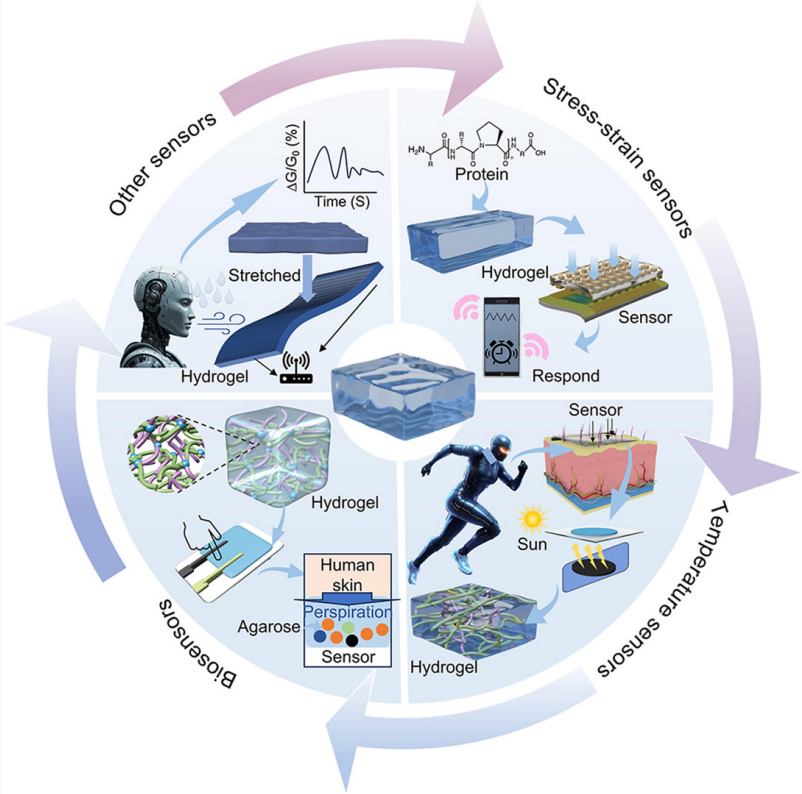
# Turning natural hydrogels into smart sensors

GA, UNITED STATES, June 26, 2026 /EINPresswire.com/ -- Natural biomass hydrogels are emerging as promising building blocks for intelligent sensors because they combine softness, water-rich structures, tunable networks, and abundant functional groups. A new review brings together recent progress in turning materials such as cellulose, chitosan, sodium alginate, gelatin, starch, hemicellulose, proteins, and lignin into responsive sensing platforms. By focusing on the correlation between crosslinking networks and sensor behavior, the review connects material design with practical performance, including sensitivity, response speed, durability, and environmental stability. The work offers a clearer roadmap for developing sustainable sensors for wearable electronics, healthcare monitoring, environmental sensing, and smart human–machine interfaces.



Natural biomass hydrogels for smart sensing.

Hydrogel sensors can translate pressure, strain, temperature, humidity, or biological signals into measurable electrical responses. Natural biomass hydrogels are especially attractive because they are renewable, biocompatible, flexible, and rich in water- and ion-transport channels. However, their performance depends strongly on internal crosslinking networks, which determine mechanical strength, conductivity, self-healing ability, swelling behavior, and long-term stability. Previous reviews have discussed biomass hydrogels and flexible sensors, but few have systematically explained how different crosslinking structures control sensing performance. Due to these challenges, further research is needed to clarify the relationship between natural biomass hydrogel crosslinking networks and intelligent sensing performance.

The review was conducted by researchers from Tianjin University of Science and Technology, the University of Wisconsin–Madison, and Nankai University, and was published online on March

2026, in eScience. The article reviews natural biomass hydrogel sensors from the perspective of component design, crosslinking engineering, and stimuli-responsive mechanisms, with a focus on stress–strain sensors, biosensors, temperature sensors, and humidity sensors.

The review first examines the structural features of major natural biomass materials. Cellulose offers abundant hydroxyl groups and mechanical flexibility; chitosan provides amino groups and water responsiveness; sodium alginate forms ionically crosslinked networks; proteins contribute biological recognition; and lignin adds structural stability and mechanical strength. The authors then compare three main crosslinking routes: physical crosslinking, chemical crosslinking, and physical–chemical dual crosslinking. Physical crosslinking, including freeze–thaw processing, supramolecular self-assembly, ionic crosslinking, and temperature regulation, gives hydrogels dynamic reversibility, rapid response, and self-healing properties. Chemical crosslinking builds more stable covalent networks, improving strength, fatigue resistance, and long-term reliability. Dual crosslinking combines these advantages, creating hydrogels that can be both tough and responsive. The review further links these network designs to different sensing functions. Stress–strain sensors depend on conductive pathway changes under deformation; biosensors rely on selective molecular recognition; temperature sensors respond to thermal network changes; and humidity sensors detect water adsorption and release through changes in conductivity, capacitance, or impedance.

The authors said the central message is that natural biomass hydrogels should not be viewed simply as soft materials, but as programmable sensing platforms. By adjusting crosslinking density, bond reversibility, ionic pathways, and network architecture, researchers can tune how a hydrogel responds to the outside world. They said this structure–function understanding is essential for moving biomass-based sensors from laboratory demonstrations toward reliable devices that can work in real environments.

Looking ahead, the review highlights several priorities for application. Physical crosslinking hydrogels still need stronger mechanical performance and broader sensing ranges, while chemical crosslinking systems must reduce cytotoxicity and preserve biological activity for biosensing. Dual crosslinking is expected to play a larger role because it can improve sensitivity, environmental tolerance, and signal stability. For industrial translation, the field will also need scalable manufacturing, including automated additive manufacturing and three-dimensional/four-dimensional bioprinting, as well as standardized testing for biosafety, reliability, and long-term performance. These advances could support greener, more reliable sensors for healthcare, agriculture, wearable devices, and environmental monitoring.

References

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