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Innovative Sensor Technologies for Monitoring Food and Healthcare Applications

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ABSTRACT

This study explores developing flexible sensor-enabled prototypes for food safety and healthcare, leveraging advanced sensor technologies for real-time, non-invasive monitoring. These innovations address challenges in food freshness assurance and personalized health management, utilizing sustainable materials and advanced fabrication techniques to deliver scalable, efficient, and eco-friendly solutions.

Food Safety and Meat Freshness Monitoring

Food waste and insecurity necessitate innovative solutions. Our prototype integrates intelligent packaging with sensors to monitor meat freshness by detecting hydrogen sulfide (H_2S) gas, temperature, and relative humidity (RH). We fabricated our sensors using sustainable materials and advanced printing techniques like aerosol jet and screen printing. Initial tests on fresh and expired meat validated the system's ability to detect spoilage indicators. The H_2S sensor, based on indium oxide nanoparticles (In_2O_3 NPs), reliably identified concentrations below 100 ppb, while temperature and RH sensors responded swiftly to environmental changes. Testing on fresh chicken meat revealed distinct response patterns correlating with spoilage stages, demonstrating the system's practical utility in supply chains. Future work will enhance sensor longevity, stability, and adaptability to diverse conditions, ensuring reliable performance across various meat types and storage scenarios.

Healthcare and Breath Analysis

Non-invasive diagnostic tools are crucial for early disease detection and personalized health management. Our breath analysis prototype integrates flexible sensors to monitor exhaled biomarkers like H_2S, RH, and temperature. The H_2S sensor, validated for high sensitivity, distinguished breath variations linked to dietary intake, such as elevated levels after consuming sulfur-rich foods. Temperature and RH sensors provided insights into hydration and respiratory function, showing consistent baseline measurements across multiple volunteers. This tool highlights the potential of personalized medicine, enabling early diagnosis and tailored treatments. Future research will expand the system's capabilities by incorporating additional biomarkers, such as ammonia and nitrogen monoxide, to enhance diagnostic accuracy for a wider range of health conditions.

Technological and Societal Implications

Both prototypes emphasize sustainability and innovation, utilizing green graphene-based RH sensors, polystyrene-graphite temperature sensors, and In_2O_3 NPs-based H_2S sensors. In food safety, the system addresses supply chain inefficiencies, reduces waste, and ensures quality assurance, contributing to sustainable consumption practices. In healthcare, the breath analysis tool exemplifies the potential of personalized medicine, offering non-invasive, real-time monitoring for improved patient outcomes. Future research will refine these prototypes for broader applicability, including large-scale testing, material safety assessments, and interdisciplinary collaborations with industry and medical experts. By bridging technology and real-world applications, these innovations promise transformative impacts on food safety and healthcare.