Multi-stimulus responsive bilayer soft actuator

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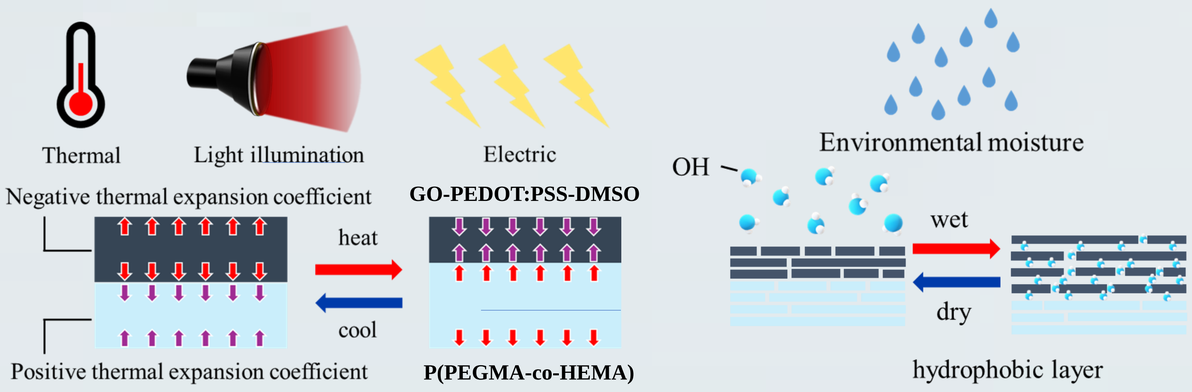
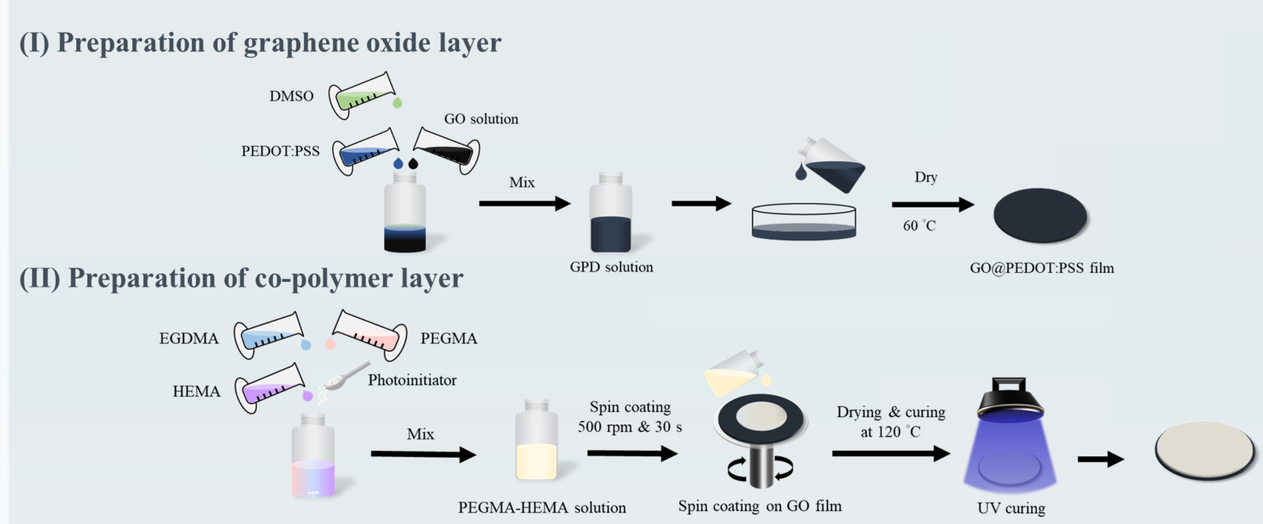
Abstract

In daily life, we can observe animals and plants achieving various complex movements by receiving different types of external stimuli in nature. To simulate this characteristic, we propose a bilayer soft actuator with dimensions (5 × 20 mm) capable of sensing multiple stimuli, including photothermal, electrothermal, and humidity responses. The actuator is composed of a combination of polyethylene glycol methyl ether methacrylate (PEGMA) and 2-hydroxyethyl methacrylate (HEMA), stacked on a layer of graphene oxide (GO) and conductively polymerized with PEDOT:PSS Material enhancement to achieve electrothermal drive. This flexible, self-aware, lightweight two-layer actuator aims to create robots that can be driven by a variety of external stimuli, replacing humans in performing dangerous, complex and repetitive tasks. It has broad application prospects in fields such as soft robots, smart switches, and artificial muscles.

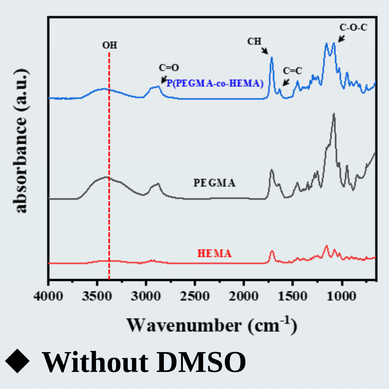
Working principle

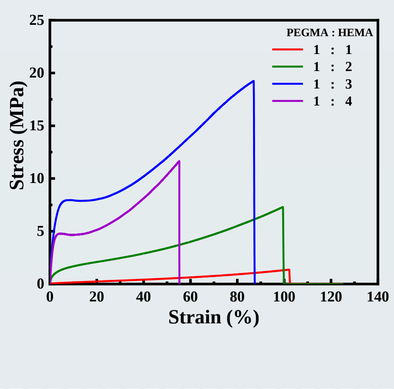


Experimental



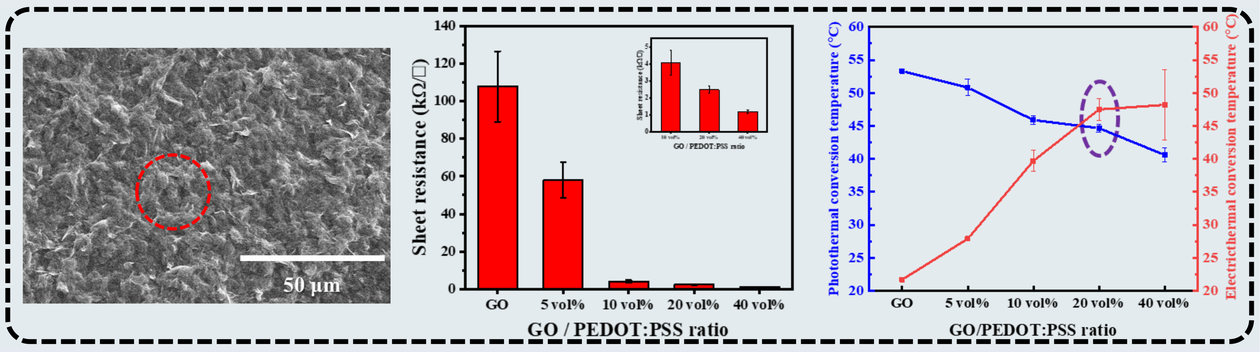
Material characterization



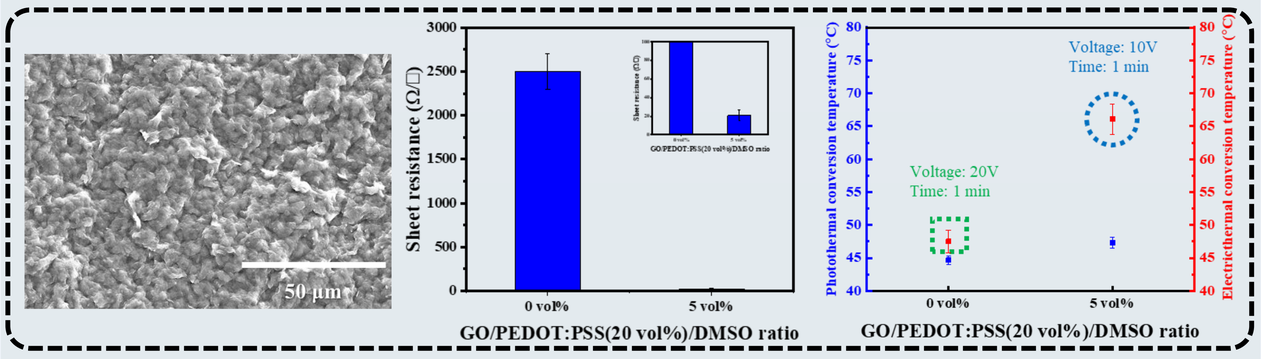


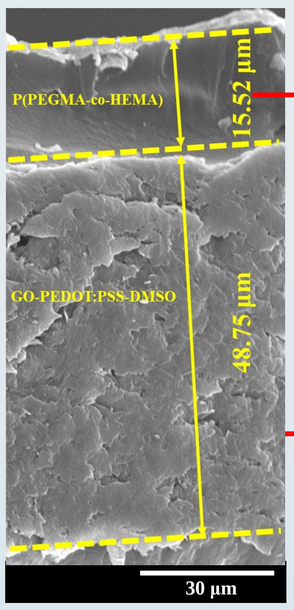
- After adding PEGMA, the OH peak of P(PEGMA-co-HEMA) is increased which enhances hydrophilicity of P(PEGMA-co-HEMA).
- The stress is increased by increasing the amount of HEMA. However, the strain is reduced.
- The optimum condition of P(PEGMA-co-HEMA) is ratio of 1:3 which are PEGMA and HEMA, respectively.

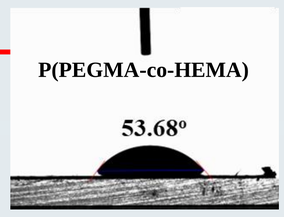
◆ Without DMSO

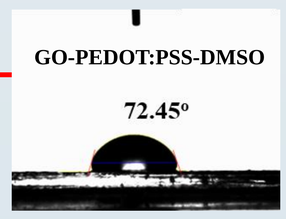


◆ With DMSO





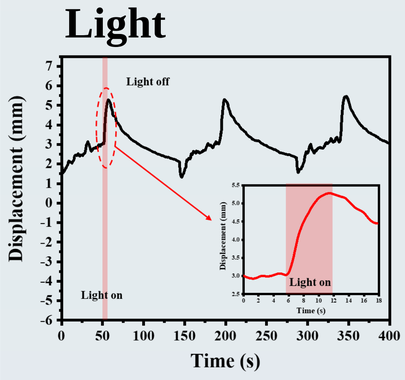




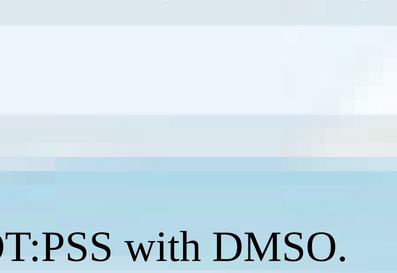
- The best photothermal and electrothermal conversion temperatures of GO can be obtained at 20 vol% of PEDOT:PSS.
- The sheet resistance is further reduced after adding DMSO because of removing of PSS from PEDOT surface which improved of connection of PEDOT.
- SEM image reveals the interface between P(PEGMA-co-HEMA) and GO-PEDOT:PSS-DMSO layers are good.
- The contact angle of P(PEGMA-co-HEMA) and GO-PEDOT:PSS-DMSO are 53.68 ° and 72.45 °, respectively. It can be observed to facilitate humidity-responsive due to differences in water contact angles of bilayers .

Actuation performance

Light

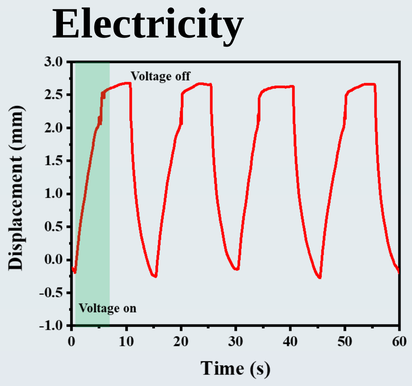


- The actuator is activated by 1000W/m² NIR-light with a start-up time of 8 s and a recovery time of 82.3 s.



- Schematic diagram of actuator driving according to NIR light.

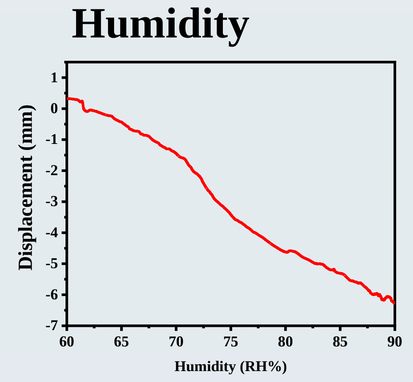
Electricity



- The actuator started by 10 volts has a response time of 5.02 s and a recovery time of 4.3 s.

- Thermal diagram of actuator powered by 1000W/m² and 10V.

Humidity



- The actuator increases the humidity from 63% to 88% causing it to bending.

- Schematic diagram of actuator driving according to humidity change.

Future work

- Investigation of actuation applied in different light power and voltage.
- Make bionic flowers, fixtures and other applications.
- Study the stability of actuator.
- Driving actuator by using different solvents.

Conclusion

- The toughness of PEGMA is increased by adding HEMA .
- The sheet resistance of GO is reduced after adding 20 vol% of PEDOT:PSS with DMSO.
- A bilayer soft actuator is capable of sensing multiple stimuli such as photothermal, electrothermal, and humidity responses.