Journal of Fiber Bioengineering and Informatics 14:1 (2021) 21–39

Cite as: M. Umar et al.
doi:10.3993/jfbim00366

Advanced Smart Material Based Nano sensors for Viral Detections ⋆

Muhammad Umar [a], Hifza Nawaz [a], Iqra Nawaz [b], Yi Li [a,*]

[a] *Department of Materials, University of Manchester, Oxford Road, Manchester, M13 9PL, UK*

[b] *Nuclear Institute for Agriculture and Biology, Jhang Rd, Faisalabad, 38000, Pakistan*

Abstract

Now-a-days, researchers focus on the use of smart materials due to their multiple functional capabilities. A "smart material" is one having a nano level structure that can responds in a specialised and controlled way to influence on its sensing mechanisms. Due to the multiple properties of smart materials, they have a great influence on current analytical methods and diagnostic strategies by reorganizing the sensing modules for nano-sized objects (protein biomarkers and viruses) and biomolecules detection. Incontestably, current sensing mechanisms need a continuous update for addressing the growing challenges in the field of diagnosis for viruses because these viruses altered and spread rapidly from person-to-persons. It becomes critical to take into consideration several factors for viral diagnosis ranging from the type and quality of specimen collected, mode of transport, time of specimen collection, level of accuracy or specificity, viral detection sensitivity, and the type of diagnostic method used. In this review, we briefly explained the principle and different types of smart materials being used for diagnosing infectious viruses. The development in the field of smart material based nano sensors with resource-scarce settings is further discussed and elaborated the pros and cons of current methods for viral detection as a conclusion and future perspective.

Keywords: Viruses; Smart Materials; Nanosensors; Graphene; Sensing Mechanism

1 Introduction

Smart materials has the capability to work in an intelligent and sustainable direction by combining all its services into a cohesive unit and employing clever devices to control and monitor the viral infections [1]. Nowadays, thousands of people suffer from several diseases due to numerous medical problems [2]. Most of them are related to the infectious diseases that not only

⋆Project supported by the EU Horizon 2020 and University of Manchester through projects with project codes 644268 - ETEXWELD - H2020-MSCA-RISE-2014, AA14512 (UMRI project "Graphene-Smart Textiles E-Healthcare Network") and R119938 ('Protective Efficiency of Respiratory Protective Equipment (RPE) against Byssinosis for Cotton Workers')

*Corresponding author.
Email address: henry.yili@manchester.ac.uk (Yi Li).

affect humans lives but also danger for animals and plants lives [3]. These diseases (human immunodeficiency virus (HIV), malaria, and tuberculosis) mostly affect the people of undeveloped countries [4]. Viruses contaminating the sources is one of the main reasons of spread of diseases in these countries which not only causes suffering among the people but also lead to deaths of hundreds and thousands of people each year. Viruses are the type of parasites that require the host cell for generation and replication process. Complex protection mechanisms have been developed by mammalian cells to detect and hinder viral replication. In response, viruses can break down and control the host immune reactions. This has allowed the growth of viruses that are proficient at destroying host immune reactions [5]. The early determination of pathogenic agents like bacteria and viruses is crucial for clinical point-of-care purposes [6]. Polymerase chain reaction [7], enzyme-linked immunosorbent assay, reverse transcription polymerase chain reaction [8], and different smart material based nano sensor technologies are being used to detect or treat them [9]. A smart material based nano sensor basically contain three type of modules: a detector, a receptor, and a transducer which give digital output. Firstly targeted molecules attach with the receptor sites where biological molecules are detected through a reaction that take place on biologically detecting component [10]. Then transducers are used to convert these changes into the signal which are quantified with the help of the detector [11]. Nanosensors are built from such type of smart material which have multiple properties of exceptional performance, high specificity, practicable operation, excellent sensitivity, fast response, portability and condensed size with real-time analysis [12]. Nowadays, mostly investigators give preference to the methods which improve the specificity and sensitivity through focusing on the smart material based nanosensor production. It also improves the quality and increases affinity between the surfaces by employing nanocomposites such as quantum dots [13] and gold nanoparticles [14] for signal amplification studies. From the previous decades, smart material based nanosensors have revolved due to detection of distinctive type of analytes such as cancer biomarkers [15], explosives [16], nucleic acids [17], proteins [18], bacteria [19] viruses [20], and toxins during food processing [21], environmental monitoring [22] and clinical diagnostics.

There are various kind of smart material based nanosensors that have different principles of viral detection. Electrochemical nanosensors including screen-printed electrodes and semiconductors can monitor changes in dimension, charge distribution, dielectric properties and shape, while the complex charge is produced on the electrode. Electrochemical nanosensors are divided into three different groups, amperometric, impedimetric, and potentiometric transducers, and all of them are utilized to detect targeted viruses [23]. Optic nanosensors measure the change of the reflective index of the transducer when the target and recognition element produces a complex [24]. They have a multipurpose detection scale and can sense various kinds of biomolecules from different specimens [25]. Piezoelectric type of nanosensors can measure change in mass and viscoelasticity through modified quartz crystal resonator and recorded frequencies. Such kind of sensing require isolation equipment which can minimize hindrance effects to achieve high sensitivity for different environmental conditions. These smart materials based nanosensors have been used in a wide variety of applications to identify targeted viruses. Thermal nanosensors are based on the principle of heat absorption or evolution to exploit the basic properties of biological reactions [26]. Magnetic smart material based nanosensors carry out the magnetic beads which were coated with a ligand, so they have ability to be detect viruses through magnetic field [27].

In this review, we will briefly explain the principle and different types of smart material based