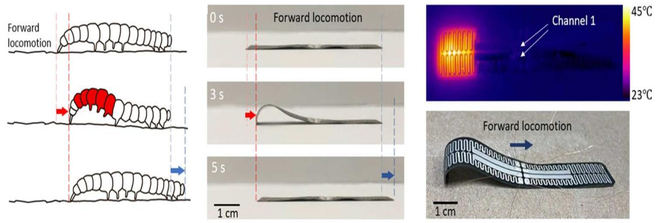
Caterpillar-inspired Robot with Battery and PCB board

Xizhe Hao[1,2], Jianzhi Tang[1,3], Zhiqi Guo[1,4], Yong Zhu[1]*

1 Department of Mechanical and Aerospace Engineering, North Carolina State University, Raleigh, NC 26975, USA
2 School of System Design and Intelligent Manufacturing, Southern University of Science and Technology, Shenzhen, China
3 Weiyang College, Tsinghua University, Beijing, China
4 School of Microelectronics, Southern University of Science and Technology, Shenzhen, China

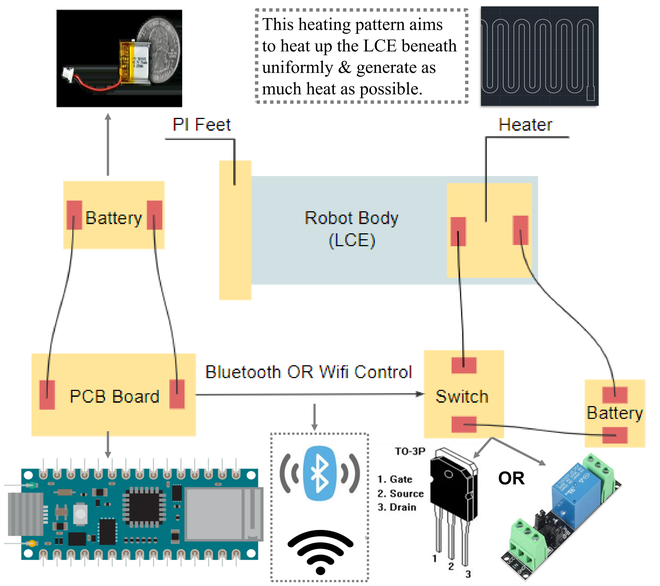
BACKGROUND

Soft robots have attracted wide attention in various fields. Prof. Yong Zhu's lab has built a caterpillar-inspired crawling robot with multiple crawling modes, enabled by joule heating of a patterned soft heater (consists of silver nanowire networks) on LCE (shrinks when heated) and the friction competition between the front and rear end with the ground.



Demonstration of how this caterpillar-like robot moves forward

OVERALL DESIGN

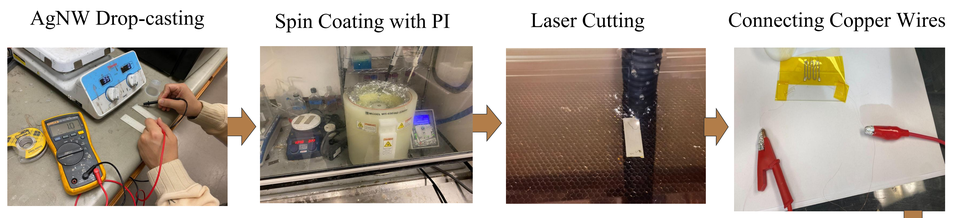


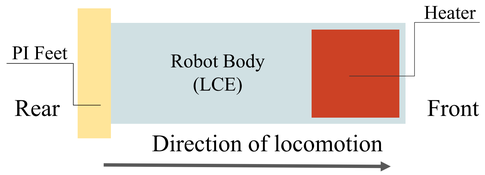
Final Goal:
Use PCB Board to control the movement of the robot & Use light batteries as power supply to replace clumsy current generator

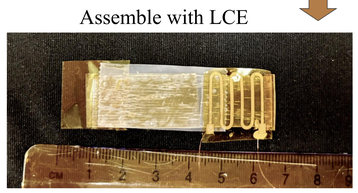
Key Technique:
-Wi-Fi 2.4G
-BLE (Bluetooth Low Energy)

Components:
1. Materials:
- PI
- LCE
- Silver nano wires (AgNW) network
- Copper wire
2. Control Part:
- Battery (3.7V, 150mah)
- Arduino Nano 33 IoT
- Relay (1 Channel DC 3V)
- NMOS (IRLB3034PBF)
- Male & Female Connector

ROBOT MANUFACTURING



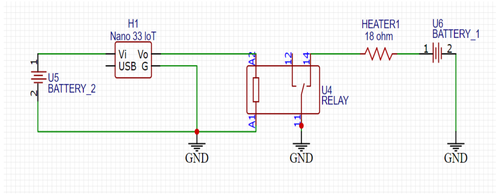




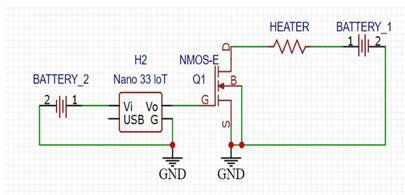
Under Joule heating, the temperature rise would result in the PI layer expanding and the LCE layer shrinking, creating a bending at the front. With power off, the PI/LCE bimorph would return to its flattened shape. The PI feet create a friction competition between the front and rear end with the ground. So the rear end would maintain its contact position with the ground while the front cools down and releases the shrunk length. Thus the robot moves forward.

CONTROL

1- Control Circuits

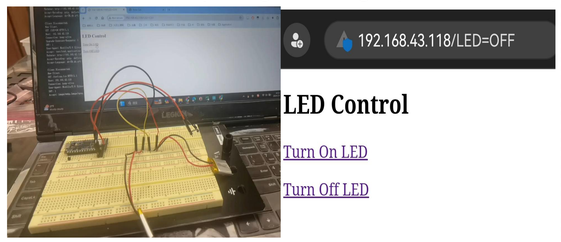


(1) Circuit Using Relay As A Switch

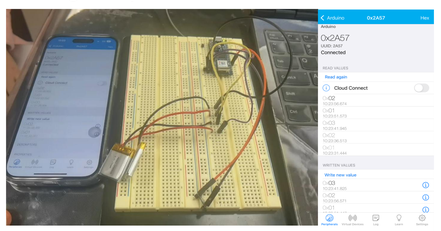


(2) Circuit Using NMOS As A Switch

2- Control Method (Test generating square-wave output using LED)



(1) Testing circuit using **Wi-Fi communication method** while the figure on the right is the **control website interface**



(2) Testing circuit using **Bluetooth communication** while the right figure is the **control app interface**

Functions	Wi-Fi	Bluetooth
Generating Square-wave Output	√	√
PC/Phone Remote Control	√	√
Multi-device Control	√	×
Low Energy Consumption	×	√

RESULTS

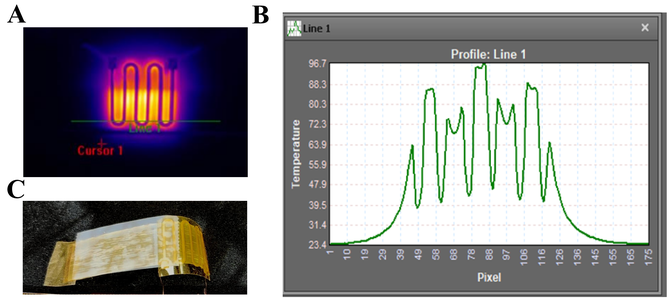


Figure A: IR image of the heater under 7.7 volts
Figure B: Temperature distribution along Line1
Figure C: Photograph of the robot during locomotion

Working within the complete the circuit, figure A, B show the heater located on the head part of the robot can be heated up to 94°C.

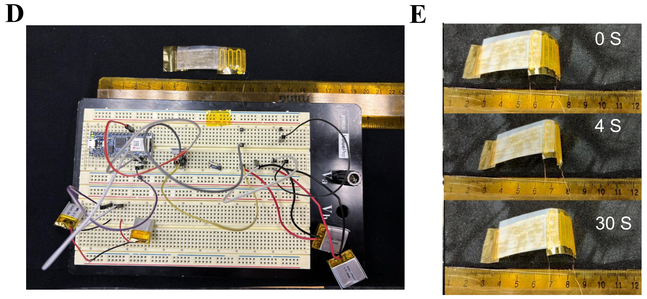


Figure D is the complete circuit using NMOS. Figure E shows, with the total voltage around 8V, the robot advances 1 cm in about 30 seconds.

REFERENCES

【1】Wu, S., Hong, Y., Zhao, Y., Yin, J., & Zhu, Y. (2023). Caterpillar-inspired soft crawling robot with distributed programmable thermal actuation. Science advances, 9(12), eadf8014. https://doi.org/10.1126/sciadv.adf8014

【2】He, Q., Wang, Z., Wang, Y., Minori, A., Tolley, M. T., & Cai, S. (2019). Electrically controlled liquid crystal elastomer-based soft tubular actuator with multimodal actuation. Science advances, 5(10), eaax5746. https://doi.org/10.1126/sciadv.aax5746

ACKNOWLEDGEMENT

Great thanks to the generous assistance from Shuang Wu, Jennifer Lee, and the Nanomechanics and Nanoengineering Laboratory, Department of Mechanical and Aerospace Engineering, NCSU. This small creation could not have been here without their incisive suggestions and enduring encouragement.