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A Brief Review on Memristive Biosensors

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Abstract

In this paper a brief review is presented on how memristor, the fourth passive circuit element with the properties of resistor(R), inductor (L), and capacitor (C) together can be used in biosensing and medical science. The first concept of memristor as the fourth passive circuit element was introduced by Lion Chua in 1971[1] and the first practical memristor was developed at HP labs in 2008 by Dmitri B Strukov [2] and his group. Due to its time dependent resistive property, memristor is investigated widely as a memory element and switch. This nonlinear electrical property is also useful for detection of diseases and they can be used as biosensors for biomedical applications. The data for this paper is collected from internet and from papers of other researchers.

Keywords: Memristor; Biosensor; Biomedical application; Resistor; Inductor; Capacitor; Vascular endothelial growth factor; Prostate specific antigen

Introduction

Memristor is a passive two terminal nonlinear electrical component that relates the electric charge to the magnetic flux and was first introduced by Lion Chua [1] in 1971. However after 35 years, first practical implementation of memristor was reported by Strukov et al. [2] at HP labs in 2008. Kosta et al. [3] in 2011 proposed a physical model of memristor from human blood. The human body tissues like blood, bone, muscle, skin, fat, etc. are mostly conducting in nature. The conductivity is due to the dynamic mobility of ions and its mass/weight is responsible for the change in velocity. The ion profile of a normal healthy man is different from a man with illness. The research work of Kosta et al. focuses on supply of ions to the body of a ill man with the help of electrical components which will be made of human blood. They found that, blood plasma resembling electrolyte can be used to produce liquid memristor.

Sacchetto et al. [4] reported use of memristive property of antibody functionalized schottky-barrier Silicon nanowires for biosensing. From their observations it is noticed that the Ids-Vds hysteresis characteristics curve narrows as antigen is injected in the system. Based on this work, Sandro Carrara [5] and his group proposed a new detection method based on silicon nanowire memristor. The silicon nanowires were fabricated using lithographic process that shows schottky barrier contacts. These nanowires are then used for bio-molecular detection of dried samples. The as-fabricated memristive nanowire devices were functionalized using rabbit antibody so that they can sense antigens. The detection sensitivity was found in the range of 37±1mV/fM and 3.4±1.4fM respectively. The said work was claimed to be the first to use memristive behavior of nanowires as biosensors for dried biological films.

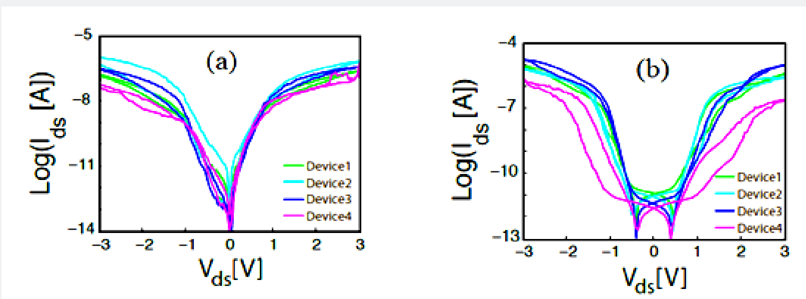

Figure 1: (a) Pinched hystersis loop with bare SiNWs, (b) Voltage gap appearance in NWs modified with anti VEGF. Puppo et al. [6].

In 2014, Francesca puppo [6] and his group proposed a novel new technique for molecular sensing based on memristor functionalized with bio-molecular thin films. The hysteresis loop of the nanowire is affected by the injected biomolecules and the voltage gap is changed. The proposed detection method uses this voltage difference to sense femto-molar concentrations of biomarkers such as Vascular Endothelial Growth Factor (VEGF). Figure 1a & 1b shows the variation in memristive hysteresis loop for bare SiNWs and antigen modified NWs respectively. Another important application of Si nanowires as memristive biosensor was reported by Tzouvadaki et al. [7,8].

In the proposed system, the Si nanowires are functionalized by anti-free-Prostate Specific Antigen (PSA) antibody using two different techniques,

a. Direct passive adsorption on the device surface, and

b. Bio-affinity approach using Biotin-Streptavidin combination and their respective electrical behavior is recorded.

From the difference in the memristive property resulting from the presence of the biomolecules, they proposed that the said system could be used for detection in the femtomolar ranges that allow early detection of the cancer disease. In another similar work, Lu et al. [9] reported the application of memristive nanowires for level free sensing of liquid and dried samples via leveraging the modification of the hysteresis in the devices electrical response as a consequence of the surface modification. Alessandro Vallero [10] and his group proposed a novel technique for cancer prognosis based on nanofabricated Memristive Biosensors integrated for the first time with a micro fluidic structure.

Discussion

In this paper a review is presented based on the recent works done in the field of memristive biosensors. Although the number of papers discussed in this study is not very high but they reflect a very good overview on how memristive devices may be the future of biosensors in bio-medical applications.

Conclusion

Due to its unique electrical properties Memristor has many potential applications in different field of science and technology. Some of the fields are already explored, where as others are still in early stage. In bio-medical field, memristor could be a major contributor as biosensor for detection of different diseases, antigen, molecules etc. As an emerging field, in future more number of researchers is expected to explore the possibilities of memristive biosensors for use in real world.

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