An Ultrathin Flexible Sensor Based on Graphene-Polymer-Graphene Structures

Villanova University Investigator

Bo Li, PhD, Assistant Professor, College of Engineering, Department of Mechanical Engineering, Director of the Hybrid Nano-Architectures and Advanced Manufacturing Laboratory (HNAM)

Background and Unmet Need

Thin film sensors are increasingly sought after across industries, including automation, robotics, semiconductors, healthcare, medicine, security, and flexible electronics.[1] There is a constant demand to further reduce sensor thickness while improving sensitivity for highly integrated and compact devices.

Inorganic dielectric materials based on oxides and nitrides provide a high dielectric constant, low leakage, and stability at high temperatures. However, their mechanical stiffness and brittleness limit their applications in soft and flexible electronics, particularly in sensors and actuators.

The demand for sensor technologies that can meet these evolving needs across multiple industries is growing exponentially.

Opportunity

With development of one of the world's thinnest film sensors, the Li lab has achieved significant advancements in the field of sensor technology. Comparable state-of-the-art sensors range between 0.1 to a few millimeters thick, reported to be five orders of magnitude higher than the Li sensor. This innovative sensor offers exceptional sensitivity to a variety of stimuli, including force, weight, pressure, and temperature.

The core of this technology lies in the fabrication of an organic, nanoporous dielectric layer, which has enabled the creation of an ultrathin inorganic-organic capacitor. The unique properties of this material allow it to deform in response to applied pressure, resulting in sensing functionality with ultra-high resolution.

One of its standout features is the ability to control the manufacturing thickness of the inner layer, which ranges from several nanometers to several microns. This flexibility is achieved because the center layer is "grown," allowing for precise adjustments as needed.

Due to the sensitivity of the flexible polymer dielectric layer to force, temperature, and chemicals, this ultrathin capacitor can also operate as a multifunctional sensor. It is designed to integrate seamlessly onto various surfaces, such as rigid silicon wafer and soft polymer substrate, with both flat and curved configurations. This versatility makes it particularly valuable for highly integrated systems, such as robotic hands used in robotic surgery and other applications that require strict adherence to thickness limitations while maintaining sensing capabilities.

Initial studies have demonstrated the potential of this sensor technology, showcasing an ultrasensitive force sensor capable of detecting forces as low as one micro-Newton (1

[1] This Film Sensor Market., Transparency Market Research, March 2023.

Continued on back

mg) during compression. Additionally, this versatile sensor functions effectively as a temperature sensor, operating safely at temperatures of up to 80°C.

The developments at the Li lab represent a significant leap forward in sensor technology, combining ultra-thin film structures with multifunctional capabilities. This innovative approach offers multiple adaptable and sensitive sensing solutions for modern technology.

Applications

A multifunctional sensor with advanced force and temperature sensing capabilities can be integrated onto various surfaces, whether flat or curved. This technology is particularly valuable for highly integrated systems, such as robotic hands used in surgical applications, integrated weight balance, motion tracking for insects, fingerprint detection, or other sensing applications where strict thickness limitations and nanoscale precision are essential.

Unique Attributes

- **Versatile Integration:** Seamlessly integrates with a wide range of surfaces, from flat to curved, making it adaptable for any application.
- **Customizable Thickness:** The innovative grown center layer allows for adjustable thickness, ranging from just a few nanometers to several microns, tailored to meet your specific needs.
- **Multi-Functional Sensor:** This advanced sensor is designed for diverse environments, effectively measuring force and temperature.

Stage of Development

Technology Readiness Level 3: Proof of concept demonstrated in the laboratory.

Intellectual Property

United States Patent Application Filed October 2025.

Licensing and Collaboration Opportunity

Villanova is seeking a licensee or collaborators to support technology development research and /or commercialize the invention.

INSTITUTIONAL CONTACT

Amanda M. Grannas, PhD
VP & Chief Research Officer
+1 610.519.4881
Email

L2C PARTNERS CONTACT

Merle Gilmore, MBA
+1 610.662.0940
Email

Alex Toglia, MS
+1 610.937.1067
Email