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Conducting polyaniline nanowire electrode junction

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In this paper, a synthesis of conducting polyaniline nanowires electrode junction (CPNEJ) has been reported. Conducting polyaniline nanowires electrode junction on Si/SiO_2 substrate (having 3 μm gap between two gold microelectrodes) is prepared. Polyaniline nanowires with diameter (ca. 140 nm to 160 nm) were synthesized by one step electrochemical polymerization using galvanostatic (constant current) technique to bridge this gap. The surface morphology of CPNEJ was studied by scanning electron microscope (SEM). The synthesized CPNEJ is an excellent platform for biosensor applications.

Keywords: Conducting polyaniline nanowires; microelectrode junction; polymerization; galvanostatic technique; electrochemical technique.

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1. Introduction

Conducting nanostructured materials, including conducting polymer nanowires, carbon nanotubes, metal- and/or oxide-based nanowires, have attracted much attention across scientific and engineering disciplines.[1–10] Conventional bulk materials are being replaced by these materials in micro and nanoelectronics devices.[11,12] Although these materials are being used in various micro and nanoelectronics devices and sensors, it remains a challenge to discover efficient, scalable, approaches for incorporating these nanomaterials into lithographically patterned electrode junctions.

Conducting polymer nanostructured materials provides various promising features viz.: (i) material flexibilities, (ii) easy processing, (iii) high surface areas, etc. Therefore, these materials are being extensively used as nanowires in resistive sensors.[1,2,10–12]

Various methods are in practice for the synthesis of conducting polymers in nanostructures form. These methods include (i) template directed electrochemical techniques,[13] (ii) electrospinning,[14] etc. Although these methods have been successfully used for the synthesis of conducting polymer nanostructure, there are certain limitations in terms of device yields, potential for further miniaturization, scalability, and fabrication costs that prohibit sequential developments of these types of resistive sensors.

In the present paper, conducting polyaniline nanowires electrode junction (CPNEJ) has been successfully fabricated, which is having a gap of 3 μm between two gold microelectrodes. Polyaniline nanowires with diameter (ca. 140 nm to 160 nm) were synthesized by one step electrochemical polymerization using galvanostatic (constant current) technique to bridge this gap. The conducting polyaniline nanowires electrode junction was characterized by scanning electron microscopy (SEM) to confirm the nanostructure.

2. Experimental Method

2.1. *Chemicals and reagents*

The aniline monomer (Sigma–Aldrich) was distilled twice before use and it was stored in the refrigerator to prevent UV degradation, and perchloric acid ($HClO_4$) was used as a dopant. An aqueous solution of aniline (0.5 M) and $HClO_4$ (1 M) was prepared in Milli-Q water. This aqueous solution was stirred for about 1 h and it was purged by nitrogen gas for almost 1 h.

2.2. *Electrode preparation and fabrication of conducting polyaniline nanowires electrode junction*

Figure 1 shows the electrode patterns employed for the electrochemical production of the CPNEJs. An array of 16 electrodes of thickness: ca. 100 μm at the “fingertips”

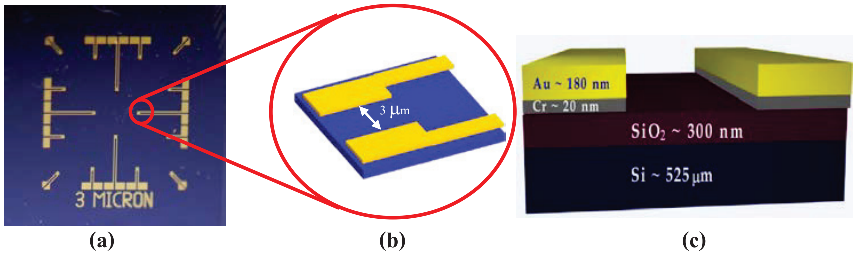

Fig. 1. Schematic of the gold electrode patterns. (a) Optical image of array of 16 pair of gold microelectrode; (b) magnified image of fingertip of pair of gold microelectrode and (c) schematic of cross-section of each microelectrode.

of electrode near junction of on 500 nm of SiO_2 layer by standard photolithographic techniques and using electron beam deposition on a silicon (100) substrate.

A gap of 3 μm is located between the "fingertips" of each pair of electrodes. Two sets of gold electrodes were connected to copper tape individually for connection to CHI660C electrochemical workstation. Electrochemical synthesis of the CPNEJs using an aqueous solution containing 0.5 M aniline and 1.0 M $HClO_4$ was carried out. A standard three-port electrochemical configuration composed of working, counter, and reference electrodes were used. Both set of junction electrodes were used as a working electrode, Pt foil as counter electrode, and an Ag/AgCl as reference electrode. Polyaniline nanowires were synthesized to bridge 3 μm gap between two junction electrodes using one step electrochemical deposition methods.

3. Results and Discussion

3.1. *Fabrication of conducting polyaniline nanowires electrode junction*

An excellent network of polyaniline nanowires across the electrode junction to bridge 3 μm using one step electrochemical depositions (constant current) method was achieved. The potentiogram recorded during synthesis of polyaniline nanowires is shown in Fig. 2. A constant current density (0.04 mA/cm^2) was applied for ca. 30 min to grow polyaniline nanowires to bridge a gap 3 μm between two gold working junction electrodes. During this time, the effective potential on the working electrodes remains at ca. 0.75 V (versus Ag/AgCl reference electrode). This is in contrast with the use of a conventional one step electrodeposition process with relatively high applied current density which could results only in the formation homogeneous polyaniline thin film on the electrode surface which always lack nanoscale features. The SEM image of CPNEJ (Fig. 3) indicates that nanowires are composed of numerous intercrossing polyaniline nanowires that have diameters ranging from 140 nm to 160 nm. This approach of fabrication of CPNEJ is highly reproducible. In fact, 16 CPNEJs were successfully fabricated from 16 attempts by using similar one-step (constant current) electrodeposition method described above.

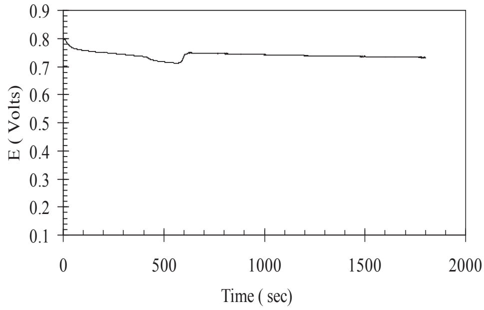

Fig. 2. Potentiogram for one step electrodeposition of polyaniline nanowires on microfabricated electrode junction.

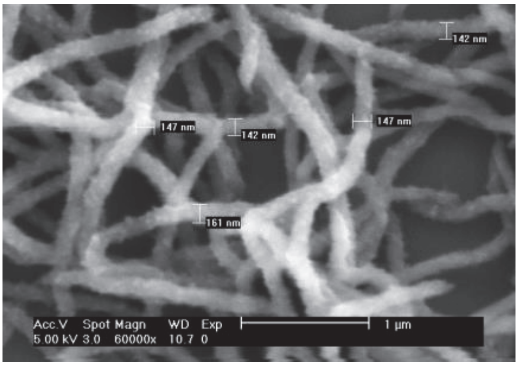

Fig. 3. SEM image of polyaniline nanowires grown on microfabricated electrode junction (CPNEJ) using one step electrodeposition method.

4. Conclusion

This study has demonstrated the feasibility of fabrication of a conducting polyaniline nanowires electrode junction (CPNEJ) by one step galvanostatic technique. Since conducting polyaniline has excellent anti-interference ability, and superior transducing ability. This approach (fabrication of a conducting polyaniline nanowires electrode junction (CPNEJ)) has provided excellent platform for biosensor applications.

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