Flexible Self-powered Sensors by Using Organic Thermoelectric Effect

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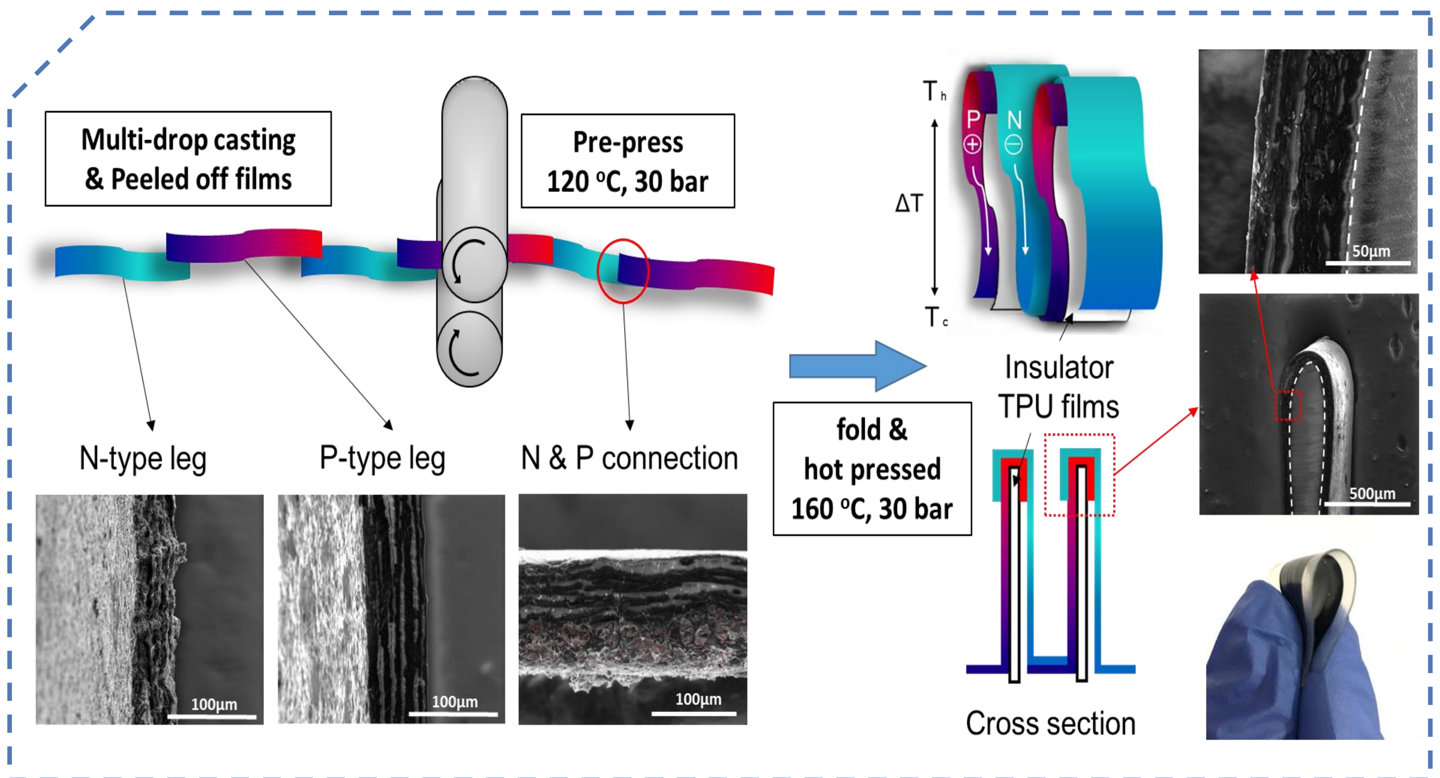
Introduction

- Smart electronic devices are in high demand, especially flexible, stretcheble durable and low costs.
- Thermoelectric energy harvesting for self-powered sensors.
- Organic thermoelectric materials for flexibility, processability and reduced costs.

Methods



Results

Mechanical properties

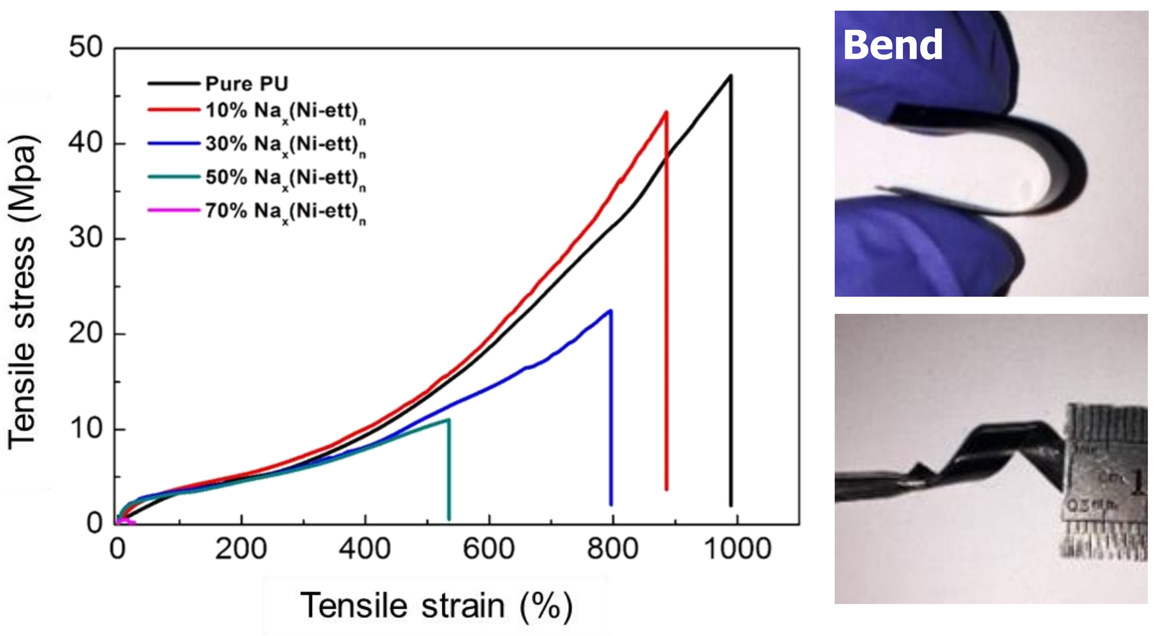


Figure 1 The tensile properties for self-standing PU/Na_x(Ni-ett)$_n$ composites films. Optical pictures showing flexibility under bending and twisting.

- ✓ Self-standing films formed successfully.
- ✓ Strain properties increase massively with PU (Lycra®) content.

Thermoelectric properties

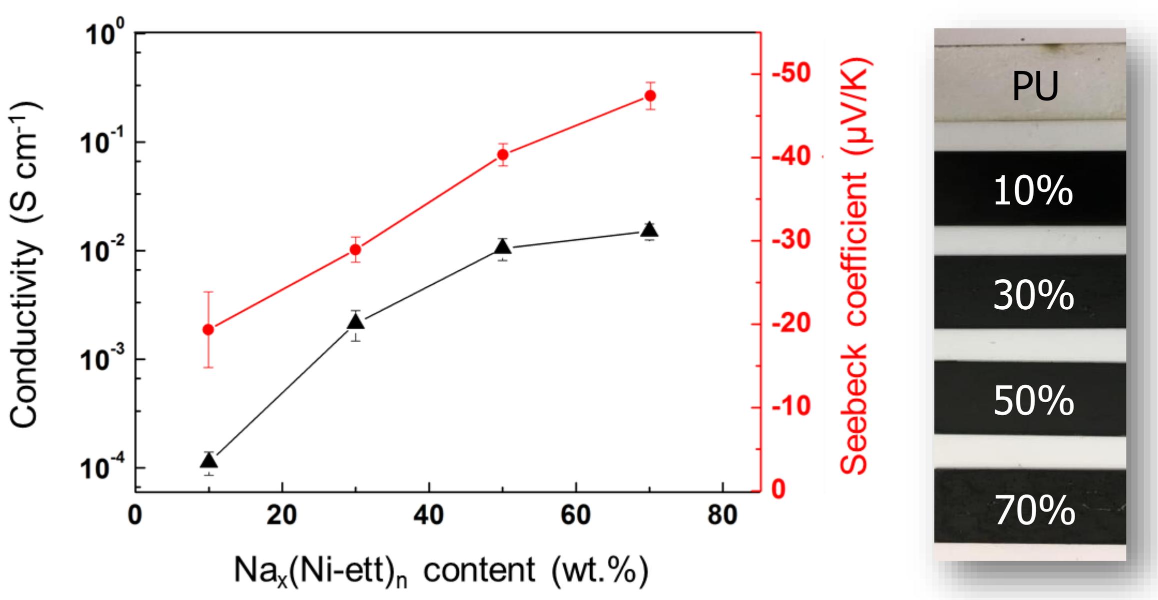


Figure 2 PU/Na_x(Ni-ett)$_n$ blends films (right) and their thermoelectiric properties (left).

- ✓ Both electrical conductivity & Seebeck coefficient increase with Na_x(Ni-ett)$_n$ content.
- ✓ 50 wt.% composite film is selected for self-powered sensing devices.

Self-powered sensing

- Strain sensing

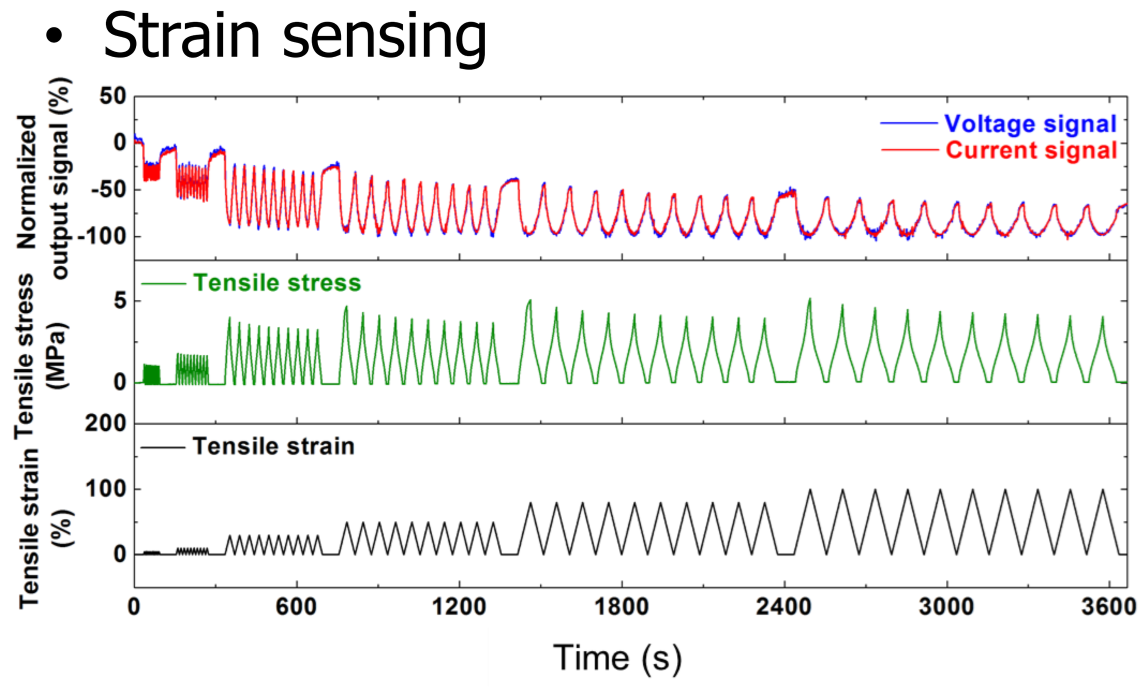
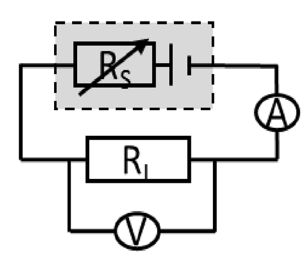


Figure 3 Signals change under cyclically tensile strain, self-powered by Seebeck voltage generated at ΔT ~ 50K.

- ✓ Sample resistance changes with strain.
- ✓ Both current (I) & voltage (V) across the load change with stain.

$$I = \frac{U_{TE}}{R_s + R_L} \qquad U = \frac{U_{TE} * R_L}{R_s + R_L}$$



- Visible light/temperature sensing

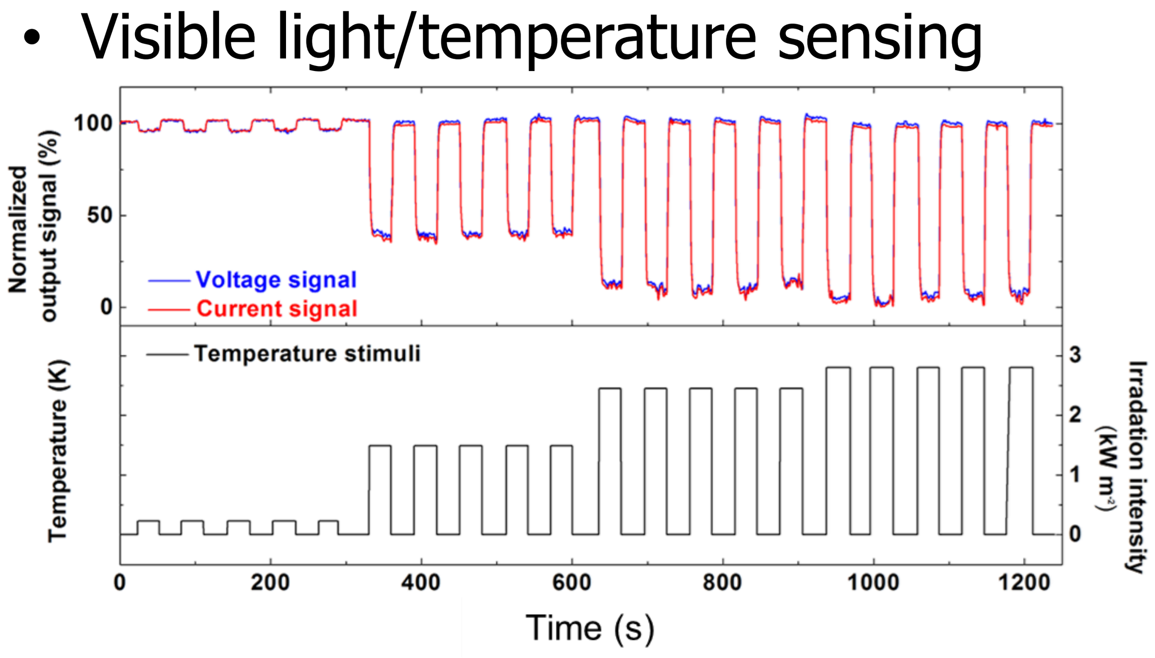


Figure 4 Signals change while light irradiated cyclically over time, self-powered by Seebeck voltage.

- ✓ Visible light irradiation mainly changing the sample temperature.
- ✓ Electrical resistance linearly decreases with light intensity increasing.

Application

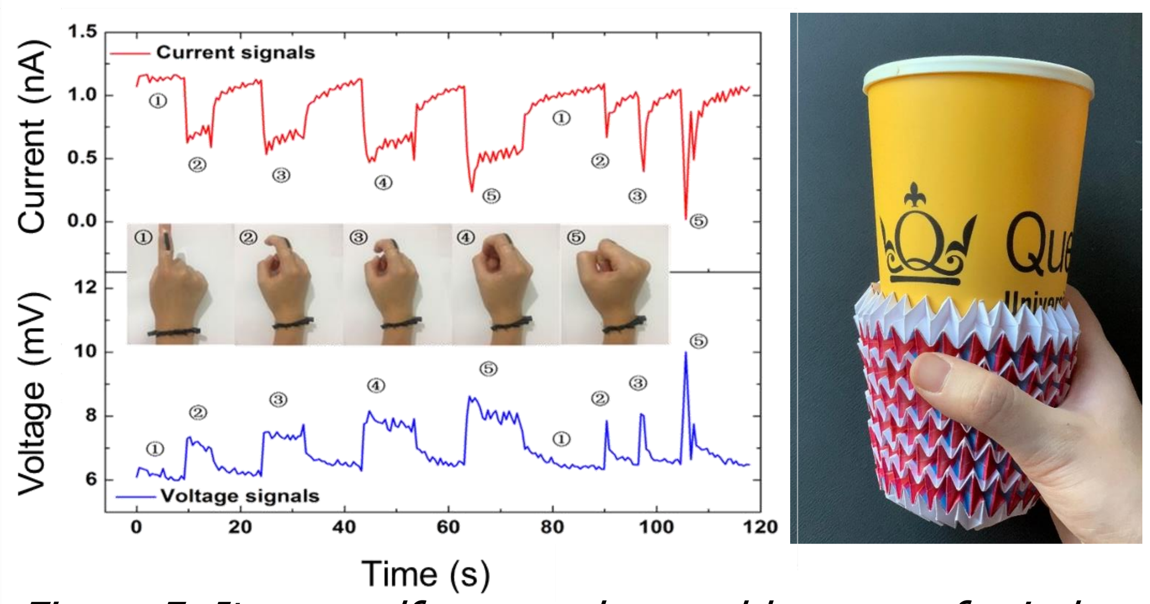


Figure 5 It as a self-powered wearable sensor for index finger positions, at ΔT ~ 20 K. And it harvests secondary heat as a generator.

Multi-leg TE device

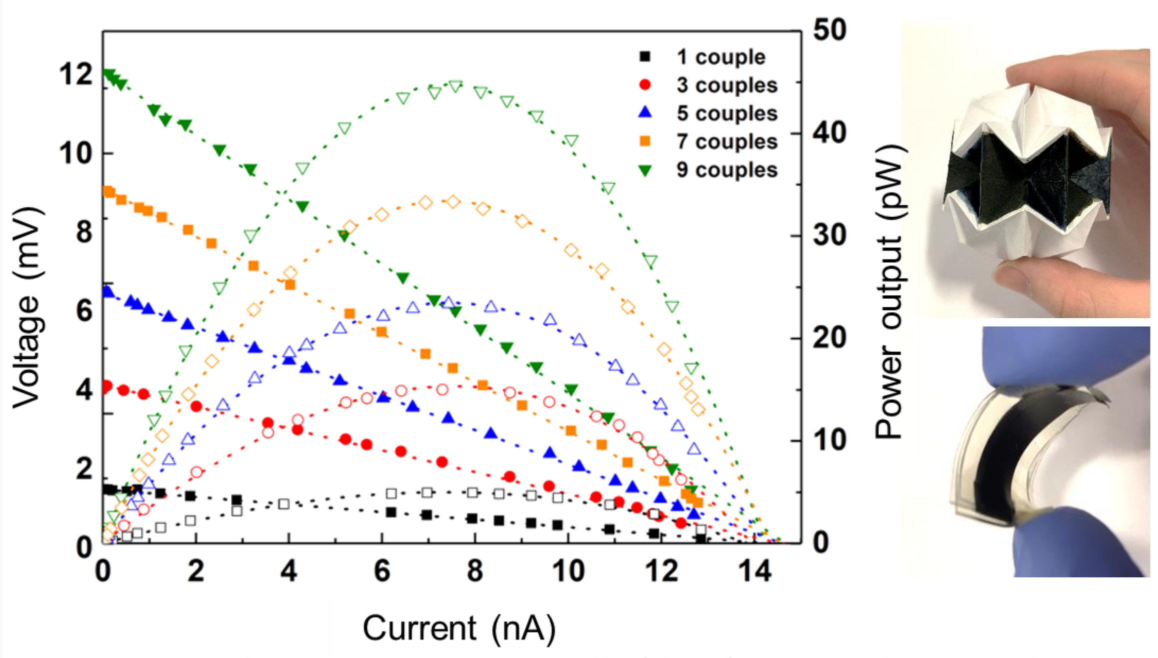


Figure 6 The power output (left) of 6-couples TE device under ΔT ~ 20 K. Two different designs for TE device assembling (right).

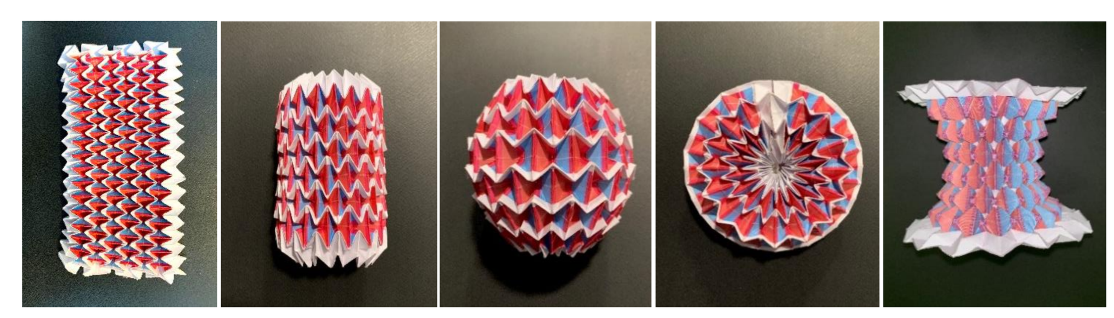


Figure 7 Demonstration of a 90-couples "magic ball" shape conformable TE device.

- ✓ Future large-scale industrial adoption.
- ✓ P-n junction is robust and TE device remains flexible.

Conclusions

- Improved mechanical properties and processability, maintaining thermoelectric properties have been achieved.
- Strain, visible light and temperature self-powered sensing has been examined.
- The concept of wearable self-powered sensing has been demonstrated.
- Flexible TE devices have been assembled to improve device power output.

References

[1] Jiao, Fei, et al. *Phil. Trans. R. Soc. A* 372.2013 (2014).
[2] Sun, Y, et al. *Advanced Materials*. 24.7 (2013).
[3] Menon, Akanksha K., et al. *Journal of Applied Polymer Science* 134.3 (2017).