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Review Article

Nanosensors Based on Lipid Films

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Abstract

This review provides information and details about the construction of nanosensors based on lipid membranes that can be utilized to monitor toxicants in food, environmental pollutants, and analytes of clinical interest. Nanosensors based on lipid films have been used to rapidly detect a wide range of these analytes, and can offer several advantages towards analytical instrumentation such as rapid response times, high sensitivity and selectivity, portability for in the field uses and small size. A description of the preparation of these devices for the rapid detection of toxicants in foods, environmental pollutants, and analytes of clinical interest is provided in this review.

INTRODUCTION

A nanobiosensor is an analytical device having a small size that detects and analyses a sample and provides its chemical concentration and composition. A chemical nanosensor is composed of two main parts: a biological element that chemically detects the unknown compound and a physical transducer such as electrical, optical, or piezoelectric. The advantages of nanosensors compared to classical analytical devices, such as liquid and gas chromatography, are plenty and include faster response times, higher throughput of samples, smaller size, and portability for field measurements. It is also cheaper and personnel do not require training for its use.

Chemosensors are similar to biosensors but are composed of a synthetically prepared molecule instead of a biological element. They recognize small molecules or metal ions by binding to them. The synthesis, design, and applications of chemosensors are of special interest for the detection of analytes.

Nanobiosensors are based on the merging of nanotechnology with biosensors. Such materials include graphene, carbon nanotubes, and nanowires. Metal-based nanoparticles are also excellent hosts for the construction of electrical and optical devices that can be applied to detect nucleic acid sequences. Various nanomaterials have been explored and their properties were analyzed for possible applications in biosensors. Nanobiosensor technology research has prompted the construction of an increasing number of novel devices.

This paper addresses the fabrication of nanosensing devices composed of lipid membranes that have been used and applied to rapidly detect toxic substances in food, environmental pollutants, and analytes of clinical interest. Figure 1 provides a schematic of a lipid-based biosensor on a graphene electrode that has been used for the potentiometric detection of urea.

METHODS FOR CONSTRUCTION OF NANOSENSORS BASED ON LIPID MEMBRANES

During the last 10 years, the preparation of stabilized lipid membranes based devices that cannot collapse due to an electrical or mechanical shock and are stabilized in air has been reported in the literature. Below we report the techniques for the construction of nanosensors that are based on lipid films with advantages such as fast response times, nanosize high selectivity and sensitivity and are stabilized in air.

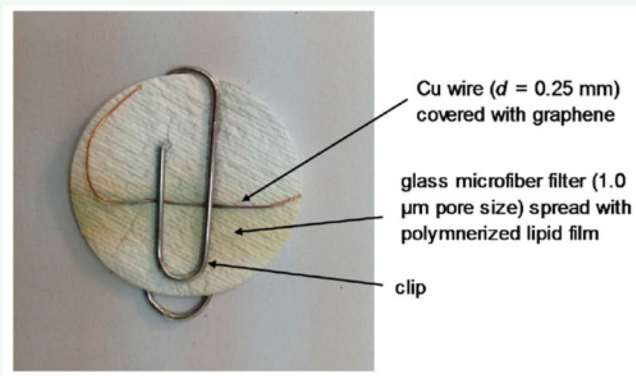

Figure 1 Schematic of a lipid membrane-based biosensor on a graphene electrode. This device was used for the potentiometric determination of urea. Reprinted with permission from Nikoleli et al. [1].

Metal supported lipid layers

Tien and Salam on have reported in the literarure a system for the construction of stabilized bilayer lipid membrane (sBLM) at the end of Teflon coated metallic wire which was freshly cut [2]. This technique was relied on the interaction of an amphiphatic lipid molecule with a nascent metallic surface. This Teflon-coated stainless steel metal wire had a diameter of 0.1-0.5mm and itys end was dipped in a lipid solution which was prepared with chloroform as a solvent and its end was cut with a guillotine which was immersed, in the solvent. An immersion of the wire in a 0.1 M KCl followed, so that the lipid membrane becomes bilayer.

sBLMs have been fully characterized [2-5]. The diameter and composition of the wires have an important impact on the time of the bilayer formation [6,7]. The diameter of the silver wire should be between 0.5 to 1.0mm and the solvent used should be hexane and not decane because the latter solvent could be retained in the structure of the bilayer and provide irreproducible results.

Stabilized lipid films formed on a glass fiber filter

The preparation of stabilized in electrolyte lipid membranes was reported by Nikolelis group and these membranes were constructed on GF/F glass microfiber (0.9cm in diameter and 0.7μm nominal pore size) filters [19,20]. The lipids used were previously described. No receptor was used in these detections. The stable in electrolyte solution lipid films were prepared as follows [8,9]: 10μL of a lipid solution in hexane was positioned at the electrolyte surface in the cylindrical cell and the level of the electrolyte was brought below the hole of the partition and then raised again within a few seconds. Once the lipid membranes were formed, the current was at the pA and the injection of gramicidin D shows that these membranes were bimolecular.

Polymer-supported bilayer lipid membranes

The use of a polymer-supported lipid film has been used to stabilize lipid membrane based devices in the air for periods of over one month [10].

The preparation of stabilized in air lipid membranes was reported by Nikolelis group [10-12]. The lipids used were previously described. No receptor was used in these detections. The polymer stable in air lipid membranes were constructed as previously has been described [10-12], and is as follows: 0.07mL of methacrylic acid, 0.8mL of ethylene glycol dimethacrylate, 8 mg of 2,2'-azobis-(2-methylpropionitrile) and 1.0mL of acetonitrile are added in 0.8 mL of a suspension that contained 4% w/v DPPC in a solvent of n-hexane [which evaporates and the lipid membranes are "solvent-free"). Then nitrogen is allowed to pass through this mixture and a sonication follows. A volume ot 0.15mL of this suspension is placed on the microfilter (Whatman, UK, GF/F microfiber glass disk haning diameter of 0.9cm and pore size of 0.7 μm) and the filters are irradiated with a UV deuterium lamp. The experimental instrumentation was the same as in Figure 1. These films were stabilized and could be stored ln air for at least 1 month.

Polymeric lipid membranes supported on graphene microelectrodes

Our group has prepared an electrode that was composed from a lipid film on a copper wire that contained graphene nanosheets [1]. These nanobiosensors were utilized for the fast monitoring of food and environmental toxicants [1], such as urea using the enzyme urease [1], cholera toxin (using its receptor) [13], carbofuran, and naphthalenic acid. The lipid used in these detections was phosphatidylcholine.

The construction of graphene microelectrodes has been reported in the literature [1]. N-methyl-pyrrolidone (NMP) was mildly sonicated for 180 hours and centrifuged at 700 rpm for 2h which provides a homogeneous dispersion (~0.4mg/mL). This dispersion was poured onto a copper wire (0.25mm in diameter) which was placed on a glass microfiber filter and the solvent was evaporated. The copper acted as the connection for the electrochemical experiments.

The method of the construction of the lipid film nanobiosensors was reported in the literature [1]. The "receptor" molecules were inserted in these devices prior to polymerization by injecting 15μL of the "receptor" suspension on the polymerization mixture. The filter-supported polymeric BLMs were finally mounted onto the copper wire that contained the graphene nanosheets.

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