

Silver Nanoparticle-Enhanced Collagen-Based Triboelectric Nanogenerators: Fabrication and Applications

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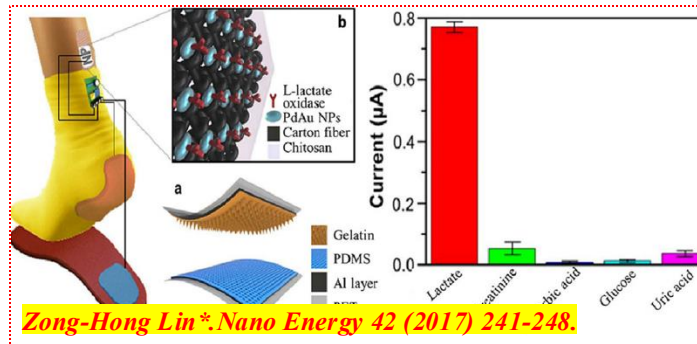
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Contents

- ◆ **Introduction**
- ◆ **Fabrication of wearable humidity-resistant TENG based on leather (WPL-TENG)**
- ◆ **Properties and utilization of WPL-TENG**
- ◆ **Silver Nanoparticle-Enhanced Collagen-Based Triboelectric Nanogenerators**
- ◆ **Conclusion**

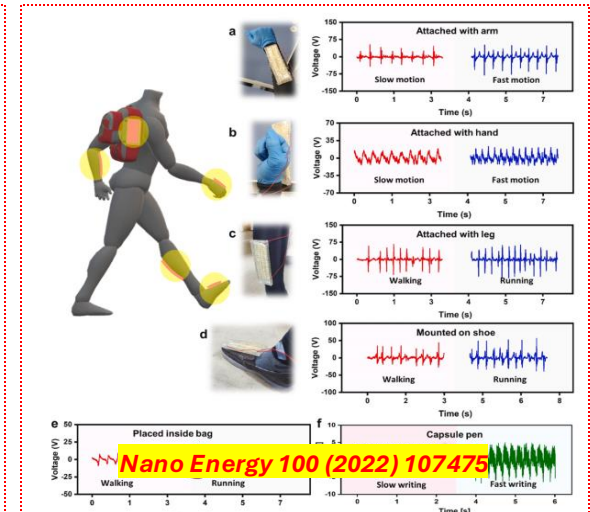
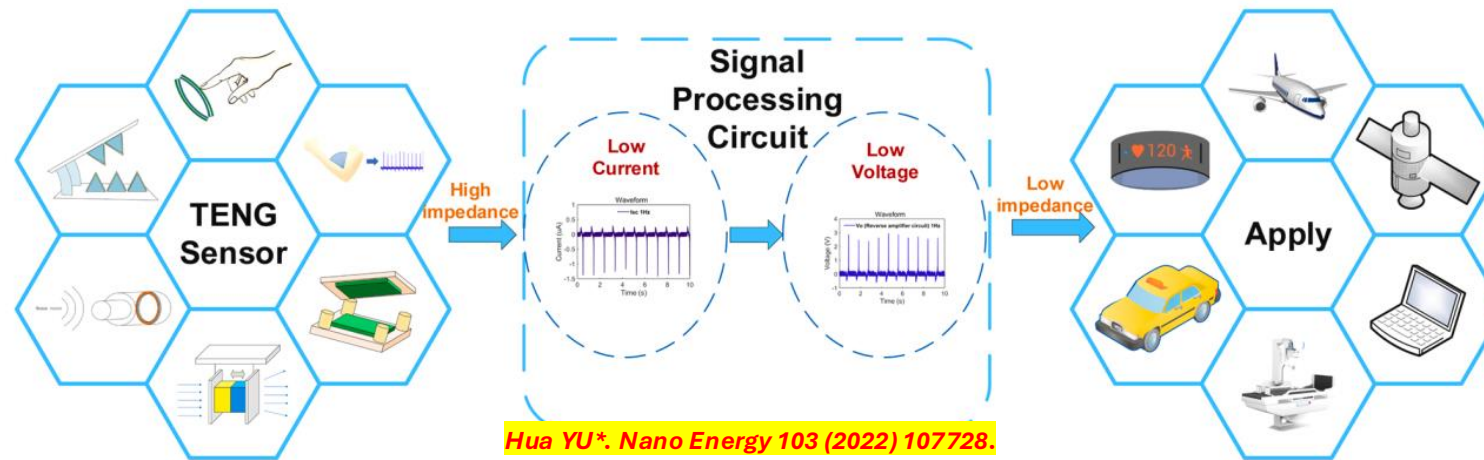
Introduction

- Recently, the demands for flexible electronics and wearable sensors with high performances were stimulated dramatically under the expansion of **internet of things** and **5G technology**.
- However, the traditional external batteries and capacitors for powering these devices have encountered substantial obstacles.
- Thus it is crucial to develop portable, recyclable and **self-sustaining power technologies** for wearable electronics.



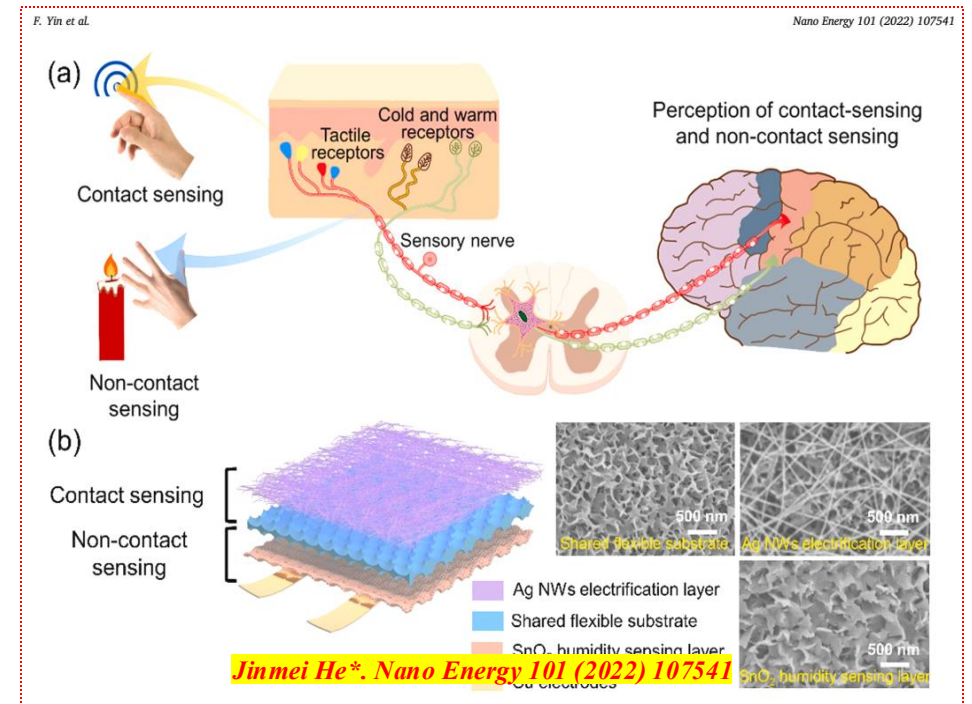
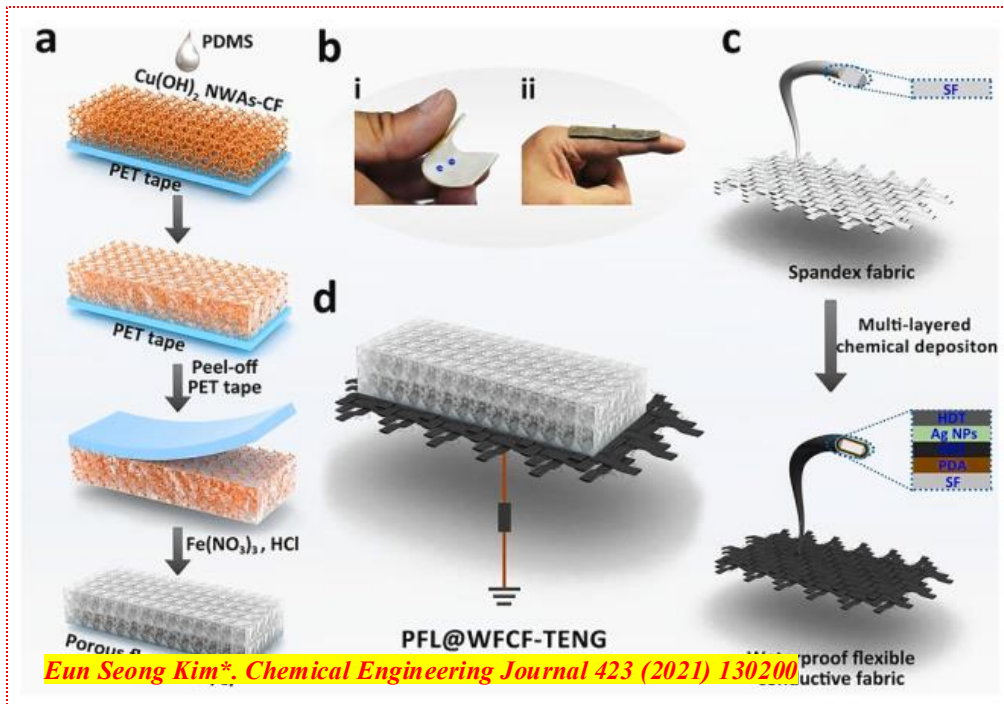
Introduction

- Since 2012, triboelectric nanogenerators (TENGs) as an **emerging tribological electricity harvesting technology** have gradually grown to realize low-frequency energy scavenging.
- Triboelectric nanogenerator (TENG) has been considered as a smart solution for **self-powering system** of wearable electronics and sensors.

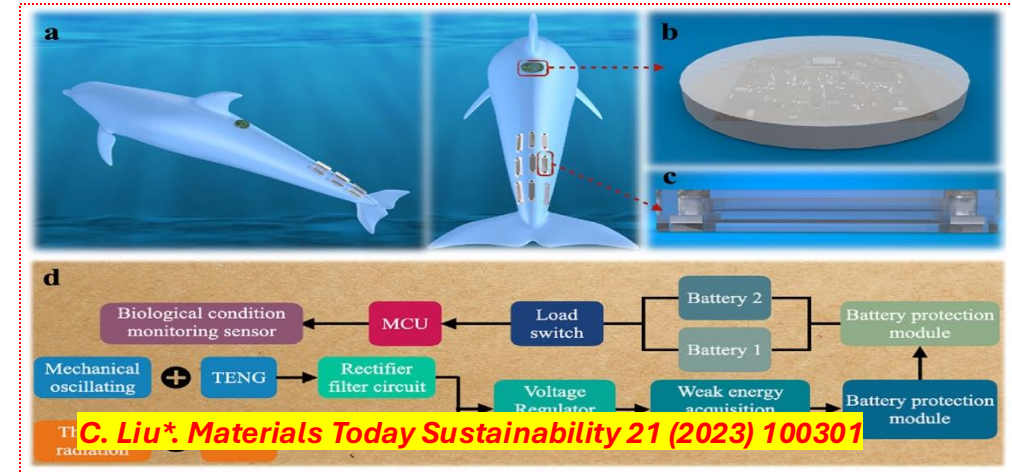


Introduction

- Based on the advantages of arbitrarily controllable mass and volume, and the ability to formulate the shape and appearance according to wearer's needs ,
TENGs are widely used in motion monitoring and personal protection.



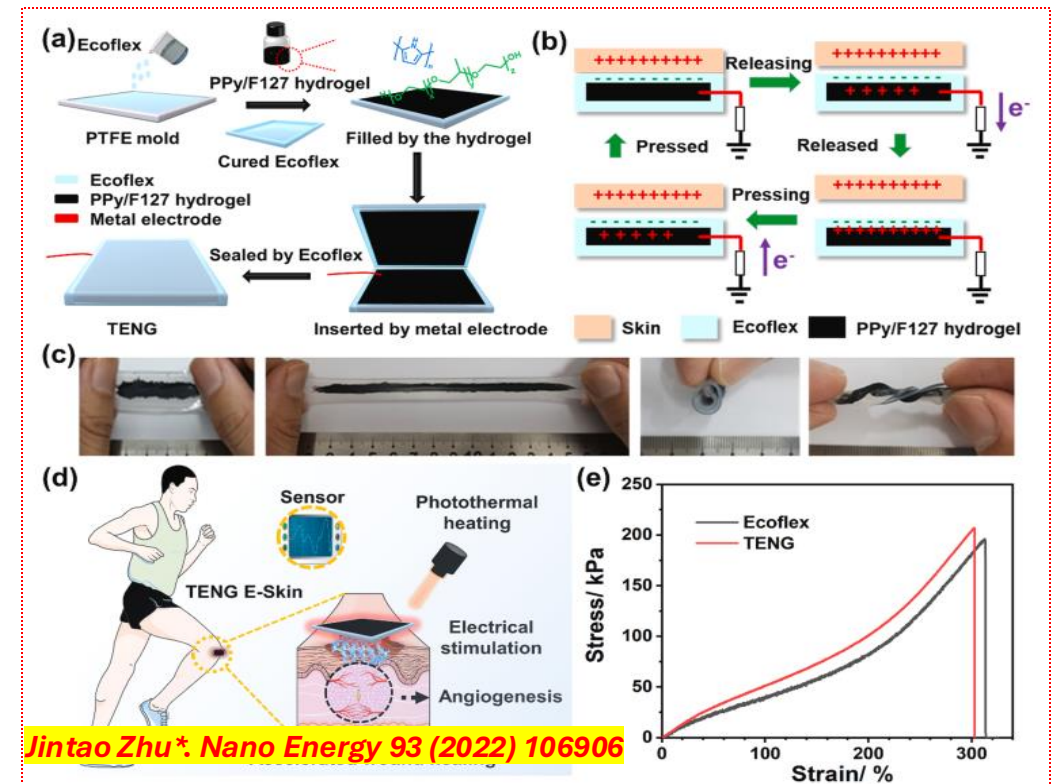
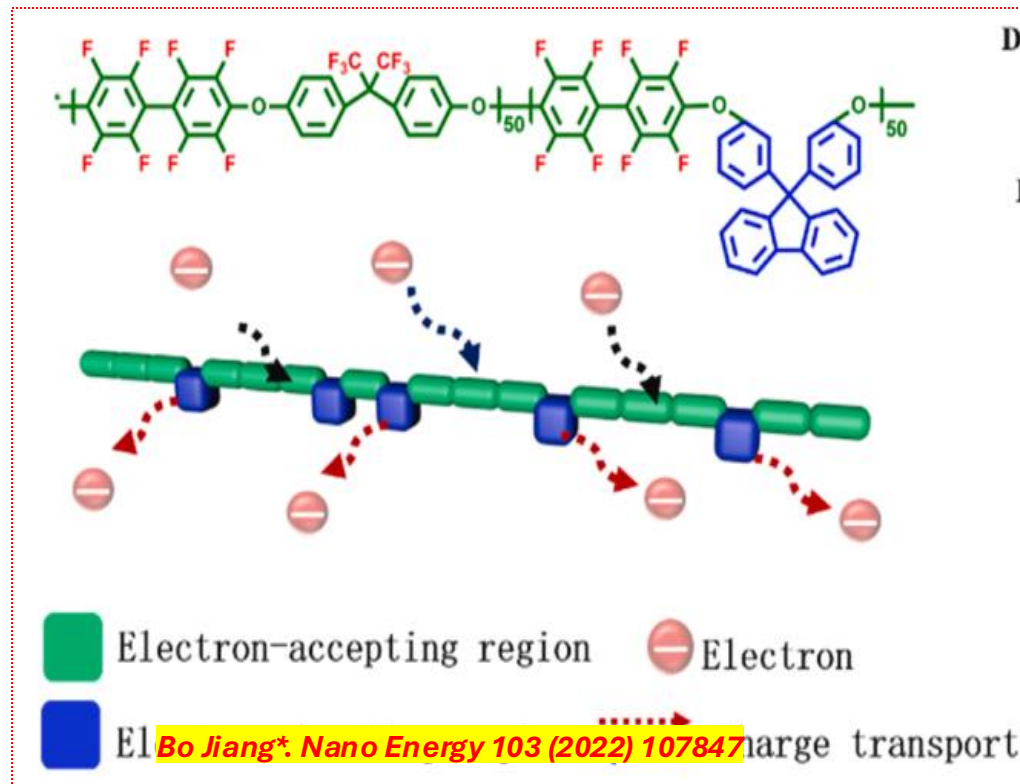
Introduction



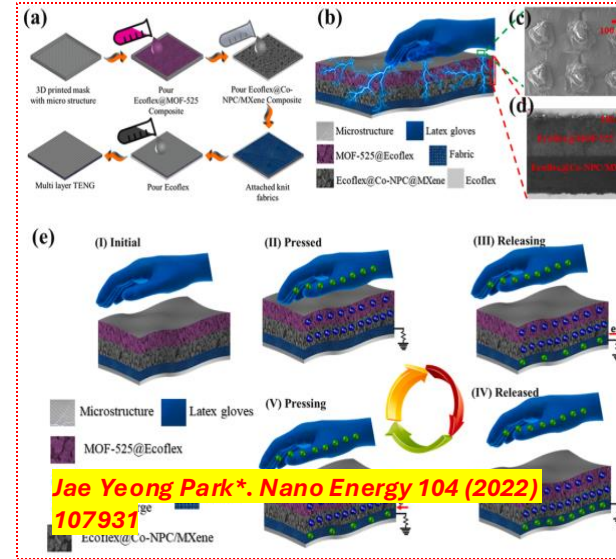
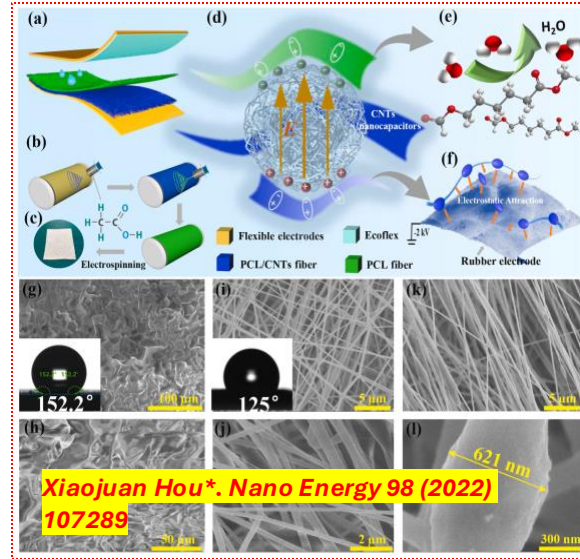
- These researches fully demonstrate the great advantages of TENG in the synchronous conversion of bio-mechanical signals into electrical signals easily detected.
- However, it is verified that the humidity generated from breathing and sweating, as well as the ambient humidity have serious negative impact on the output performances of TENGs.

Introduction

- Many researchers have put their effort in improving the output performance of TENG in high humidity environment by using different strategies.



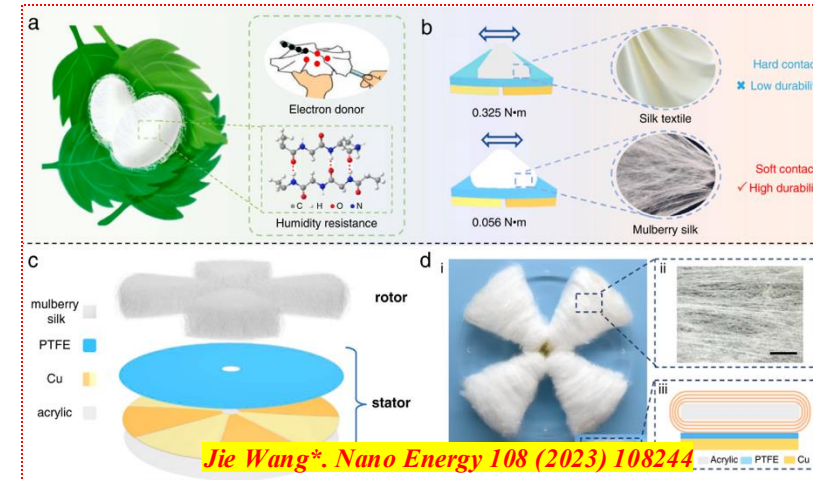
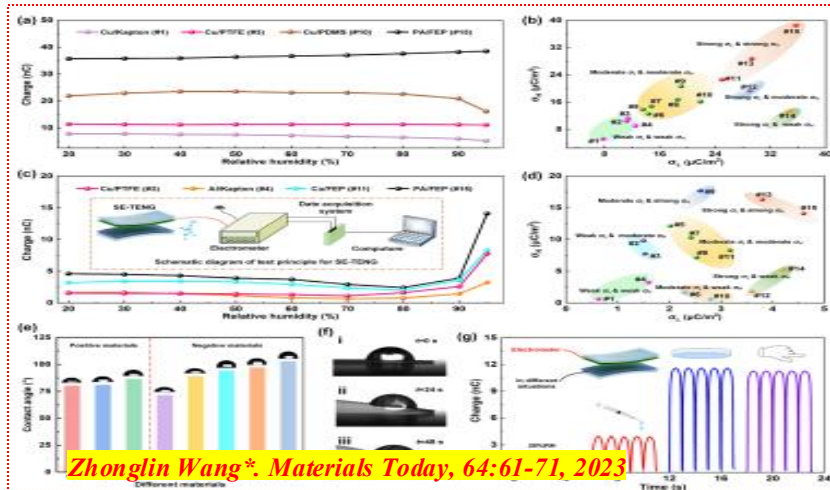
Introduction



- In spite of this, the fabrication techniques of TENG with **good output performance in high humidity environment** and the development of appropriate tribo-electric materials remain a great challenge.

Introduction

- This selection rule shows that triboelectric materials with high charge density, high moisture resistance rate and low friction coefficient can exhibit high performance at ambient environment.

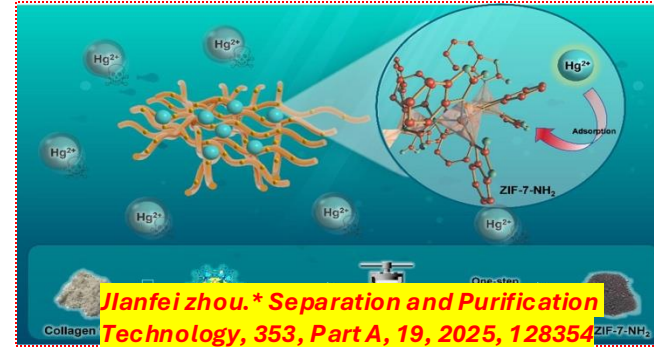
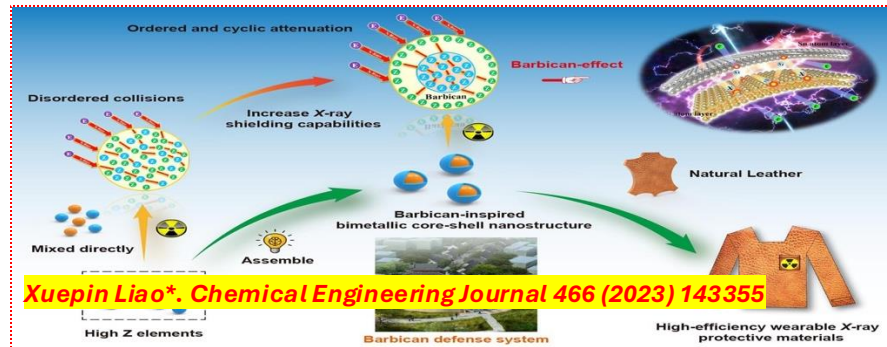


- Can a collagen matrix be used as a triboelectric material?
- How can its triboelectric performance be improved?

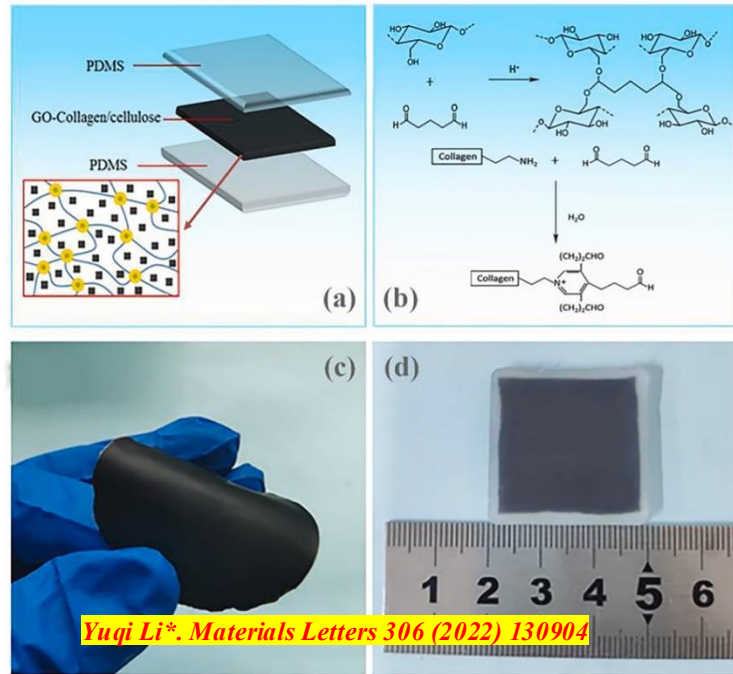


Introduction

- Abundant of active groups such as carboxylic groups, amine groups and hydroxyl groups provide the **chemical sites for the modification** of collagen matrix, which is critical for the different usage of collagen in many areas.



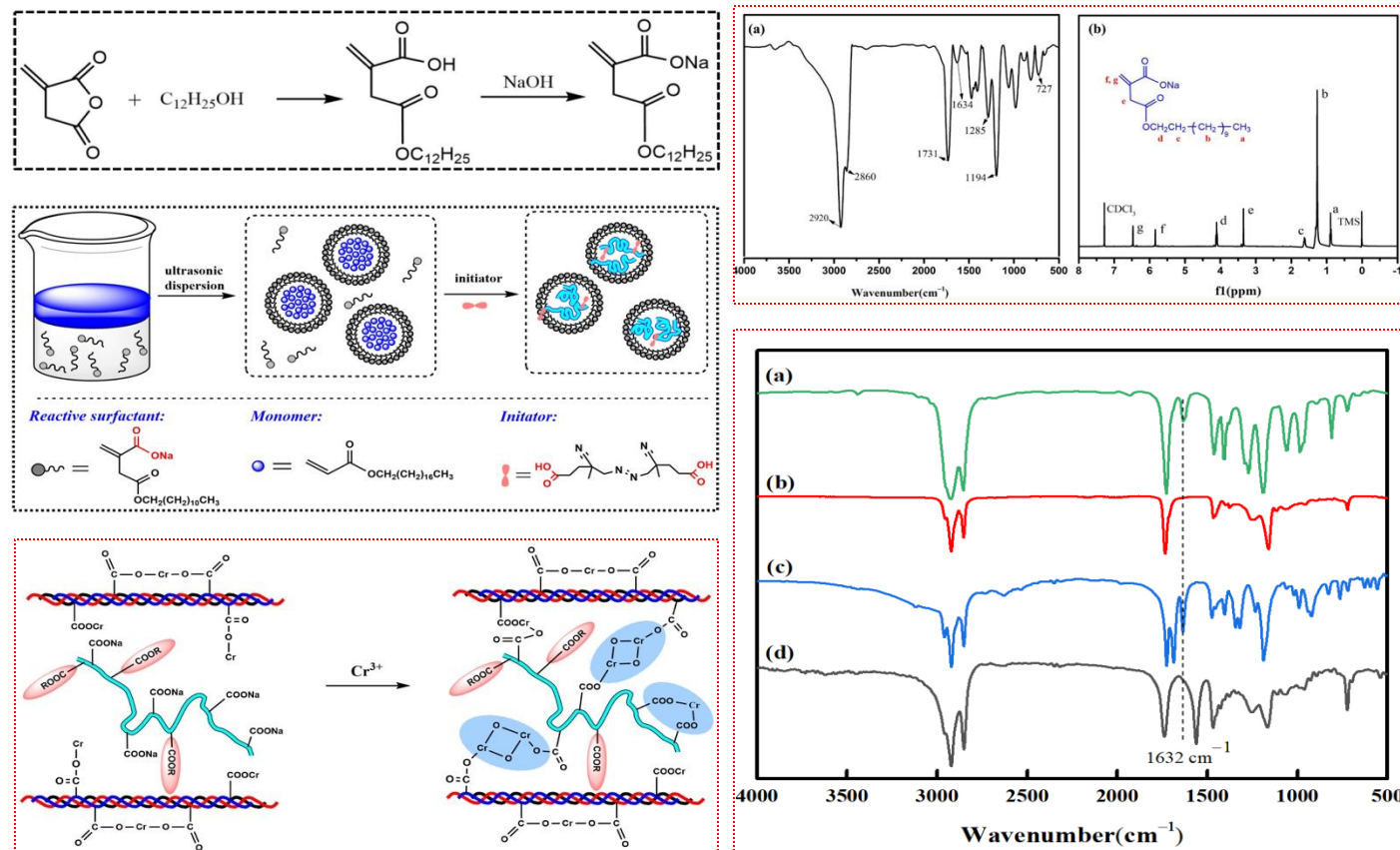
Introduction



- As a matter of fact, some researchers attempt to fabric TENG by using collagen or its derivants initially.
- Nonetheless, **low cost and durable** collagen-based triboelectric nanogenerator with exceptional output performance and environmental adaptability for wearable devices **requires a better solution urgently.**

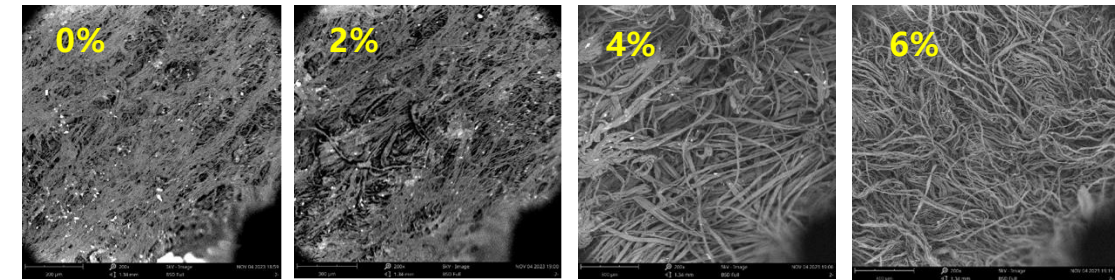
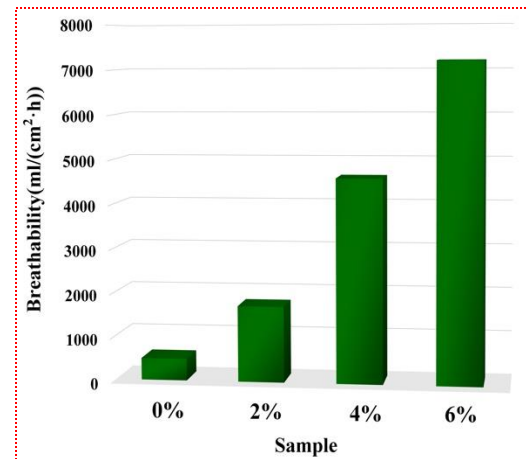
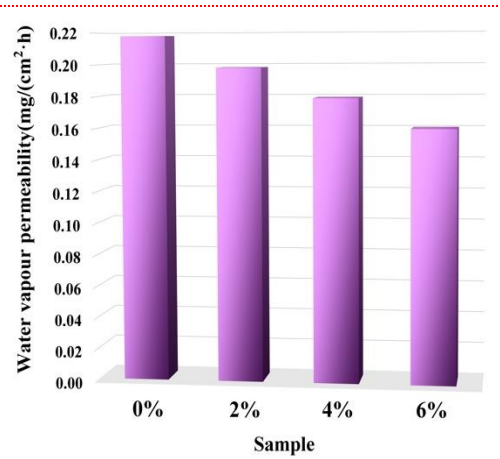
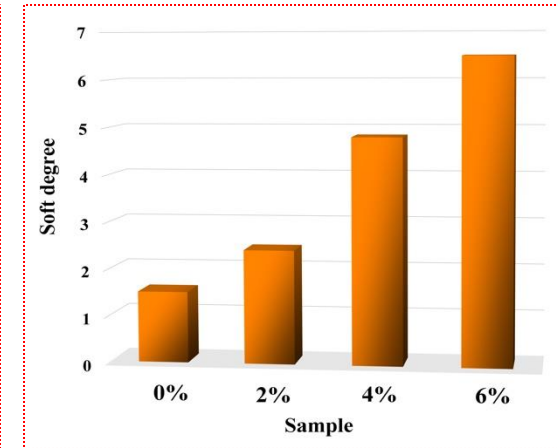
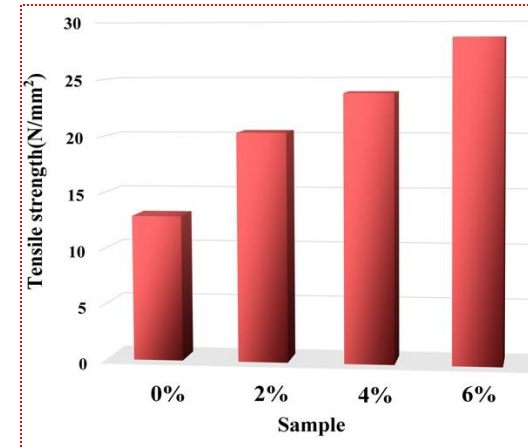
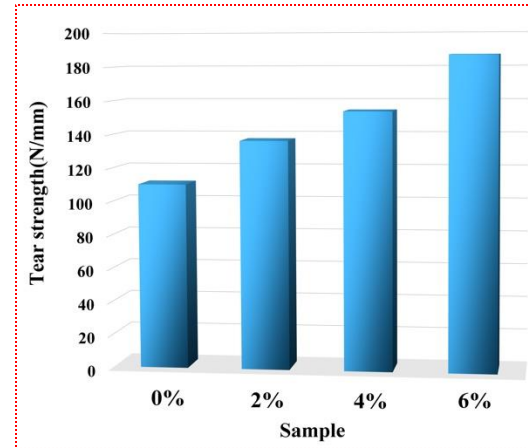
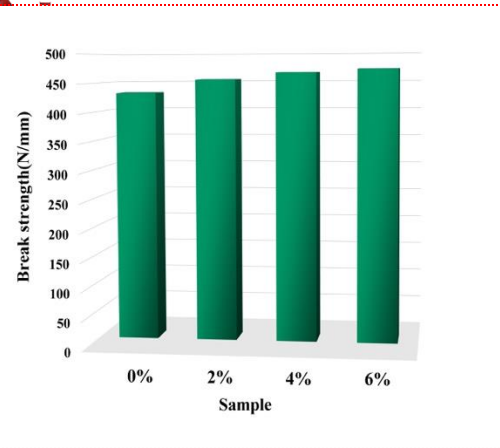
- Herein, a **hydrophobic leather** was prepared using traditional leather making process with a novel homemade waterproof fatliquoring agent and served **as a tribo-positive material.**

Preparation and characterization of waterproof leather



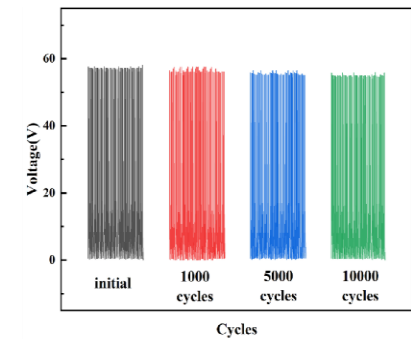
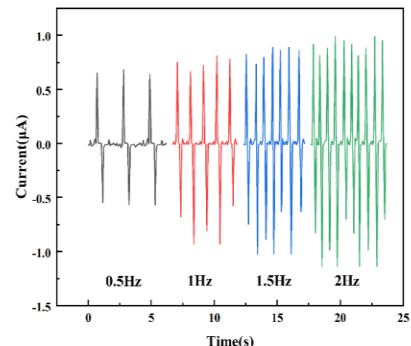
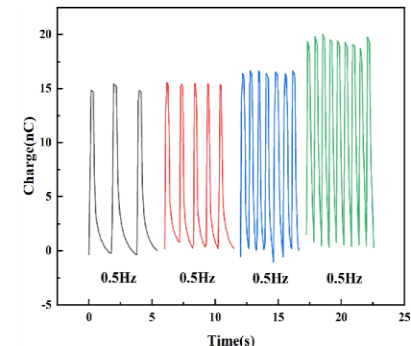
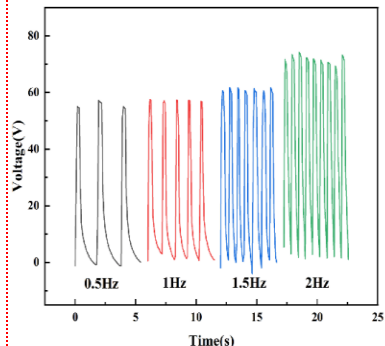
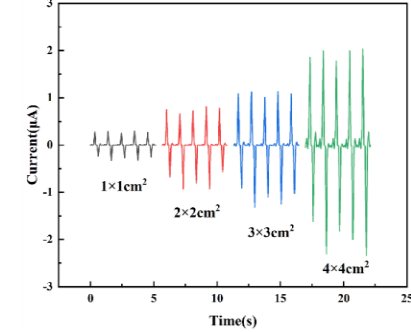
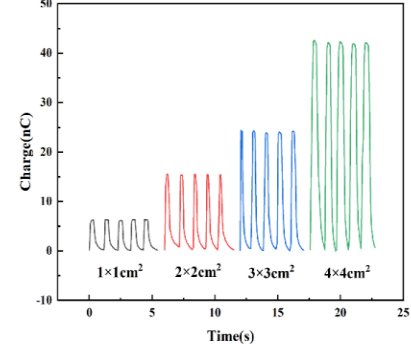
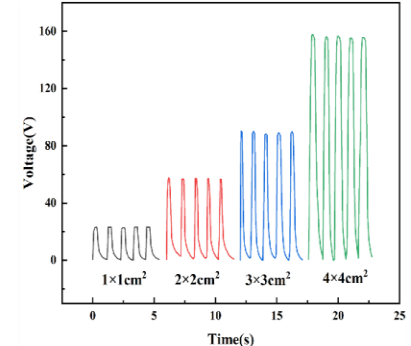
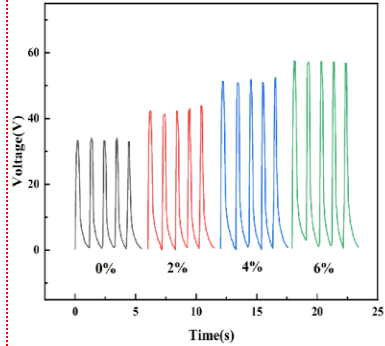
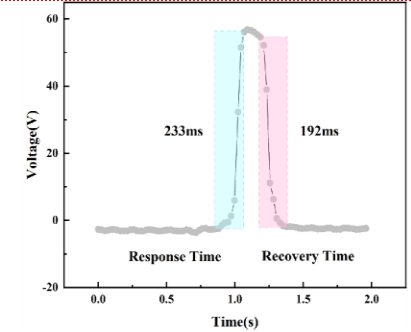
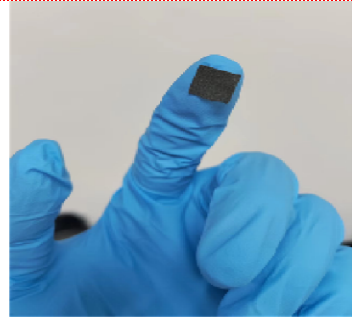
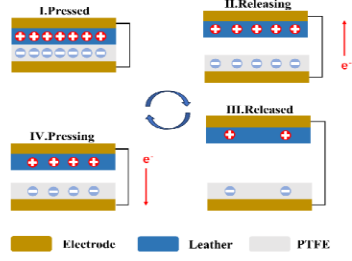
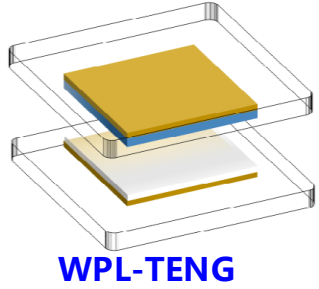
- Polymer nanoemulsions containing **carboxyl groups** were synthesized successfully and used as waterproof fatliquor for chrome-tanned leather.

Preperation and characterization of waterproof leather



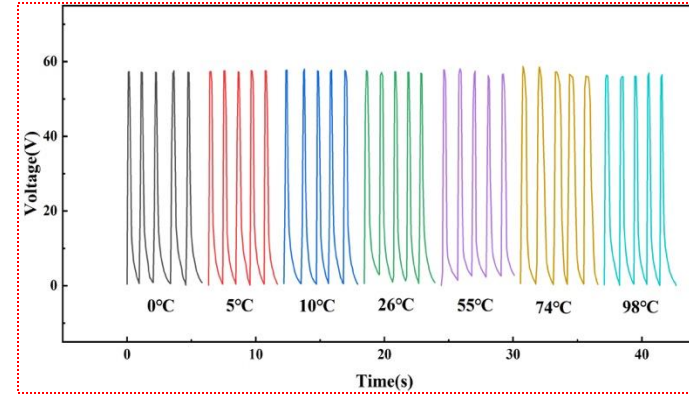
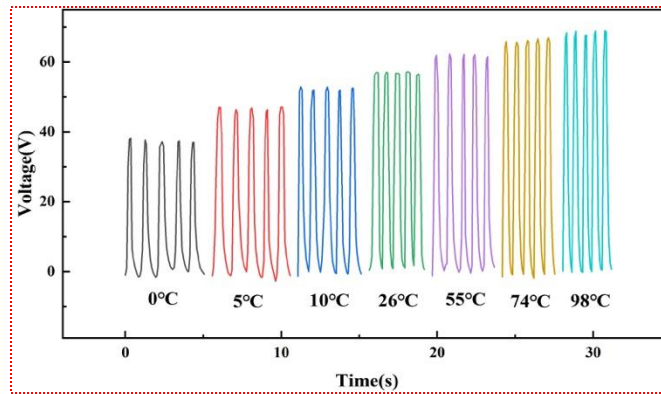
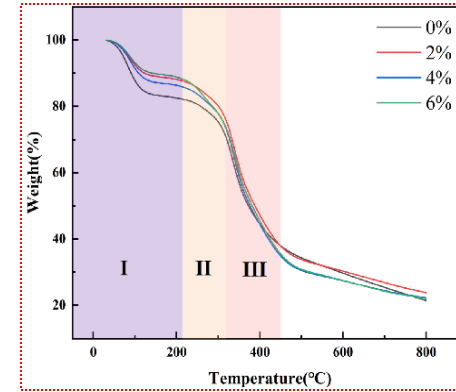
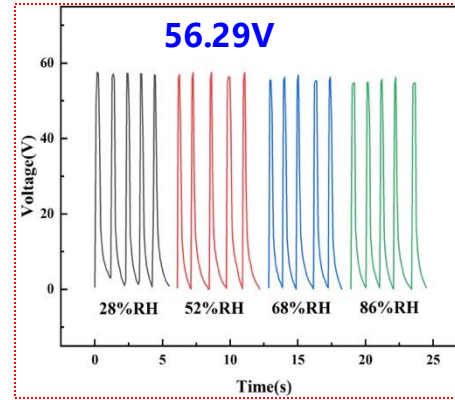
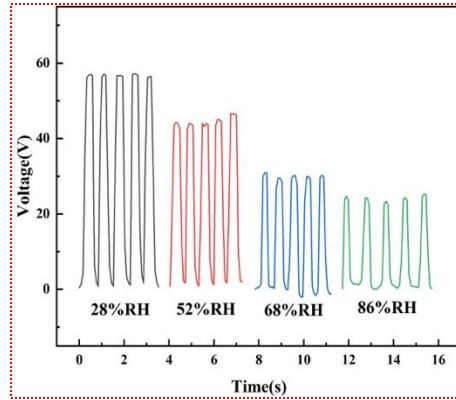
- After fatoliquoring, the leather exhibits good physical and mechanical strength, softness, durability and hydrophbic properties.

Properties of WPL-TENG



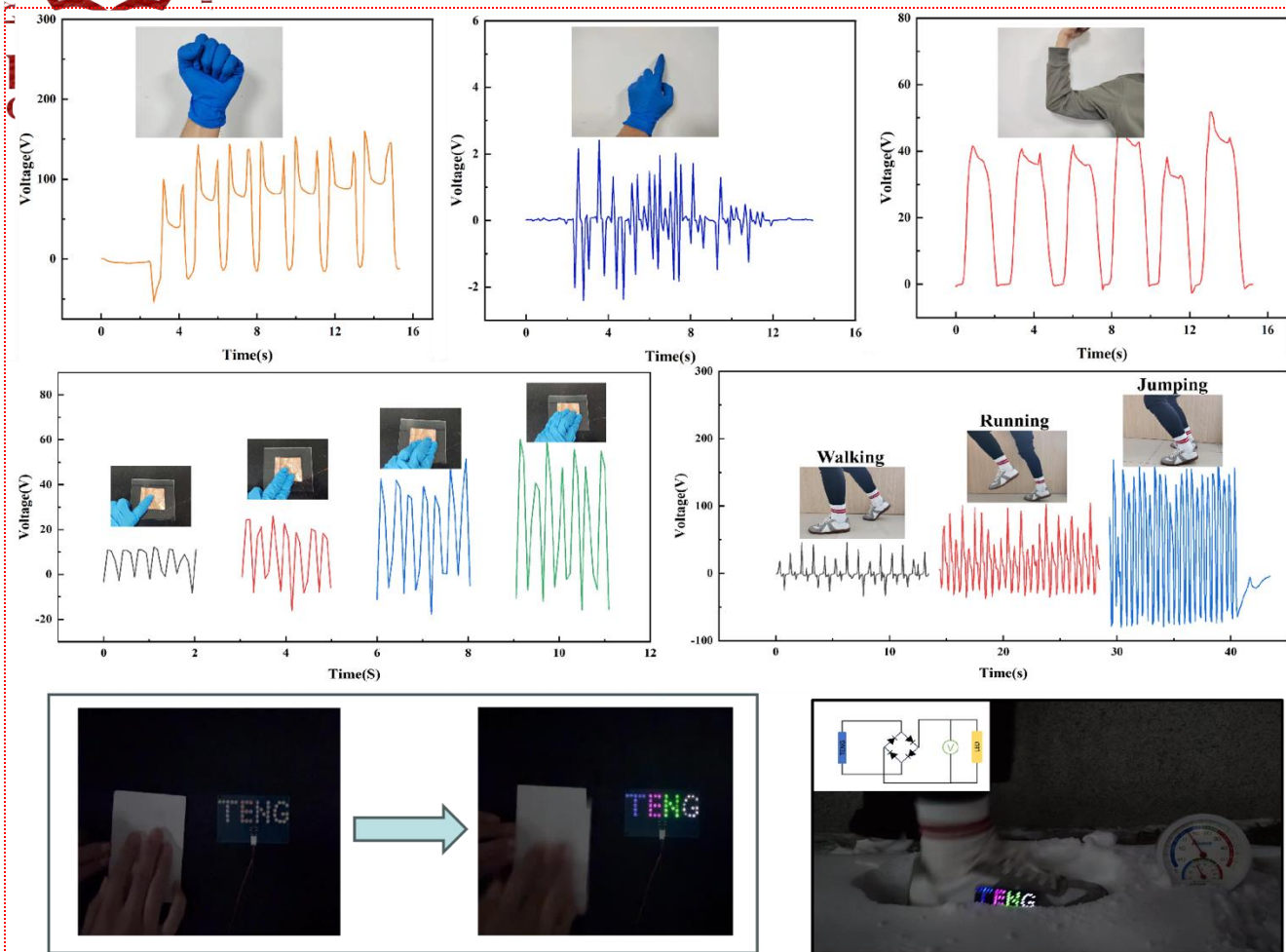
- Good sensitivity
- Good stability
- Good durability
- Be as a efficient positive triboelectric material

Properties of WPL-TENG



- Even at near 90% RH, only about 2% reduction amplitude was observed.
- The output voltages of WPL-TENG were stable over a large temperature range of 0°C to 98°C.

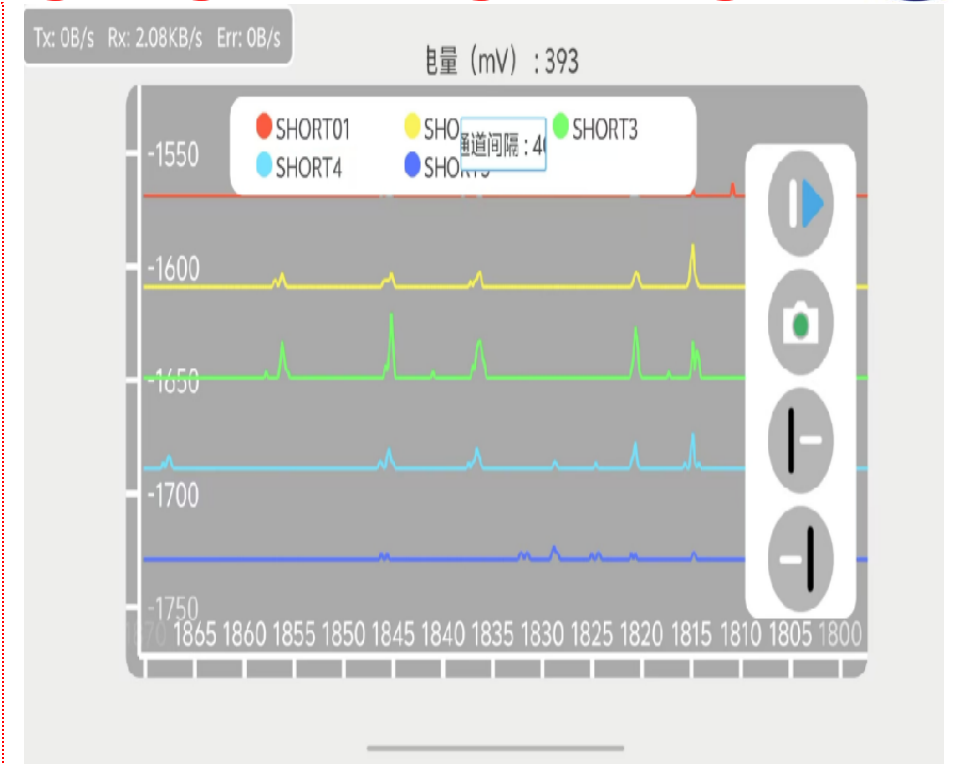
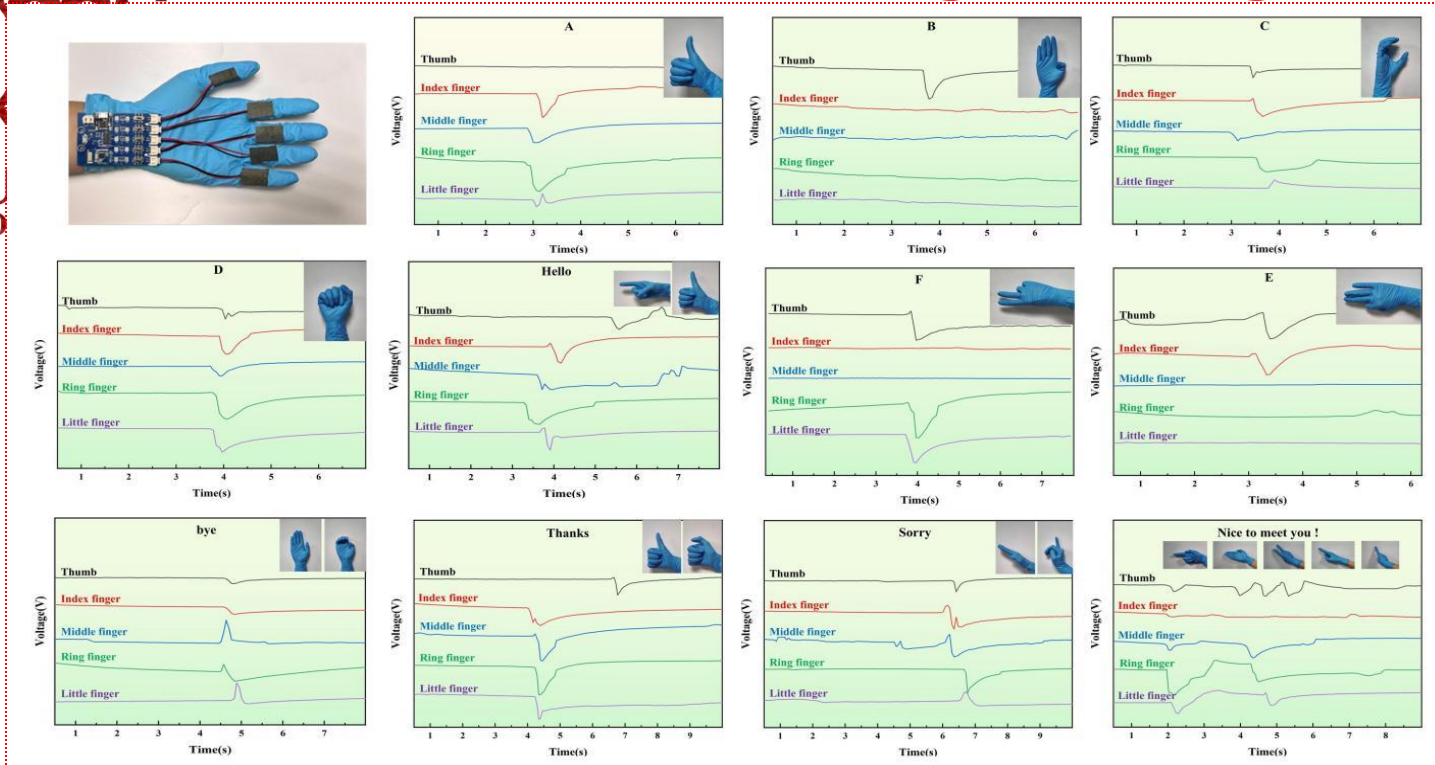
Motion monitoring and sign language recognizing



- WPL-TENG can serve as a sensitive sensor for motion monitoring.

- The practical safety warning of WPL-TENG by walking in the snow at 5°C and 48% RH (2023.12.13, Jinan, China) was very favourable.

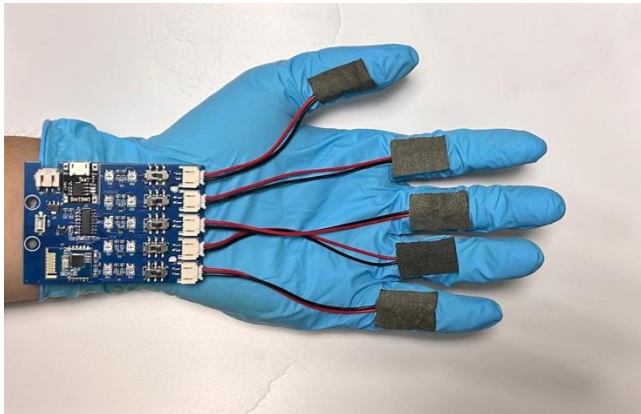
Motion monitoring and sign language recognizing



- Sign language itself has become **a huge barrier** in the present communication.
- However the sign language recognition are much more **complex and difficult**.
- Daily sign languages representing different emotions were **monitored and recognized distinctly** by WPL-TENG.

NEXT QUESTION

- Can a collagen matrix be used as a triboelectric material?

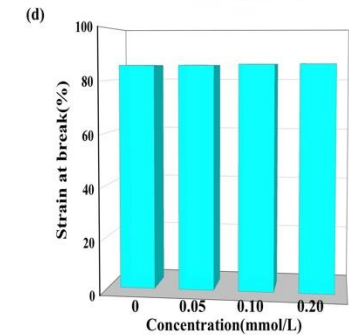
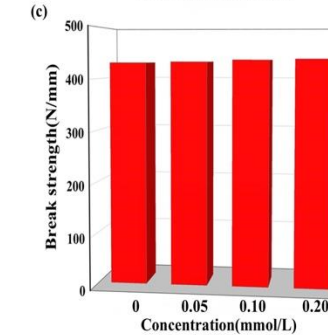
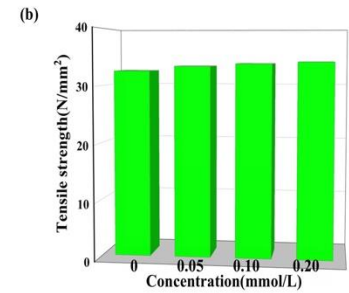
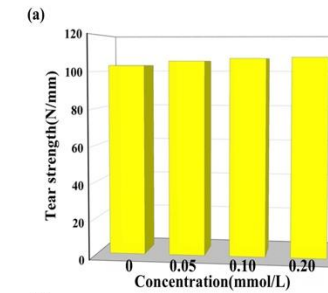
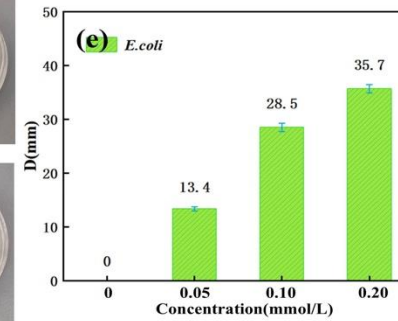
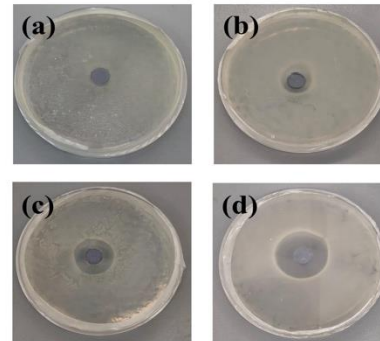
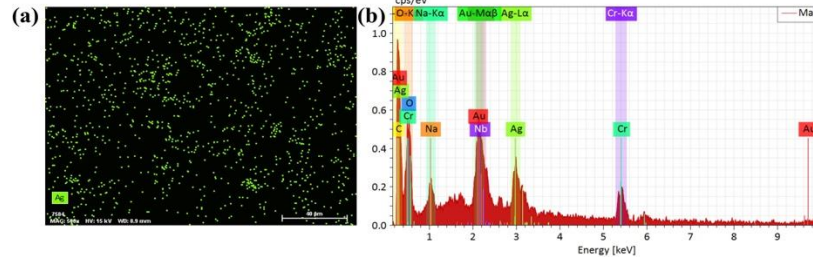
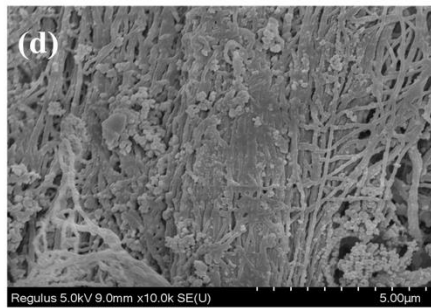
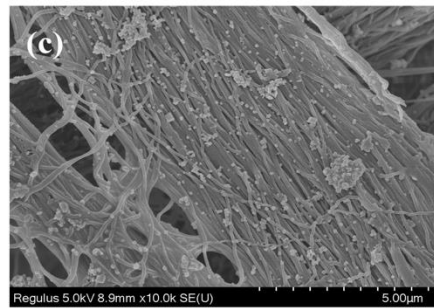
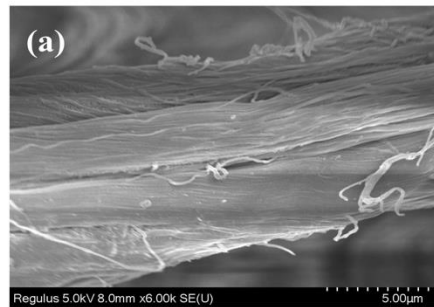


- How to further improve the performance of LEATHER BASED TENG?



Preparation of Silver nanoparticle-modified leather (SGL)

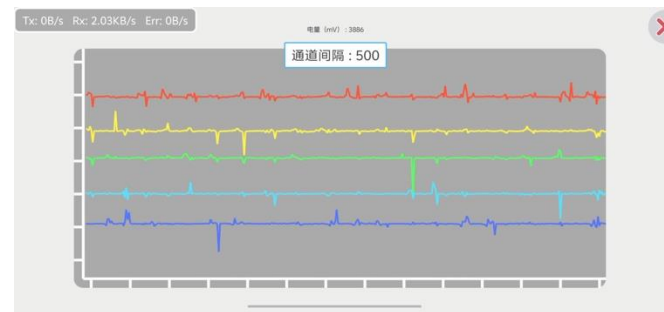
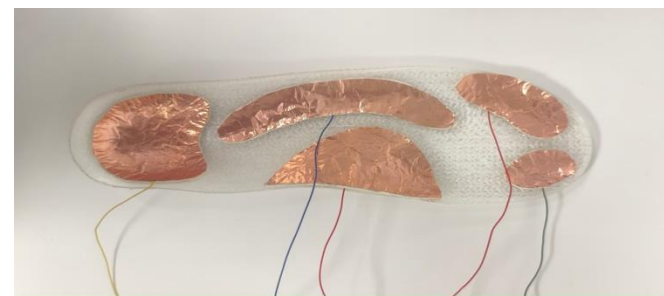
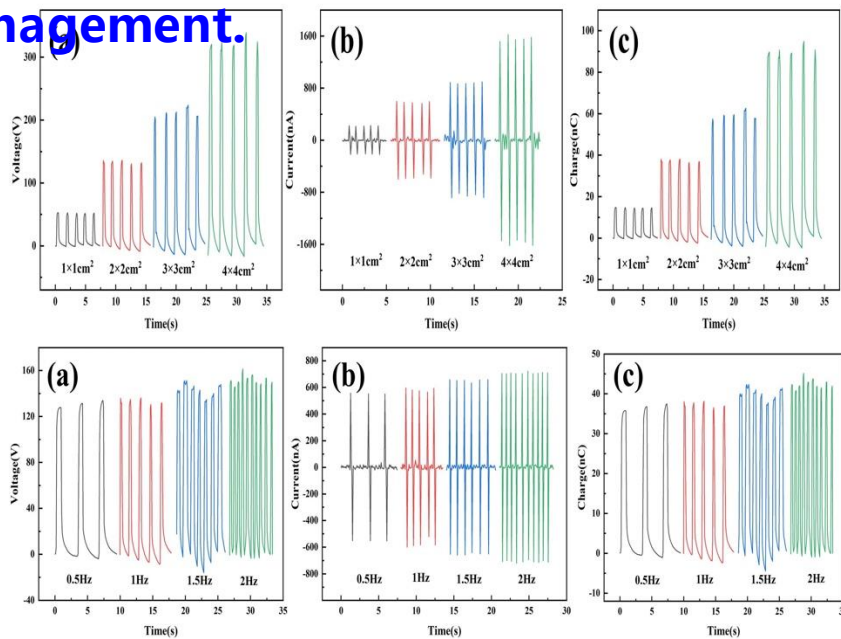
- Silver nanoparticles were generated in situ in leather (SGL) .
- Silver nanoparticles are uniformly distributed in leather sample.
- SGL exhibits good physical and mechanical strength, and high antibacterial properties.



Properties of SGL-TENG

- The output voltage of SGL-TENG approximately doubled, with a maximum output voltage exceeding 300 volts (4 cm x 4 cm).
- In the future, SGL-TENG is expected to be applied in foot health

management.



Conclusion

- **Leather is a kind of good triboelectric material.**
- **TENG based on waterproof leather has stable output performances against great changes of humidity and temperature, which can be used as sensitive self-powered motion monitoring and sign language recognition.**
- **Silver nanoparticles can significantly enhance the electrical performance of leather-based TENGs and impart excellent antibacterial properties, making SGL-TENG a highly promising candidate for foot health management applications.**

Thanks for your professional advices !



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