NREL is a national laboratory of the U. S. Department of Energy, Office of Energy Efficiency

Exploring the use of Flexible Circuit Boards to the Increase Power Density of a Rotary Triboelectric Nanogenerator

Tavis Peterson[1], Calum Kenny[1]
[1]National Renewable Energy Laboratory

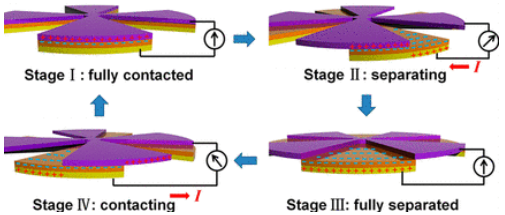
MRS Spring Meeting and Exhibit
Seattle, Washington
April 7-11, 2025
NREL/PO-5700-93920

Introduction

What are **triboelectric nanogenerators (TENG)**?

Basic Principles of TENG [Kim 2021]

- Two different materials come together creating electrostatic charges on each material
- Electric potential is created when the materials move away from each other

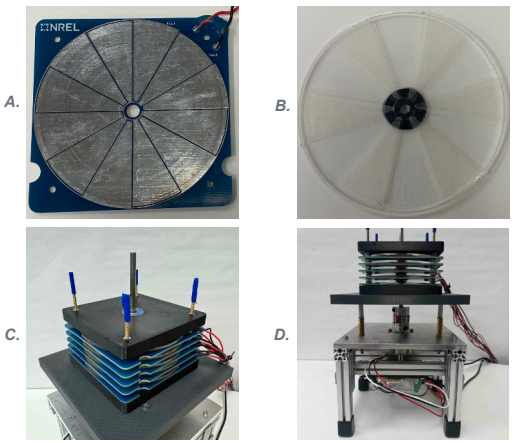


Proposed disk TENG, from "Segmentally Structured Disk Triboelectric Nanogenerator for Harvesting Rotational Mechanical Energy" by Kao et al.

Summary of Previous Work

Previous TENG prototyping included [Trayner 2023]

- Freestanding Rotary TENG, with a stator and a rotor
- Paper was used to set the surface charges of the stator and rotor
- The rotor was a 2mm thick acrylic disk with six FEP wedges
- The stator was a 1.6mm PCB with twelve copper wedges
- Each other copper wedge was connected creating two electrodes



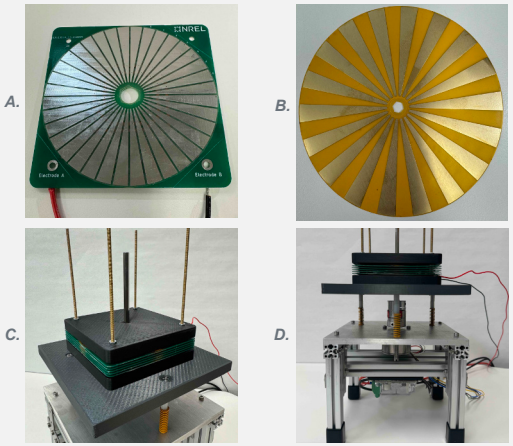
A) Stator – Printed Circuit Board, B) Rotor – Acrylic disk with FEP, C) Stack of 5 Stator-Rotor pairs, D) 5-stack mounted to Test Rig

Photo Source: C Kenny NREL

Methodology and Design

Expanding on previously conducted work

- Increasing the number of electrodes and wedges [Long 2013]
- .4mm thick flexible circuit boards as the rotors
- Stator thickness was altered to .6mm
- FEP as dielectric layer on stator [Deng 2020]
- Freestanding rotary triboelectric nanogenerator



A. Stator – Printed Circuit Board with FEP film across, B. Rotor – Flexible Circuit Board, C. Stack of 5 Stator-Rotor pairs, D) 5-stack mounted to Test Rig

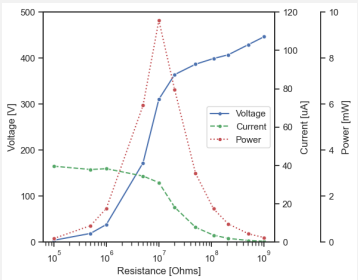
Photo Source: C Kenny NREL

Power Output Results

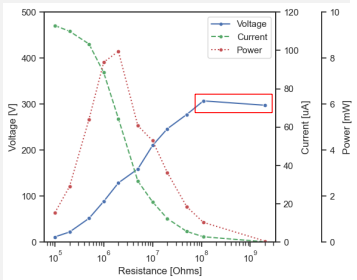
A comparison of the two 5-Layer TENG shown

- Acrylic w/ paper produced a max power output of 9.6mW
- Flexible circuit board produced a max power output of 8.3mW

Decay issue found in Flexible circuit board TENG



A. Depicts Voltage, Current, and Power of 5-Layer Acrylic TENG Device

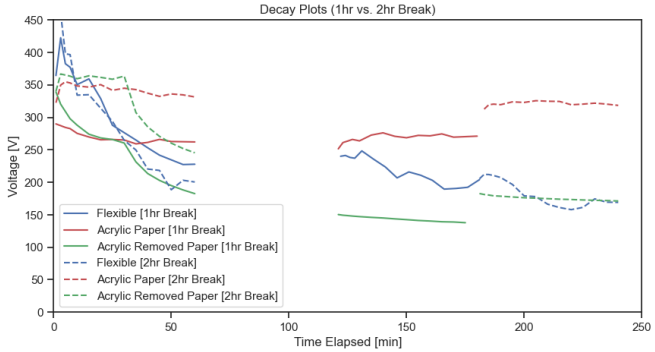


B. Depicts Voltage, Current, and Power of 5-Layer Flexible circuit board TENG Device

Decay Test Results

The flexible circuit board TENG began performing worse over an extended period. Two decay tests were performed for each TENG model, with the first test having a one-hour break and the second test having a two-hour break. Findings showed

- All tests decayed to a certain extent
- After each break the tests tended to voltage followed similar trend
- The rate of decay slows over time



C. Plot Showing the Voltage Decay Over time for both the Flexible and Acrylic TENG Designs

Discussion and Further Work

Two potential causes could be a worn FEP layer and general electrostatic charge decay. Possible physical degradation in the FEP layer due to contact and charge neutralization in the FEP layer as well. Two solutions might be

- No contact between stator and rotor
- Self-exciting design [Long 2021]

These two solutions would go together. There would be no contact so charge decay would be rapid. A self-exciting design would inject positive charge into the rotor electrodes [Long 2021]

References

- Griffin Trayner, Calum Kenny, and J. McNally, Materials Research Society, 2023
- Long Lin, Sihong Wang, Yannan Xie, Qingshen Jing, Simiao Niu, Youfan Hu, and Zhong Lin Wang, *Nano Letters* **2013** *13* (6), 2916-2923
- Long, L., Liu, W., Wang, Z. *et al.* High performance floating self-excited sliding triboelectric nanogenerator for micro mechanical energy harvesting. *Nat Commun* **12**, 4689 (2021).
- Weon-Guk Kim, Do-Wan Kim, Il-Woong Tcho, Jin-Ki Kim, Moon-Seok Kim, and Yang-Kyu Choi, *ACS Nano* **2021** *15* (1), 258-287
- Weili Deng, Yihao Zhou, Xun Zhao, Songlin Zhang, Yongjiu Zou, Jing Xu, Min-Hsin Yeh, Hengyu Guo, and Jun Chen, *ACS Nano* **2020** *14* (7), 9050-9058

U.S. DEPARTMENT OF ENERGY