Powerless Flood Detection

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Rationale

Africa accounts for 35% of weather, climate, and water-related fatalities, yet 60% do not have access to early warning systems, leaving some regions limited to manually operated rainfall detection. The issues are delayed communication and sparse coverage – 8 times less than internationally recommended, in fact. Just in 2025, there were 2,500 deaths, 4 million people displaced, and millions of hectares of farmland flooded. There is a need to develop a simple, low cost, and rapidly responsive sensor.

Objective

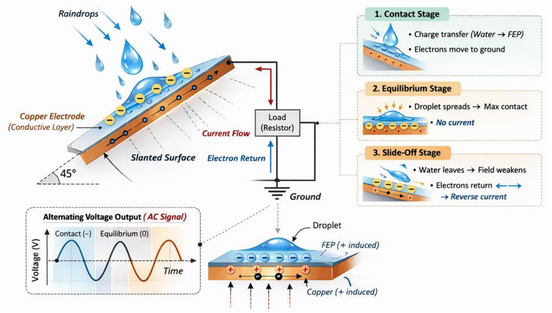
This work aims to create a self powered rain sensor that can detect rainfall and create a pathway to a system that can send a warning if it senses rainfall exceeds some threshold.

Hypothesis

It is hypothesized that an optimal device size and storage capacitance can minimize cost while still generating enough signal output to work effectively.

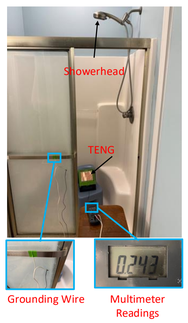
Methodology

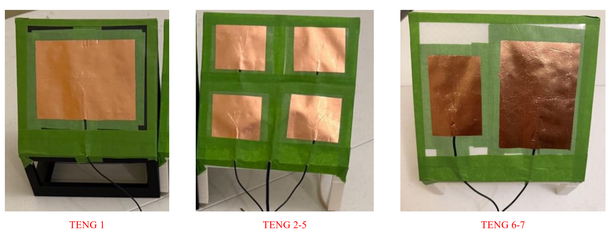
When the rain drop hits the TENG, it transfers some charge. The charge induces a current in the copper that forces electrons out of the copper. The electrons return to the copper once the rain drop slides off.



Experiment Setup and Procedure

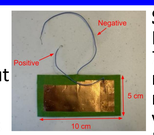
1. Set up the testing platform
2. Turn on the showerhead to cold water.
3. Record a 20-30 second period of time on the multimeter
4. Switch the item being tested
5. Repeat steps 3 and 4 for all versions
6. Extract the multimeter readings every 0.5 seconds
7. Plot the multimeter readings with respect to time



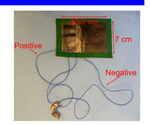


Research Designs

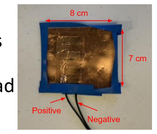
Initial Design: Copied from an online video [4], but the measured output voltage was too small



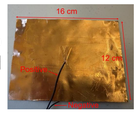
Second Design: Larger (50 cm^2 to 73.5 cm^2) created more, but the measured output voltage was still too small



Third Design: Electrical tape was used instead of FrogTape, but it had almost no effect

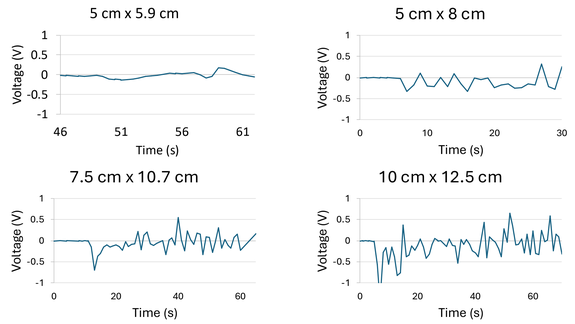


Fourth Design: Larger (73.5 cm^2 to 192 cm^2) produced more but lasted a few minutes before failed



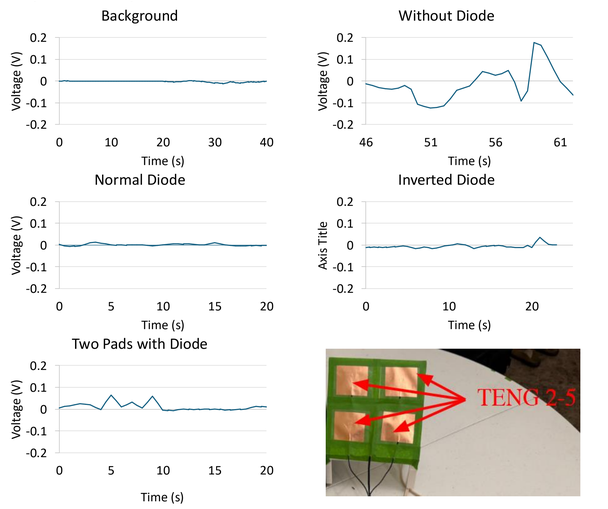
Pad Size Test

Larger pad size leads to larger peak measured voltages



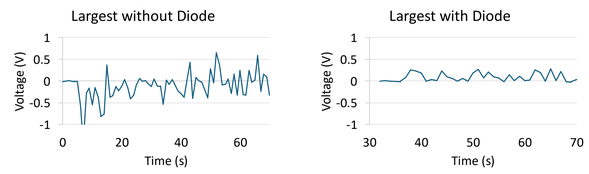
Diode Test

Orientation of the diode affects the amplitude of the measured voltage. A diode reduces the signal to the point of impracticality.

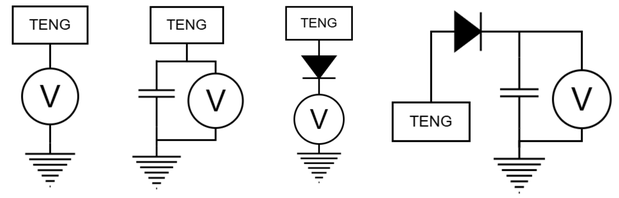


Largest Pad with Diode Test

The diode worked as expected, but the measured voltage was still reduced significantly



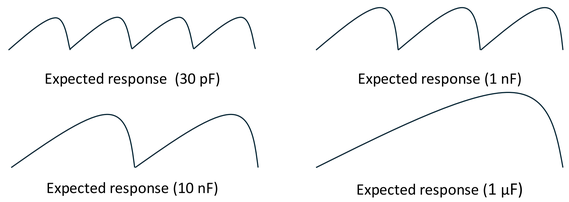
Testing Circuit Diagrams



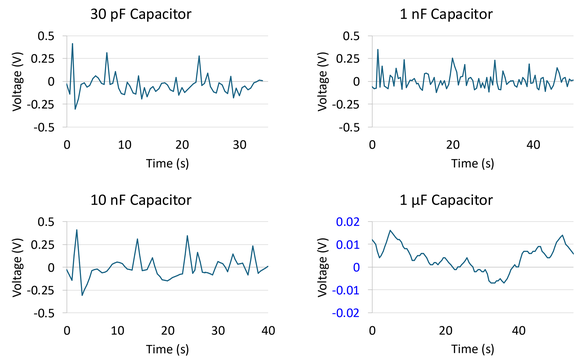
(a) TENG directly to a multimeter (no capacitor, no diode); (b) TENG to a multimeter that is in parallel with a capacitor (no diode); (c) TENG to a diode and to the multimeter (no capacitor); (d) TENG to a diode, then to a multimeter that is in parallel with a capacitor.

Capacitors with Diode Test

The expected voltage output cycle for the 30 pF capacitor was that it would grow quickly to a small peak and drop. For the 1 nF capacitor, the cycle was expected to be similar but grow more slowly and with a larger peak. For the 10 nF capacitor, it was expected for it to grow even more slowly with a moderate increase in voltage peak. Finally, the 1 µF capacitor was expected to grow the slowest and have the highest peak.



The actual measured voltage responses were very different from what was expected, most notably being the 1 µF capacitor, as it has a much smaller peak value than any others. It does show a slow decrease and an increase afterward, but the values are almost negligible. The 10 nF capacitor most closely resembles the expected graph, with peaks separated with buildup.

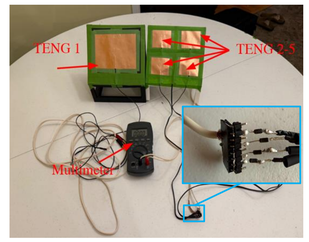


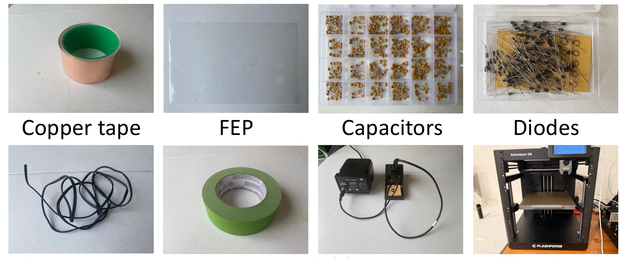
Findings

It is crucial to have good waterproofing, along with system grounding. The TENG produces alternating voltage, not direct. If a capacitor is used in conjunction with the system the measured voltage almost flat lines to zero. The diode is required to regulate the AC signal, but significantly reduced measured voltage, failing to fully function as expected.

Materials

- Copper tape
- Fluorinated ethylene propylene (FEP)
- Capacitors (10 pF - 10 µF)
- Small signal diodes
- Insulated copper wire
- FrogTape
- Soldering station at home
- 3D printer at home





Conclusion

This study demonstrated that copper pad size matters in a water-based triboelectric generator and that increased size leads to larger signal output. Diode can regulate the signal, but it significantly reduces signal and its orientation matters. The capacitance value affects the output voltage. One issue is that the current output is too small to power a warning device such as a LED or speaker. Some possible solutions to this issue are to find better materials (e.g., instead of using copper, can aluminum be used?), better surface treatment that could collect more electrons, or better interaction angle (between the rain drop direction and the sensor surface). If these solutions work, I will be able to create a rainfall sensor that could warn of floods, potentially saving lives.

Future Work

- **Rainfall intensity control**: One possible way to solve this is by using a pump-controlled system.
- **Better measurement system**: Find a voltage measurement device that can accurately measure the voltage and respond more quickly.
- **Better capacitor:** Optimize the capacitance value through experimental testing.
- **Better diodes**: Find a diode that has minimal voltage reduction; Design a better circuit such as a diode bridge that can collect more signal.
- **TENG optimization**: Find better materials to collect more electrons; Optimize the pad size.

Acknowledgements

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References

1. Mekonnen, K., Velpuri, N.M., Leh, M., Akpoti, K., Owusu, A., Tinonetsana, P., Hamouda, T., Ghansah, B., Paranamana, T.P. and Munzimi, Y., 2023. Accuracy of satellite and reanalysis rainfall estimates over Africa: a multi-scale assessment of eight products for continental applications. *Journal of Hydrology: Regional Studies*, *49*, p.101514.
2. Zheng, L., Lin, Z.H., Cheng, G., Wu, W., Wen, X., Lee, S. and Wang, Z.L., 2014. Silicon-based hybrid cell for harvesting solar energy and raindrop electrostatic energy. *Nano Energy*, *9*, pp.291-300.
3. Record Levels of Flooding in Africa Compounds Stress on Fragile Countries, Africa Center For Strategic Studies, Africa Center for Strategic Studies, 10 Dec. 2024, https://africacenter.org/spotlight/record-levels-of-flooding-in-africa-compounds-stress-on-fragile-countries/
4. Jiang, B, "Electricity from Water Drops - Triboelectric Nanogenerator for Hydrovoltaic Power Harvesting", *Youtube*, uploaded by TechBea, 4 Jul. 2024 https://m.youtube.com/watch?v=V2mgm-KDmfQ
5. Ndiritu, J.G. and Mkhize, N., 2017. Effect of monthly areal rainfall uncertainty on streamflow simulation. *Physics and Chemistry of the Earth, Parts A/B/C*, *100*, pp.51-61.
6. World Meteorological Organization, Africa faces disproportionate burden from climate change and adaptation costs, World Meteorological Organization, 2 Sep. 2024, https://wmo.int/news/media-centre/africa-faces-disproportionate-burden-from-climate-change-and-adaptation-costs