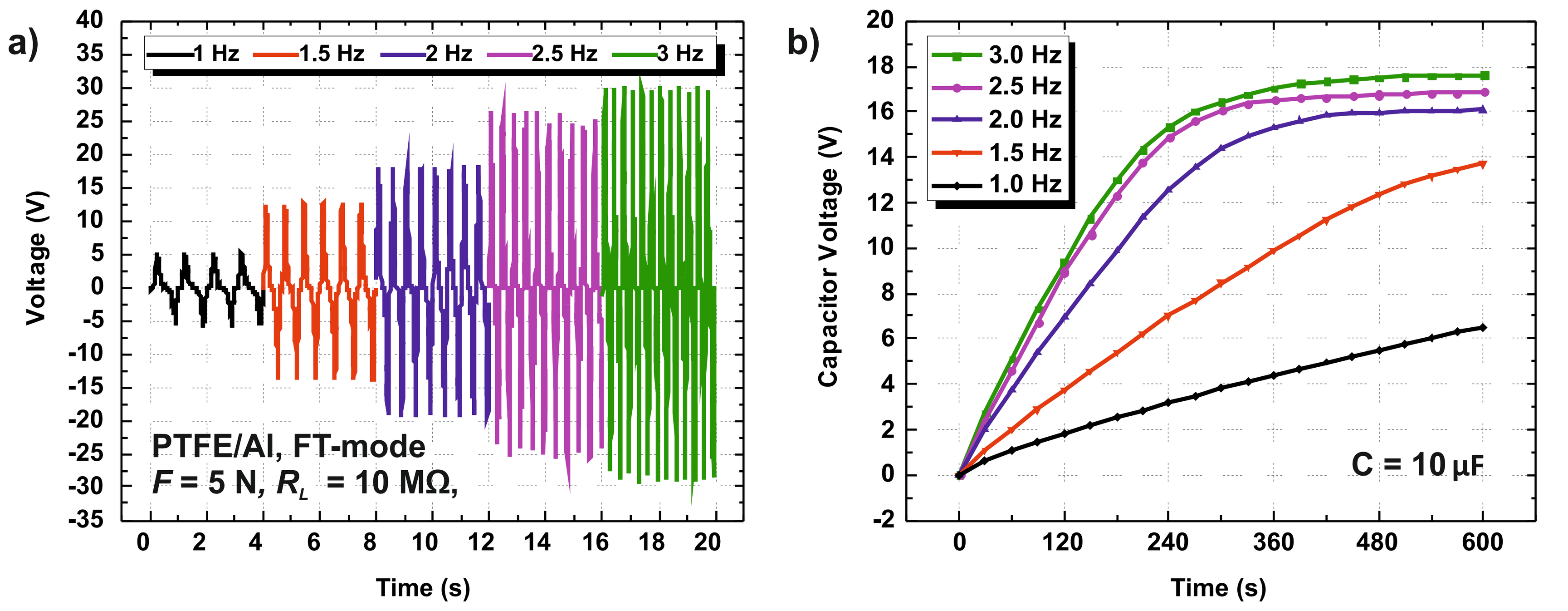

Fig. 6 Frequency dependence of a) output voltage and b) capacitor charging voltage

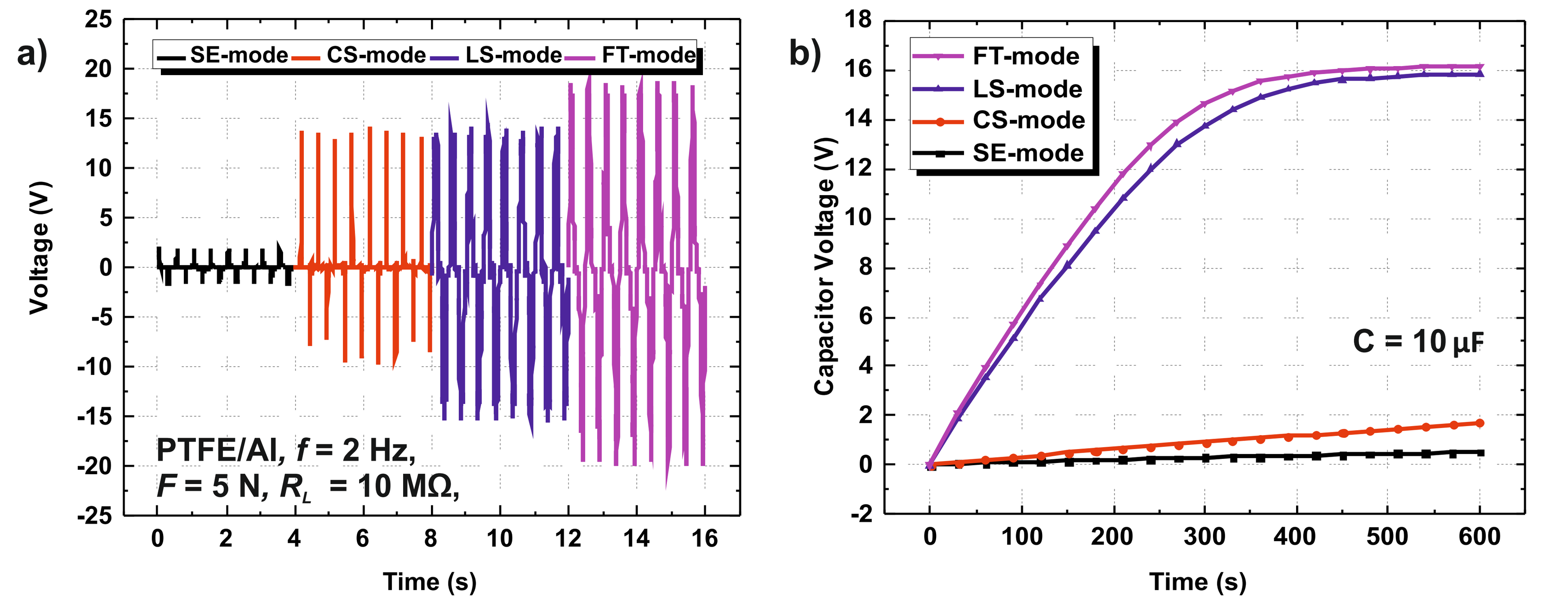

Fig. 5 a) Output voltage and b) capacitor charging voltage of TENGs with different modes

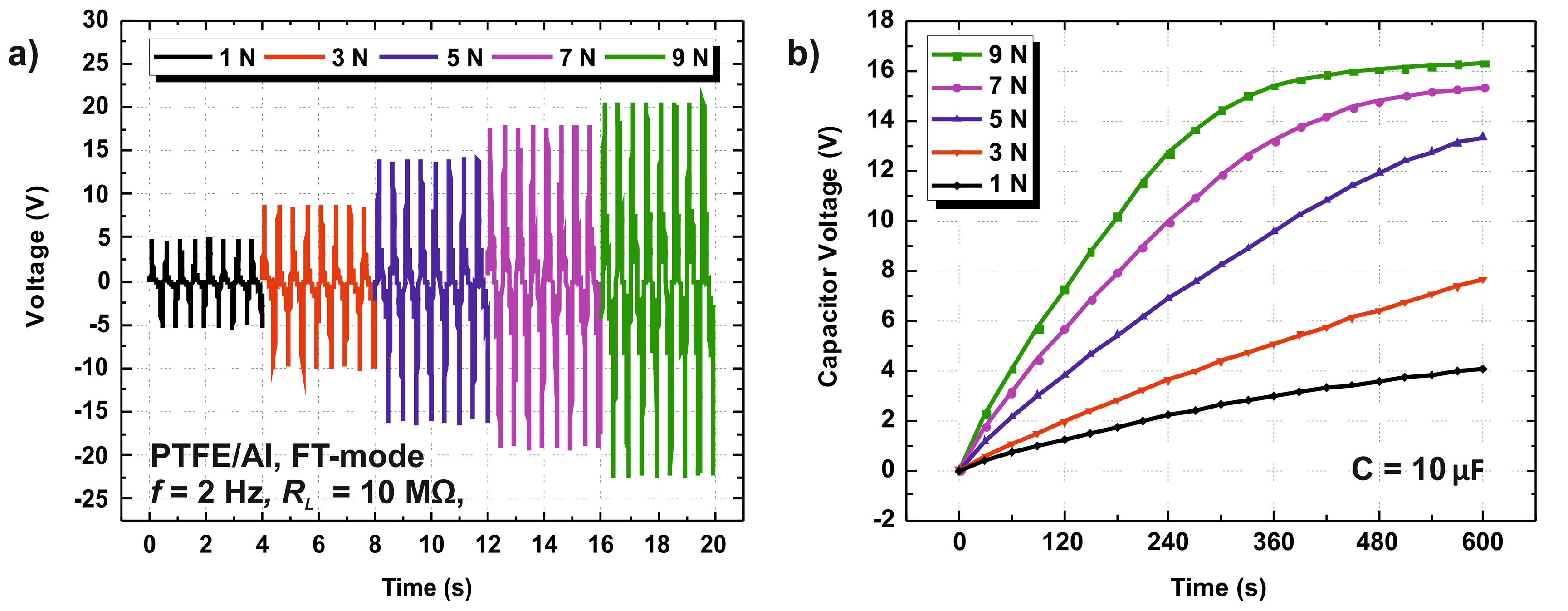

Fig. 7 Contact force dependence of a) output voltage and b) capacitor charging voltage

The TENG with PTFE/Al substrates exhibits the maximum output power in FT-mode (Fig. 4 and 5). The power rises considerably with increasing frequency and contact force (Fig. 6 and 7). At a frequency of 5 Hz, a compressive force of 5 N, an external load of 10 MΩ, in FT- mode, the TENG with PTFE/Al substrates generated an RMS voltage of 9.30 V, an RMS current of 0.93 μA and an average power of 8.66 μW corresponding to a power density of 2.7 mW/m^2.

Conclusion and Future Work

This work represents performance comparisons between different materials and operation modes of TENGs. The maximum RMS power density of 2.7 mW/m^2 was obtained from the TENG with PTFE/Al substrates operating in FT-mode. Towards the realisation of textile-based TENG, various works are still required, for example, investigating more materials, finding the maximum power point by varying load resistance, enhancing the performance by surface modification [3], embedding the TENG in textile and testing the device in a practical environmental field etc.

References

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[2] S. Wang, L. Lin, and Z. L. Wang, "Triboelectric nanogenerators as self-powered active sensors," *Nano Energy*, vol. 11, pp. 436–462, 2015.
[3] F. R. Fan, W. Tang, and Z. L. Wang, "Flexible Nanogenerators for Energy Harvesting and Self-Powered Electronics," *Adv. Mater.*, vol. 28, no. 22, pp. 4283–4305, Jun. 2016.