Sustainable Applications of Biodegradable Sensor Using Plant-Based Laser-Induced Graphene

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ABSTRACT

Growing concerns about e-waste and its environmental impact are driving the search for sustainable alternatives to sensor technology. In this study, we present the development of a flexible and transparent sensor that is fully biodegradable using plant-based laser-induced graphene (LIG) and natural packaging materials. The main goal is to present a biodegradable, plant-based packaging material that retains high mechanical flexibility and environmental friendliness as an alternative to conventional flexible materials such as polydimethylsiloxane (PDMS). LIG was directly synthesized by laser irradiation on a plant substrate to create conductive graphene circuits, which were then used to construct a complete sensor system packaged in a naturally sourced, plant-based, biodegradable material. This research can contribute to reducing e-waste and environmental impact by demonstrating the potential for sustainable and flexible electronic devices.

KEY WORDS

Laser Induced Graphene, Biodegradable, Molecular Dynamics.

1. INTRODUCTION

Laser-Induced Graphene (LIG) has been extensively studied due to its unique properties, such as high electrical conductivity, flexibility, and environmental stability, across various fields [1]. Polyimide (PI), specifically, has been a focus of active research in electronics and sensor applications due to its excellent thermal stability and mechanical strength [2]. However, due to growing environmental concerns, biodegradable materials are gaining increased attention. As a result, wood-based LIG, which is eco-friendly and addresses pollution issues, is being actively explored. Research using wood materials such as cork, wood, leaves, and other natural resources has been conducted, with theoretical studies based on Molecular Dynamics (MD) simulations providing further insights [3]. Nevertheless, these LIG circuits are often exposed to external environments, and their packaging methods are limited. Polydimethylsiloxane (PDMS) has been applied in various fields as a packaging material for flexible LIG-based sensors due to its elasticity and transparency [4]. However, PDMS is not entirely biodegradable, limiting its use in the development of fully biodegradable sensors.

Among the alternatives, Konjac glucomannan (KGM) is a plant-based material derived from the konjac plant. KGM has a unique polysaccharide structure, providing it with exceptional water retention and biodegradability. This study proposes a process for creating circuits and transparent flexible packaging using KGM to overcome these limitations. By leveraging KGM's excellent mechanical strength and flexibility, we explored a method to replace polymer-based LIG. To theoretically support this, structural phenomena were verified through Molecular Dynamics (MD) simulations. Additionally, to confirm effective biodegradability, we monitored the degradation process under real environmental conditions. This study presents a solution to challenges currently facing the field of sustainable electronics and is expected to provide improvements in environmental monitoring and energy storage applications.

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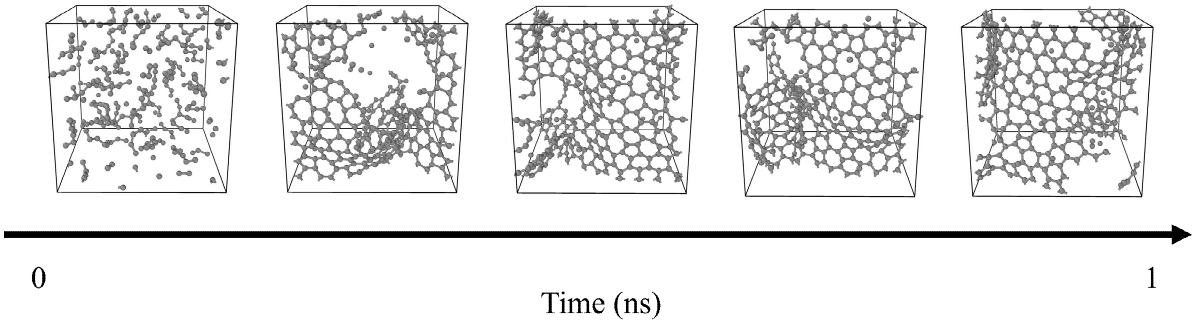

Fig.1. Evolution of carbon structure over a 1ns time period in response to a laser pulse (Only carbon atoms are shown).