Preparation of a Three-Dimensional Reduced Graphene Oxide Film by Using the Langmuir–Blodgett Method

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ABSTRACT: The Langmuir–Blodgett method has always been traditionally utilized in the deposition of two-dimensional structures. In this work, however, we employed the method to deposit three-dimensional reduced graphene oxide layers using an unconventional protocol for the first time. This was achieved by carrying out the dipping process after the collapse pressure or breaking point, which results in the formation of a highly porous three-dimensional surface topography. By varying the number of deposition layers, the porosity could be optimized from nanometer to micrometer dimensions. Employed as bioelectrodes, these three-dimensional reduced graphene oxide layers may allow improved adhesion and biocompatibility compared to the conventional two-dimensional surfaces. A larger number of pores also improves the mass transport of materials and therefore increases the charge-sustaining capacity and sensitivity. This could ultimately improve the performance of biofuel cells and other electrode-based systems.

1. INTRODUCTION

Graphene represents a new class of materials composed of a periodic array of carbon atoms densely packed in a very regular honeycomb two-dimensional (2D) structure first prepared by Brodie in 1859. However, the very first theoretical description of graphene was only reported in 2003. One year later, Geim and Novoselov successfully synthesized the 2D structure of graphene using a simple technique. Since then, graphene has been widely used due to its chemical and physical properties that come from its highly hybridized sp² bonds, resulting in strong mechanical resistance as well as heat and electrical properties and high optical transmittance. Graphene also finds use in nonvolatile memory application, infrared optoelectronic sensors, thin film transistors, transparent solar cells, and biosensors.

The mechanical properties and biocompatibility of reduced graphene oxide (rGO)-reinforced nanofiber mats have been identified to be an important feature for the development of electrodes for biosensors and biofuel cells. This particular advantage is related to the intrinsic three-dimensional (3D) structure of graphene that may play a role in cellular interactions. The low surface energy and hydrophobicity play important roles in the interaction of biocatalysts with the electrode surface in the formation of the biofilm. Also, substrate topography such as pore size and surface roughness significantly influence cell behavior in the long run. Control of pore size that can range from the micrometer to nanometer scale may prove vital for cell attachment. This could also be beneficial for biological microenvironments, which is very important for the health of cells in the biofilm. Many reports and methods for fabricating thin films of graphene oxide or rGO such as spin coating, dip coating, vacuum filtration, liquid–liquid assembly, and a chemical vapor deposition technique have been proposed. However, most procedures involve complicated and costly steps such as chemical processes, expensive and hazardous gases, high pressure, long deposition times, and catalysts that limit its use at the commercial level.

The Langmuir–Blodgett (LB) assembly technique is well-known as a powerful tool to assemble homogeneous and uniform 2D thin films. It presents the possibility of developing films of both organic and inorganic compounds with the desired structures and functionality on the molecular scale. It is also considered to be one of the most promising techniques for preparing nanometer-order thin films as it enables effective control of the monolayer thickness, large-area homogeneous deposition, and the possibility to deposit multilayers with varying layer composition. A typical surface-pressure isotherm profile for any material prepared by this method usually consists of three distinct regions ranging from gaseous, liquid, and solid states, which correlate to the molecular arrangement on top of the liquid subphase.

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