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Biodegradable and Flexible RFID Electronics: Carbon-Based Eco-Friendly Materials for a Circular Economy

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ABSTRACT

The exponential growth in electronic waste (e-waste) demands the development of biodegradable and sustainable alternatives to conventional electronic devices. RFID (Radio Frequency Identification) technology, which is being widely applied in asset management, supply chain management, and access control, is a significant contributor to e-waste due to its reliance on non-biodegradable materials. This paper presents a novel approach to transient RFID electronics using laser-carbonized graphene oxide (GO) and sodium lignosulfonate (Na-LgS) films, offering an eco-friendly and large-scale solution for RFID fabrication compared to traditional methods. The proposed method involves the fabrication of biodegradable RFID circuits by utilizing a combination of graphene oxide (GO) and sodium lignosulfonate (Na-LgS) as carbon precursors. The material is deposited on a flexible and biodegradable substrate and subsequently carbonized using laser treatment. The morphology and electrical characteristics of the carbonized films will be systematically investigated using Scanning Electron Microscopy (SEM), Raman Spectroscopy, and X-ray Photoelectron Spectroscopy (XPS) to assess their suitability for RFID applications. Experimental results demonstrate that laser-carbonized films exhibit enhanced conductivity, mechanical flexibility, and stability, making them extremely suitable for sustainable electronics.

By integrating carbon-based conductive films and biodegradable materials, this work enables the potential for sustainable RFID systems with reduced electronic waste. With the transient nature of the RFID tags, the tags will degrade naturally over time, significantly reducing their impact on the environment in the long run. Furthermore, the findings highlight the potential of graphene-based biodegradable electronics in advancing circular economy principles, where electronic components are designed for sustainable disposal and reuse. This study contributes to the new field of green electronics, demonstrating that high-performance RFID is attainable with laser-carbonized graphene-lignin films. The method developed here is a low-cost and scalable approach to fabricating flexible, conductive, and biodegradable RFID tags, rendering them a highly desirable alternative to conventional RFID technology.