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Amperometric Glucose Sensing using Simple Fabrication of ZnO Nanostructure Based Thin Film

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Abstract:
A simple fabrication process based on ZnO nanopowder and ammonia solution was used to make ZnO nanostructure based thin film for glucose sensor application. ZnO Film consists of nanoplates and sphere. Raman and FESEM was carried out to characterize the materials. Amperometric studies were performed to determine the glucose sensitivity and it is found to be 27.29 $\mu AmM^{-1}cm^{-2}$.

Key words: ZnO nanostructure, Simple fabrication, Glucose sensor, Amperometric studies.

Introduction

Diabetes is the major health problem in globally. The reason for diabetes is the excess amount of glucose available in the blood and continuous monitoring of glucose level in the blood is necessary for the diabetic patient. Continuous monitoring of blood glucose requires a cheap, cost effective, rapidly and reliable system for glucose detection. Nanomaterials are useful for making small reliable and cost effective glucose detection. Different nanomaterials like ZnO, CuO, graphene etc. are used for glucose detection. Among these ZnO, a wide band gap semiconductor of 3.3eV, is used mostly for the glucose detection. Deposition and synthesis of ZnO can be done in various ways like sputtering, thermal evaporation, electrochemical deposition, spray pyrolysis, hydrothermal or chemical precipitation etc. [1]. But these system or methods of growing/synthesis is either costly or output is low. Here we have used a simple technique to grow ZnO nanostructure based thin film on the silver coated PET substrate using ZnO nanomaterials and ammonia solution for glucose detection. This process is simple, cost effective and large scale production is possible and it removes the other complex system required to grow ZnO thin film.

Experimental Details

First Zinc oxide nanoparticles were synthesized from simple precipitation method by using zinc acetate and NaOH solution. Then certain amount of ZnO nanoparticles were mixed in continuous stirred ammonia solution at 100 ^{0}C - 110 ^{0}C. Finally silver coated PET substrate were immersed in the solution and kept it for 30-45 minutes to form a ZnO thin film on the substrate. After deposition of ZnO thin film, substrates were cleaned with DI water for several times and dried at 120 ^{0}C for 3 hrs. in a hot air oven.

For glucose sensing, 20mg/ml of Glucose oxidase (GOx) solution was prepared in 0.01M PBS buffer solution of pH 7.4. Then 10µl of the GOx solution was dropped onto ZnO substrate and kept it for 1 hr. to immobilize on it. 5µl of nafion was coated on it and dried in air for 1 hr. After that Gox nafion coated ZnO substrate was washed in the PBS solution to remove the excess non immobilized GOx and kept in a desiccator at 4 ^{0}C in the refrigerator until use.

CHI660C electrochemical workstation was used in three electrode system (Pt as counter electrode, SCE as a reference electrode and Ag coated PET substrate with ZnO-GOx-Nafion as working electrode) to use for glucose sensing at ph7.4 buffer solution.

Results and Discussion

Scanning Electron Microscope, Raman were carried to characterize the ZnO thin film. The Raman studies shows that the ZnO film has both non polar E_2^{low} and E_2^{high} peaks are prominent at 99 cm^{-1} and 440 cm^{-1}. Figure 2 shows SEM micrograph of ZnO nanostructure based thin film on the substrate. It consists of ZnO nanoplates and spheres.

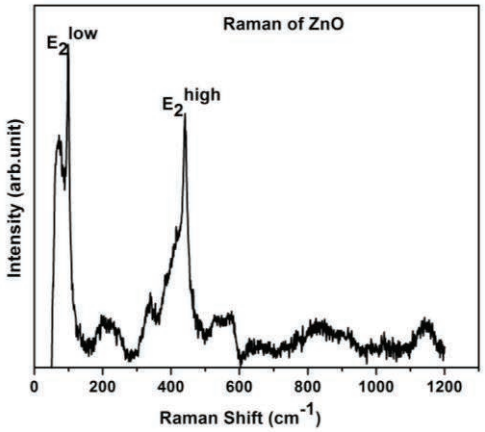

Fig. 1. Raman spectra of ZnO film

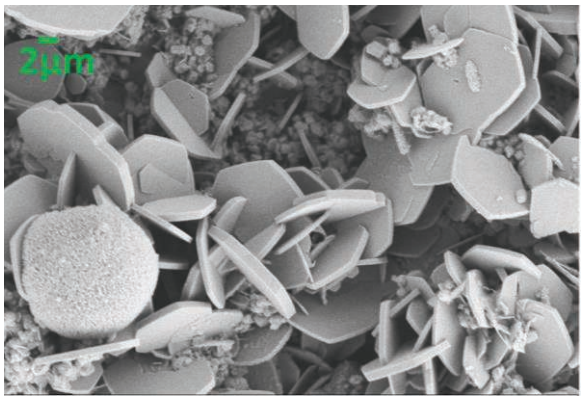

Fig. 1. FESEM images of ZnO film

Figure 3 shows that amperometric response of ZnO-GOD-nafion at an applied bias of 0.65V for continuous stirred PBS solution while adding glucose oxidase solution at certain interval of time for 0.2mM to 3mM concentration.

Glucose oxidase in the presence of glucose produces H_2O_2 which is oxidized when potential is applied at the SCE and it generates elecron. The equation is shown below.

Glucose+GOx (oxd) -----> gluconolactone+ GOx (R) …….. (1)

GOx (R)+O2 ---> GOx+H2O2 …….(2)

$H2O2 > O_2 + 2H^+ + 2e^-$ ……(3)

The sensitivity of the device is found to be 27.29 $\mu AmM^{-1}cm^{-2}$ which is higher than the some of the previous work [1-3].

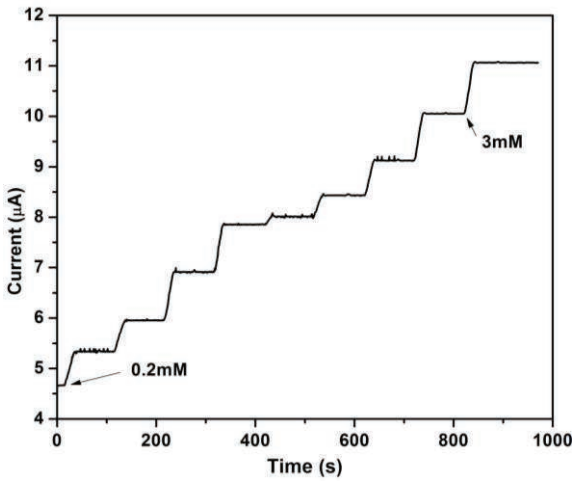

Fig. 3. Amperometric response of the ZnO-GOx-Nafion based glucose sensor.

Conclusions

We have presented a simple, low cost easy method with feasibility of large scale production to grow ZnO nanostructure based thin film by using ZnO nanoparticles and ammonia solution for glucose biosensor application. Amperometric studies shows that the film can detect as low as 0.2mm glucose soltion and the sensitivity is found to be 27.29 $\mu AmM^{-1}cm^{-2}$.

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