Color-changing sensor offers new way to track motion and stress

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This innovative strain sensor uses magnetoplasmonic nanoparticles and flexible polymers to detect mechanical stress through reversible color changes, enabling applications in health monitoring, structural safety, and eco-friendly technologies. Credit: Jaebeom Lee / Chungnam National University, Republic of Korea

Wearable devices and smart sensors are transforming how we monitor health and activity, from tracking heartbeats to detecting body movements. However, traditional tools like stethoscopes and fitness trackers often face challenges. They require user training, struggle with accurately capturing subtle signals, and are limited in flexibility and ease of use.

These shortcomings make them less effective for applications that demand adaptability, precision, and user-friendliness, such as real-time health monitoring or motion tracking.

To address these challenges, Professor Jaebeom Lee and his team at Chungnam National University have developed an advanced mechanochromic strain sensor that changes color in response to mechanical stress.

Their study, published in *Chemical Engineering Journal* on 15 October, 2024, highlights the sensor's potential as a power-free, versatile tool. The device integrates flexible polymers with innovative nanoparticles, offering a reliable, user-friendly solution for real-time health and activity tracking.

The sensor is built using magnetoplasmonic nanoparticles (MagPlas NPs). These nanoparticles have a silver core (60 nm) and an iron oxide (Fe_3O_4) shell, which help them interact with light and magnetic fields. They are produced using a method called solvothermal synthesis, which controls chemical reactions at high temperatures to create highly uniform particles in large quantities.

"This nanosized material can be synthesized with exceptional consistency and scalability," explains Prof. Lee.

A critical part of the sensor's design is the arrangement of MagPlas NPs. When a liquid droplet containing these particles is placed on a porous material, such as filter paper or a polyethersulfone (PES) membrane, and exposed to a magnetic field, the particles pack tightly together on the surface rather than seeping into the pores.

This forms a uniform layer called an amorphous photonic array (APA), producing bright, consistent colors that remain stable when viewed from different angles.

These APAs are then transferred onto a flexible, stretchable material called polydimethylsiloxane (PDMS), which enables the sensor to change color under mechanical stress. By adjusting the nanoparticle size between 91 and 284 nanometers, the researchers controlled how the sensor's color changed.

The most noticeable color shift—from blue to red—occurred when the particles were 176 nanometers in size. These color changes are fully reversible and stable, even after repeated stretching, making the sensor durable and reliable.

The sensor could transform many areas, offering a wide range of applications. In health care, it could be used as a wearable device to track motions like knee bending, neck turning, or even subtle movements such as heartbeats or eye twitches. The sensor could also ensure the safety of buildings and bridges by visually detecting stress or damage without complicated setups.

"The mechanochromic change of the device could be monitored constantly, to predict and prevent fatal structural failures for buildings, civil structures, and industrial systems," explains Prof. Lee.

Looking ahead, the sensor could enable new possibilities for dynamic displays and secure data storage. For example, researchers created a special "data matrix" code that is only visible when the sensor is stretched. In the next five to 10 years, these power-free sensors could become key in developing sustainable, eco-friendly technology.

Their ability to work without power makes them ideal for use in remote or extreme environments like deep-sea missions or space exploration. "Power-free sensors and optical devices have a great amount of impact on the future of sustainable and green technology," adds Prof. Lee.

More information: Huu-Quang Nguyen et al, Mechanochromic strain sensor by magnetoplasmonic amorphous photonic arrays, *Chemical Engineering Journal* (2024). DOI: 10.1016/j.cej.2024.155297

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