Screen Printed Electrodes a Tool for Advances in Sensors' Field for Monitoring Analytes of Environmental Relevance

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ABSTRACT

Environmental pollutants such as heavy metals, dissolved oxygen, pesticides etc. need to be monitored as when their limits exceed a certain value they pose a threat for the environment. Thus there is a need to measure all these analytes within a single drop of drinking water, upon economical and disposable electrodes. In view of this requirement sensors persist to make significant impact in daily life. There has been a strong demand for producing highly sensitive, selective, responsive, and cost effective sensors. As a result, research emphasis is on developing new sensing materials and technologies. In this context, the use of nanomaterials for the construction of sensor devices constitutes one of the most exciting approaches. The extremely promising prospects of these devices accrue from the unique properties of nanomaterials which include extremely high surface to volume ratio, mechanical strength, toughness and electrical or thermal conductivity. Different nanomaterials e.g. carbon nanotubes, nanoparticles, graphene etc. are employed for the construction of sensors that allows the achievement of enhanced analytical performance with respect to other designs. With the advent of nanotechnology, research is on track to create miniaturized sensors. Miniaturized sensors can lead to lower power consumption, reduced weight, low cost and can be used for immediate monitoring in real samples on the field. In this context, sensors prepared using screen printed electrodes (SPEs) using nanocomposites offer advantages due to their scales of economy, ease of fabrication, facile modification and disposable nature. To fulfil this need screen printed electrodes can be readily designed, fabricated and tested for the detection of environmentally important analytes in field.

Keywords: SPEs, nanomaterials, graphene, biosensor, environment.

1. INTRODUCTION

Sensors are devices in which the recognition system utilizes a chemical mechanism. Several electrodes are used in the fabrication of electrochemical sensor i.e. platinum, gold, glassy carbon electrode, carbon based electrode, chemically modified electrodes as recognition part but, screen printed electrode is now in interest. From the technological point of view, various patterns have

appeared in the last few decades, using various deposition techniques, such as spraying, screen printing, blade coating, sedimentation, and electrospraying where mediators and other organic molecules are entrapped in a (bio) composite electrode or a carbon paste electrode. Screen printed electrodes (SPEs) are categorized under carbon electrodes for analysis of various environmental samples and other analytes. Generally, nanomaterials, several redox mediators as well as enzymes are deposited on the surface of the electrode for modification, called chemically modified electrodes. This technique solves the immobilization problem and the leaching of molecule is negligible. Commercially, most enzyme electrodes are produced by using thick film technology and these arrangements are much more acquiescent to screen printing technology than the modification of the surface. Moreover, screen printed materials are a possible precursor and the most technologically viable alternative for the detailed study of the stability of the mediator also, for the determination of the kinetics of catalyzed reactions and the heterogeneous electron transfer surface immobilized species [1].

1.1.What is SPEs?

Printed electrodes, named SPEs, are miniaturized devices that are manufactured by printing manifold successive layers of different inks on a ceramic or plastic solid support, after a well established design, in accordance to the performances and the analysis in which they will be used [2]. It includes reference electrode, auxiliary electrode and working electrode as shown in Fig. 1.

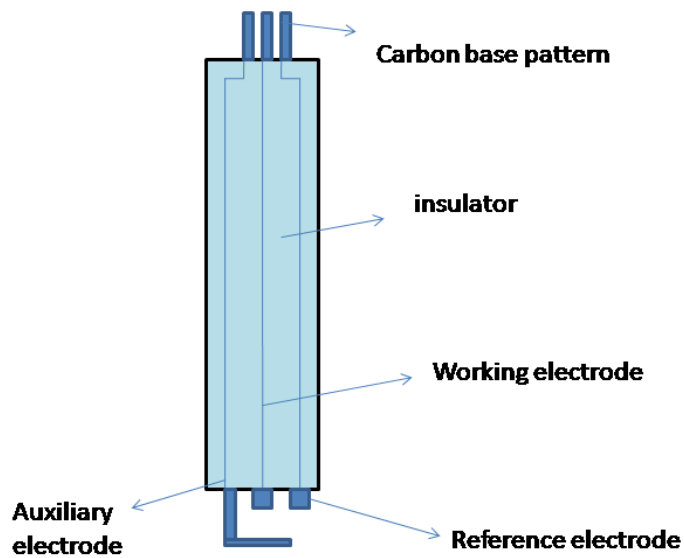

Fig 1. Screen printed electrode

1.2. Significance of SPEs:

Screen-printed electrodes (SPEs) have a number of advantages versus conventional electrodes as they are suitable for working with a very less volumes and for decentralized assays and allow the development of mass produced portable, precise and reproducible sensors [3]. It also offers low cost, disposable, miniaturized form and suitable for large production. Further, the application of arrays of screen-printed electrode offers the advantages of quickness and the possibility to make the calibration and the analysis of several unknown sample simultaneously [4].

2. APPLICATION IN SENSORS

Various screen printed electrodes are in interest for the sensing of environmental samples. To enhance the electron transfer of bare SPEs, it is modified with certain materials. Now a days, screen printed electrode is modified with various redox mediators, nanomaterials, carbon nanotubes, nanoparticles, as recognition part of the sensor device with increased selectivity, high sensitivity, large linear range, and low limits of detection. The phenothiazine derivative was immobilized on screen-printed electrode through electropolymerization by Gao et al. [5]. Herschkovitz et al, reported a novel sensor by coupling FALDH/Os(bpy)2-poly(vinylpyridine) modified screen printed electrode with a flow-injection system, which can detect 30 μg /L formaldehyde in aqueous solution. The sensor is selective, stable, inexpensive as well as simple to manufacture and operate [6]. A variety of other biosensors have been constructed by the combination of Os(bpy)2-poly (vinylpyridine) modified screen-printed electrode with different dehydrogenases. Kataky et al. developed a disposable screen-printed biosensor for monitoring formaldehyde. Amperometric glucose-6-phosphate biosensor was fabricated by immobilizing p-hydroxybenzoate hydroxylase (HBH) and G6PDH onto screen-printed electrode [7,8]. Surfactants are also used to modify the SPEs. Sato et al. developed a SWCNT- modified screen printed electrode using a ferrocene modified surfactant for the glucose detection [9]. Thiol surfactant assembled on gold nanoparticles ion exchange for screen printed electrode was fabricated by Ali et al. for the potentiometric determination of Ce(III) in environmental polluted samples [10]

Carbon nanotubes (CNTs) are most popular structures to enhance the sensitivity of SPEs [11]. Lin et al, reported a disposable CNT-based biosensor for OPs using a binary AChE and ChO/CNT-modified screen printed carbon electrode [12]. Fabregas and co-workers [13] proposed the immobilization of multiwalled carbon nanotubes (MWCNTs) by L-b-L self-assembling of polyelectrolytes on a screen printed electrode for the detection of ascorbic acid at potentials 350 mV less positive than at the bare electrode. The efficiency of the new sensor is improved from the combination of the conducting properties of MWCNTs with the biocompatibility and flexibility of the polysulfone polymer and screen printed assembly [14]. Trojanowicz et al. prepared pesticide biosensor by the physical adsorption of organophosphorus hydrolase on the surface of MWCNT

modified working graphite ink electrode of the three electrode screen-printed sensing stripe [15]. A screen printed carbon electrode modified with polyacrylic acid (PAA)-coated MWCNTs has been prepared for the simultaneous determination of norepinephrine, uric acid, and ascorbic acid[16]. Selective detection of dopamine in the presence of ascorbic acid using carbon nanotube modified screen-printed electrodes has been done by our group [17].

Various nanoparticles are also used to improve the sensitivity of SPEs e.g. Gold nanostructures [18], Palladium Nanoparticles [19], Nickel oxide nanoparticles [20], Platinum nanoparticles [21]. Kong et al. [22] prepared a paper disk equipped with graphene/polyaniline/Au nanoparticles/ glucose oxidase biocomposite modified screen-printed electrode toward whole blood glucose determination. Wang et al reported electrochemical determination of lead and cadmium in rice by a disposable bismuth/electrochemically reduced graphene/ionic liquid composite modified screen-printed electrode [23]. Noyrod developed the simultaneous determination of isoproturon and carbendazim pesticides by single drop analysis using a graphene-based electrochemical sensor [24]. A novel electrochemical sensing platform based on electrochemically reduced graphene oxide film modified screen-printed electrode was developed for the detection of heavy metals in milk [25]. Our group is actively involved in preparing screen printed electrode using CNTs and nanoparticles. Recently we have prepared screen printed electrode using nanostructured composite of anthraquinone moiety/cysteamine functionalized-gold nanoparticle for the detection of dissolved oxygen [26].

3. CONCLUDING REMARKS

In this chapter, we discussed the various format of screen printed electrodes. Modifications with nanomaterials are done to enhance the sensitivity and selectivity of the SPEs. Using these modified SPEs, the performance and stability of sensors can be improved considerably. We believe that this area will be the thrust area in coming years for analyzing analytes of environmental and biological relevance.

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