Development of Biodegradable Membranes Functionalized with Reduced Graphene Oxide Reinforcement for Microbial Fuel Cell Applications

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Microbial fuel cells (MFCs) are bio-electrochemical systems that can generate energy from organic waste [1]. MFCs are among the promising technologies for environmentally friendly and renewable energy production. In recent years, intensive research has been conducted in various areas, including the improvement of electrode materials, optimization of microbial consortia, selection of suitable substrates, and development of low-cost proton exchange membranes, to enhance the performance and economic viability of MFC systems.

Proton exchange membranes (PEMs), one of the critical components in these systems, directly affect system performance in terms of ion conduction and gas separation between compartments. While commercial PEMs offer high performance, they are disadvantageous in terms of sustainability due to their environmentally persistent nature and high cost. In this study, environmentally friendly composite membranes were developed by reinforcing reduced graphene oxide (rGO) into poly(3-hydroxybutyrate-co-4-hydroxybutyrate) (P34HB) matrix, a biodegradable polyester, and their use in microbial fuel cells was evaluated.

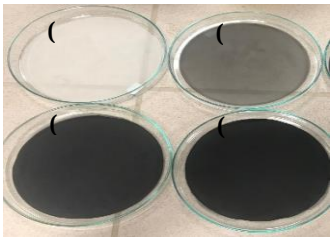

Figure 1. Pure P34HB (a) and P34HB reinforced with different ratios of rGO: 1wt.% rGO (b); 3wt.% rGO (c); 5wt.% rGO (d)

P34HB/rGO composite membranes were prepared by the solution casting method. Solutions containing pure P34HB and rGO at ratios of 1, 3, and 5% were dissolved in 95/5% chloroform/DMF solvent and homogenized in a magnetic stirrer, then poured into glass petri dishes and dried at room temperature. The resulting films were then placed in an oven at 60 °C to remove solvent residues. Three replicates were performed for each additive ratio, and membranes with homogeneous surfaces and a thickness of approximately 130 ± 5 µm were obtained. Figure 1 shows images of pure P34HB and its composites with rGO. The fabricated membranes were named according to the rGO ratio (e.g., 1 rGO; the membrane with 1wt.% additive).

The fabricated membranes were characterised in detail in terms of thermal properties, mechanical strength, hydrophilic properties, electrochemical performance, and fuel cell performance.

Proton conductivity measurements were performed using electrochemical impedance spectroscopy (EIS) at 100% relative humidity and the temperature range of 30-80 °C. The oxygen diffusion coefficient was calculated by measuring dissolved oxygen levels in the dual-chamber microbial fuel cell assemblies.

This study demonstrates that membranes developed with rGO reinforcement in biodegradable P34HB matrix can offer a sustainable and effective proton exchange membrane alternative in microbial fuel cell systems with their high proton conductivity, low oxygen permeability, and environmentally friendly structure. In addition, these membranes are considered to have a wide potential for use in energy generation applications from decentralized wastewater sources.

Acknowledgment

This study was supported by the Scientific and Technological Research Council of Turkey (TUBITAK) (Project 124C192-TUBITAK 2218).

References

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