Smart devices, Health monitoring, Disease diagnosis

Development of dynamically crosslinked composite hydrogel sensor with efficient self-healing and adhesive properties

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Abstract

Multi-functional hydrogel-based flexible sensor was developed through an "one-pot" strategy benefiting from lignin sulfonate (LS)-Fe^{3+} dynamic redox system and reversible non-covalent cross-linking formed between 3-acrylamidophenyboronic acid (APBA) and cellulose nanocrystals (CNC). The synergistic interactions of massive hydrogen bonding, the boronic ester bond between APBA and CNC as well as the metal-ligand complexation of Fe^{3+} and polymer chain endowed the hydrogel with reliable and efficient self-healing properties. Based on the reliable conductive traits of abundant ions, the multifunctional hydrogel was employed as a real-time monitoring device for elderly healthcare and sleeping management, ensuring the stable transmission of movement signals. This work paved a novel avenue for efficiently developing long-lasting conductive hydrogels for wearable electronics and communicators.

Background & Results

Multifunctional conductive hydrogels exhibit tremendous potential for applications in human-machine interfaces, flexible electronic devices and soft robotics. However, the time-consuming and energy-intensive preparation process, as well as the inefficient and unstable self-healing capabilities, limit their practicality and reusability. Herein, we utilized lignin sulfonate (LS)-Fe^{3+} dynamic redox system to induce the generation of ammonium persulfate (APS) radicals at room temperature. Additionally, the polymerization of acrylamide (AM), sodium acrylate (AAS), and 3-acrylamidophenylboronic acid (APBA) formed polymer networks through multiple dynamic crosslinking via the synergistic interactions of Fe^{3+} and cellulose nanocrystals (CNC). The dynamic and reversible boronic ester bonds, ion coordination bonds, and hydrogen bonds endowed the hydrogel with high stretchability (1170%), low hysteresis and efficient self-healing (91.76%, 2 h) capability. Interestingly, the intermediate catechol groups generated by the LS-Fe^{3+} dynamic catalytic system provided the hydrogel with repeatable and reliable adhesive performance. Thanks to the excellent ionically conductivity, the fabricated hydrogel-based sensors exhibited a wide sensing range (500%), rapid response time (139 ms), and high sensitivity (GF=8.98), that accomplished specific voice recognition and subtle body motion detection for real-time elderly health and sleep management. This multifunctional hydrogel is of great significance for efficiently developing prolonged lifespan wearable electronics and healthcare flexible devices.

Significance of the research and Future perspective

The developed hydrogel can be assembled into multifunctional wearable sensors for smart elderly care system, accurately monitoring and identifying the movements of the human body, including fingers, wrists, elbows, shoulders, and even faint physiological signals (sound, swallowing, and coughing). Additionally, this hydrogel wearable sensors can also be assembled into a "smart eye mask" for real-time sleep monitoring, demonstrating a sensitive capability to distinguish rapid eye movement sleep and deep sleep. We believe that this environmentally friendly, time-efficient, and cost-effective hydrogel holds significant potential for applications in flexible electronics, health monitoring, and disease diagnosis.

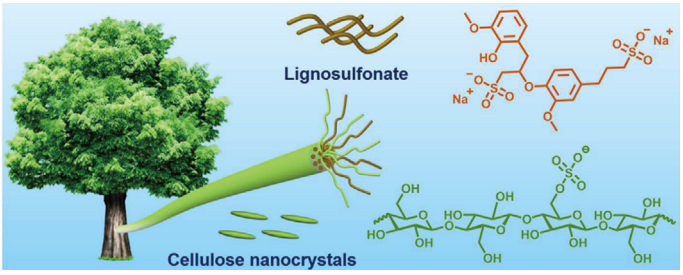

Figure 1

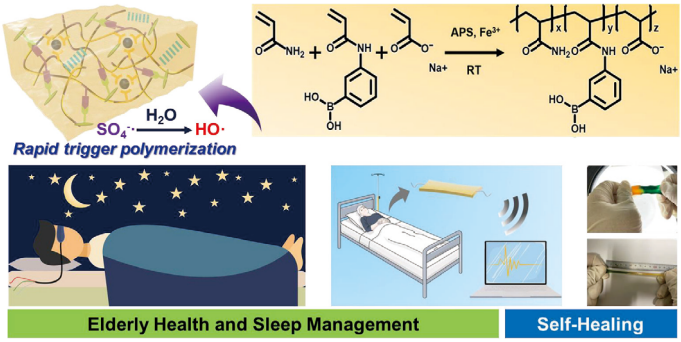

Figure 2

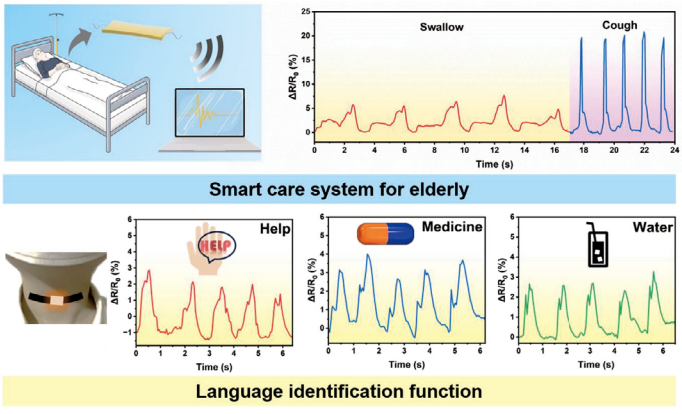

Figure 3

Patent

Treatise Wang, Juan; Hsu, Yu-I; Uyama, Hiroshi et al. Rapid preparation of dynamic-crosslinked nanocomposite hydrogel sensors with efficiency self-healing and adhesion properties for elderly health and sleep management. Chemical Engineering Journal. 2024, 480, 148324. doi: 10.1016/j.cej.2023.148324

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Keyword dynamic-crosslinked nanocomposite, hydrogel sensor, self-healing, adhesiveness