Nanoionics-based memristor device for albumin detection

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Background

Sensors that can detect bio-molecules have been of great interest as conventional methods pertinent to their detection suffer from high throughput, sensitivity, dynamic range, detection limit, etc. Hence, there is a quest for the development of improved analytical techniques that would allow rapid, trustworthy, cost-effective biomolecule detection. In this regard, nanoelectronic biosensors are promising alternatives, which offer label-free, high-sensitive, and real-time detection of biomolecules that are important for biomedical applications. Despite all the above, these devices can be prepared as miniaturized devices that may be helpful for the development of lab-on-chip devices.

Albumin is the most abundant protein in vertebrate blood and helps in transporting protein. Bovine serum albumin (BSA) is a widely used albumin in the research field as a model protein due to its structural similarities with human serum albumin (HSA). Several analytical methods are used for BSA detection such as spectroscopy, immunoassays, and chromatography; but these methods are cumbersome and labor-intensive.

Objective

It is of interest to detect bovine serum albumin through an electrical method using a nanoionics-based memristor device.

A memristor device is one which changes its resistance state with an externally applied voltage. Indeed, there are several memristor devices such as Tunnel magnetic resistance (TMR), Giant magnetoresistance (GMR) phase change memory (PCM), resistive random access memory (RRAM), etc. Among them, RRAM-based memristors are simple and one can fabricate easily. Here, the resistance state can be switched between a high resistance state (HRS) to a low resistance state (LRS) depending on the polarity of the applied voltage bias. The physics of such devices can be understood by the formation and rupturing of conducting filaments formed due to oxygen defects in the device.

Methodology and Results

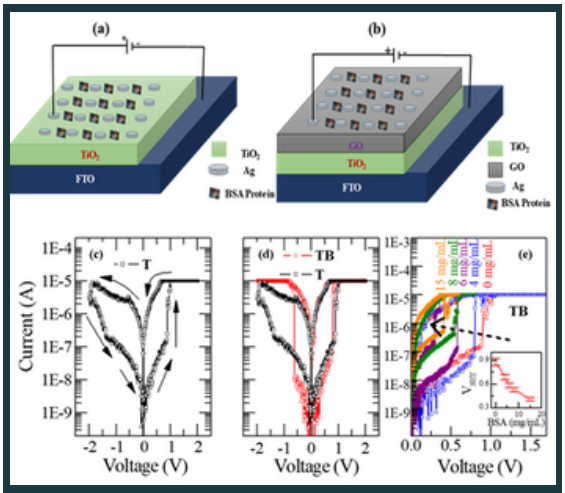

Fig. 1: (a) & (b) Schematic of the devices Ag/ BSA/TiO2/FTO (TB) & Ag/BSA/GO/TiO2/FTO (TGB) respectively. (c – d) I – V characteristics, which demonstrates that these devices are sensitive to the detection of BSA.

The present device is fabricated using titanium dioxide (TiO2) as an active material, to which BSA protein was added (Fig. 1a). In addition, we also tried to prepare Ag/BSA/GO/TiO2/FTO (TGB) (Fig. 1b) device for BSA detection with better sensitivity. For all the devices silver (Ag) and fluorine-doped tin oxide (FTO) were used as top and bottom electrodes respectively. Fig. 1c depicts typical I – V characteristics of an Ag/ TiO2/FTO-based bipolar RRAM device, Upon adding BSA to Ag/ TiO2/FTO device (Fig. 1d), as depicted there is a variation in switching voltage.

Further, variation of switching voltage is evidenced by increasing the concentration of BSA (from 0 – 15 mg/mL), (Fig. 1e). Despite the above, a graphene oxide (GO) layer was inserted between TiO2 and BSA to enhance the sensitivity of the detection for the lower concentrations of BSA (4 mg/mL) (Ag/BSA/GO/TiO2/FTO (TGB)). Graphene oxide contains oxygen functional groups on its surface, which enhances the conductivity properties, thereby increasing the sensitivity of the device to detect bovine serum albumin. The devices were also tested for their durability, which could be cycled 650 times.

Apart from the above, the constituents of the device (TiO2, GO and BSA) are environmentally friendly, economic, and bio-compatible. This is a proof of concept and extensive work is being carried out to make a portable device to render as lab-on-chip for BSA detection. Therefore, this kind of new concept will try to put a step forward in the development of efficient tools for protein detection.

Reference

1. Dwipak Prasad Sahu & S. Narayana Jammalamadaka, Detection of bovine serum albumin using hybrid TiO2 + graphene oxide based Bio – resistive random access memory device, Scientific reports 9, 16141 (2019).

2. S. Narayana Jammalamadaka and Dwipak Prasad Sahu Patent Application No: 201941034084; Filing Date: August 23, 2019 (published by Indian Patent Office in the Official Journal No. 09/2021).

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