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Article

High sensitivity detection of influenza virus using polymer-coated microcavity biosensor

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Abstract: Influenza viruses are a major global public health concern because they cause seasonal epidemics and sporadic pandemics. The sensitivity and specificity of viral detection can be improved through recent developments in biosensor technology. The capacity of microcavity biosensors to detect biomolecules, including viruses, in real-time without requiring labels caused interest among them. In this study, we present a novel polymer-coated microcavity biosensor for the high-sensitivity detection of the H1N1 influenza virus. The main microcavity structure of this label-free biosensor is intended to improve sensitivity by optimizing performance characteristics specific to viral samples. The simulation indicates the microcavity resonator's outstanding sensitivity in H1N1. Our biosensor efficiently detects H1N1 at lower concentrations than conventional diagnostic techniques by utilizing a polymer coating that improves binding affinity and encourages the immobilization of certain antibodies. Using the polymer layer enhances the sensor's functionality and confers biocompatibility, opening up possible uses in point-of-care environments. The polymer-coated microcavity biosensor, according to our research, is a potential platform for early, sensitive, and quick influenza virus detection, greatly assisting with public health response and monitoring activities.

Keywords: H1N1 influenza virus; polymer coated; micro cavity biosensor; sensitivity detection

1. Introduction

Seasonal viruses are known to infect people, mainly causing respiratory diseases with huge impacts on the economic as well as health sectors. Influenza A viruses (IAVs) are the annual epizootic diseases that circulate in human populations and are descended from a diverse pool of ecological sources, while influenza type B viruses are primarily adapted to humans [1]. How the Genetic material of the virus is arranged in several Ribonucleic acid (RNA) segments allows the mixing of the material of different IAV strains and creates completely new viral strains with gene rearrangements [2]. During pandemic outbreaks, this process, called antigenic shift, can sometimes result in the formation of viral strains with significantly different characteristics and the ability to attack immunologic naive individuals with increasing pathogenicity. In this context, zoonotic viruses that are prevalent in swine and avian populations that exhibit significant fatality rates when transferred to human hosts are of particular concern [3]. These viruses, known as H7N9 or H5N1 "bird flu," now only have a minimal capacity for human replication and almost ever spread among

people, but they are being actively watched since it is thought that they may evolve into extremely effective human-to-human transmission [4].

A major pathogen that causes respiratory illnesses in millions of people worldwide is the influenza virus, sometimes referred to as the flu virus. Its segmented RNA genome allows it to be classified as a member of the Orthomyxoviridae family [5]. A and B Influenza viruses are the most common in humans, there are four primary varieties of influenza viruses A, B, C, and D. Hemagglutinin (H) and neuraminidase (N), two surface proteins that are essential to the virus's capacity to infect host cells and elude the immune system, are used to further divide type A virus into subtypes [6]. When an infected individual coughs, sneezes, or talks, respiratory droplets are the main way that influenza is disseminated. Additionally, the virus can spread through infected surfaces, where it can persist for variable lengths of time. Seasonal epidemics, marked by an abrupt onset of a high temperature, cough, sore throat, muscular pains, and exhaustion, can be brought on by the virus [7]. Influenza can have serious consequences, especially for vulnerable groups including the elderly, small children, and individuals with pre-existing medical disorders, even though most healthy persons recovered in a week or two. The influenza virus's structure is shown in **Figure 1**.

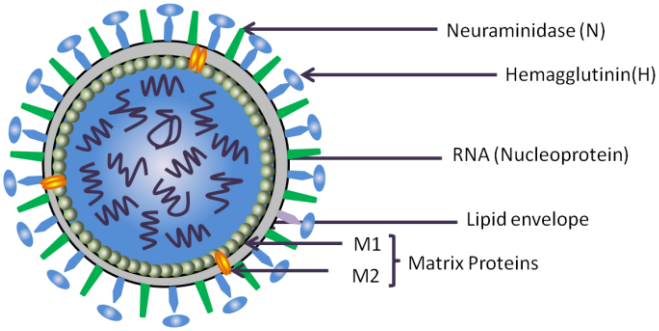

Figure 1. Structural components of influenza virus.

An analytical technique of biological substances is biosensor technology which is designed to determine the analyte-sensor interaction and transduce the response into analytical signals [8]. These gadgets are a type of transducer that can transform a biological touch into electrical, visual, as well as mechanical signals and a biological recognition part that would comprise antibodies or enzymes. Because they enable to determination of specific biomolecules and are highly selective biosensors are applied in various branches like environmental monitoring, medicine, and the food sector [9]. Real-time detection, label-free: Real-time detection in biosensing does not require the use of chemical tags or probes that are used to indicate the target analyte.

The prospects are numerous as in label-free biosensors, the useful and highly effective biomolecular recognition element, and a direct interaction with the target biomolecule without changing the latter [10]. Chemical Identification does not invade into signals or alter them; reading measurements is relatively faster and more accurate. The real-time biosensors are able to identify viral particles during the viral detection process by evaluating changes in properties such as mass, refraction index, or electrical resistivity, when the virus begins to bind to the sensor surface, thus enabling ongoing monitoring as these changes occur continuously [11]. Epidemic control and disease control respond to the ability of timely and efficient implementation of early

detection and monitoring of viral diseases like the flu. Timely treatments that reduce transmission and enhance public health management are made possible by early diagnosis [12]. This research introduces a new polymer-coated microcavity biosensor for the H1N1 influenza virus's high sensitivity detection.

Key contribution

1) The polymer-coated microcavity biosensor outperforms standard methods in providing high-sensitivity, label-free H1N1 detection.
2) The optimization design and polymer coating enhance binding affinity, allowing for detection at low viral concentrations.
3) The sensor's biocompatibility makes it suitable for rapid, on-site influenza monitoring, aiding public health responses.

The remaining portion of the study is split up into many sections to guarantee that the results are presented clearly and thoroughly. To contextualize the current inquiry, Section 2 examines previous studies and fundamental research to give relevant research. In Section 3, several strategies are examined, and the research tactics and processes used are described. Part 4 looks at the results and their consequences, including the findings from the experiment. The discussion is demonstrated in section 5. In Section 6, the research is effectively concluded by summarizing the key findings, elucidating their significance, and proposing potential directions for further research.

2. Related works

The development of sophisticated biosensors for the detection of inflammatory biomarkers, viral infections, and serological tests was covered in the article [13]. Thus, it focused on advantages and disadvantages, as well as the prospects for using various technologies. The growth and development of subsequent generation biosensing technologies, like the clustered regularly interspaced short palindromic repeats (CRISPR) based biosensors, which were capable of having higher sensitivity and selectivity was also discussed. Besides focusing on current problems, the analysis provided a roadmap for future biosensing technology advancements for pandemics.

Modern biosensors have been developed due to advanced nanotechnology, hence increasing the sensitivity of the biosensors and the detection of bacteria and viruses [14]. These selectivity, affinities, and effectiveness of devices have been improved with the help of electrospun nanofibers, graphene quantum dots, and nanoparticles. The use of biosensors became investigated thoroughly because the fundamental goal tentatively aims at revealing the role of biosensors in the identification of bacteria and viruses and at offering some input to improve the speed and the reliability of COVID-19 diagnosis.

A biosensor that used a core microring with microscopic gold rings to identify influenza viruses in avians was explained in the research [15]. High sensitivity to H1N1 and H9N2 viruses was made possible by the resonator's design performance. The sensitivity for H1N1 and H9N2 is 880 nanometer (nm)/ Refractive Units Index (RIU) and 2025 nm/RIU , respectively, according to simulations. Black phosphorus materials in two dimensions were used to increase the sensitivities as 1425 nm/RIU for H9N2. Because of its small size and wider

wavelength shift for H9N2, the biosensor could hasten the fabrication of nanooptic biological sensors for early, sensitive, and quick viral detection.

The critical need for precise, ultrasensitive, quick, and reasonably priced diagnostic methods for viral illnesses, including COVID-19, was covered in the article [16]. It examined a number of nanophotonic biosensor technologies and processes, such as fiber Bragg gratings, surface-improved Raman scattering, plasmonic field enhancement, and microresonators. Quantitative concerns about optical sensing and transmission methods were also covered in the investigation, with particular attention given to reaction times, sensitivity, specificity, and limit of detection. Prospects for the future included mass-manufacturable, ultrahigh-sensitivity, lab-on-a-chip viral detection systems that were affordable.

The necessity for quick, sensitive, and precise viral detection techniques was demonstrated by the COVID-19 pandemic [17]. Because of their small size, low analyte needs, and great sensitivity, photonic biosensors were a modern invention. Modern developments in photonic biosensor technology were examined, including interdisciplinary methods for enhanced biosensors with high sensitivity, quick response, and selectivity, material innovations, surface modification, and processes based on wavelength shifting and fluorescence.

Public health was seriously threatened by viral infections, which could lead to pandemics, severe disease, and financial strain on healthcare systems [18]. To minimize social and economic harm and save lives, prompt and precise diagnosis was essential. Polymerase chain reaction (PCR) based methods have limitations, including the need for complex lab equipment and lengthy processing periods. To provide quick, accurate, and high-throughput viral diagnosis platforms, biosensor devices were being developed. For viral detection, optical tools such as optical resonators, fluorescence-based sensors, and interferometry-based platforms were very desirable.

The COVID-19 pandemic highlighted to illuminate the shortcomings of the biosensors that were now available for quick widespread testing and population-level identification of new viruses [19]. Traditional approaches need the creation of virus-specific receptors, biological amplification, lengthy development times, and expensive equipment. By utilizing optical or electrically powered amplification, avoiding biological amplification, and cutting down on testing time, new adaptive multiplexed sensors could resolve such issues.

Pandemic outbreaks were triggered by extremely contagious infectious illnesses, such as bacteria and viruses [20]. For both prevention and healing, early diagnosis was essential. Long wait periods and expensive equipment were disadvantages of traditional diagnostic methods. Point-of-care (POC) devices, which were based on microfluidics or plasmonics platforms, provided mobility, cheap prices, and quick, sensitive detection. The healthcare sector was experiencing a transformation due to recent advances in POC technology.

COVID-19 caused attention to how crucial POC sensors were to infection control. Biosensors have been utilized to improve sensitivity and dependability [21]. It included metal nanoparticles, nanoparticles with magnetic properties, quantum dots, carbon-based nanomaterials, and molecularly imprinted polymer nanoparticles (NPs). Utilizing nanomaterials in a variety of transducers for biosensor devices offered a glimpse into the development of dependable, portable viral biosensors.

The application of two-dimensional carbon nanomaterials in biosensors to improve sensitivity and shorten analysis times was examined in the research [22]. It discussed fluorescence biosensors based on graphene and two-dimensional carbon materials for the detection of several human viruses. It focused on several multiplexing detection systems and the Förster resonance energy transfer (FRET) process. Additionally, it addressed the difficulties in employing fluorescent biosensors and provided advice on how to overcome issues.

The influenza virus in both people and animals, viruses caused severe respiratory infections which induced high levels of cytokines and death [23]. For viral attachment, entrance, and the release of the virus particles, the external glycoprotein neuraminidase (NA) was mandatory. NA removed sialic acids from carbohydrate chain reactions and efficiently cleaves cell surface proteins as a sialidase. It was to develop and design the drugs that would alleviate the immunological damage caused by influenza without affecting the NA protein.

The utilization of high-quality factor optical microcavities particularly optical whispering-gallery-mode (WGM) microcavities in confining light for resonant circulation in the micrometer regime was proposed [24]. Potential biochemical applications of the high-sensitivity optofluidic sensor include protein, nucleic acid, virus detection, and cell activity analysis for biological research applications which can be integrated with microfluidic technology. Optofluidic sensor technologies using high-Q microcavity Optofluidic sensors were reviewed based on the latest developments in the field and observed how they have been employed in investigating biological systems.

To identify tiny respiratory viruses like COVID-19, the article [25] incorporated surface plasmonic resonance (SPR) into a whispering-gallery-mode (WGM) optical microsensor. Fast, precise, and targeted viral detection was made possible by the integration, which increased sensitivity by three to five times. Using a 10-picometer (pm) resolution optical analyzer, the sensor could identify a single 20-nanometer (nm) airborne virus; for viruses in aqueous solution, the detection limit was around 0.005%.

3. Methodology

To detect the H1N1 virus, samples are obtained from the respiratory system using nose and throat swabs, as shown in **Figure 2**. These swabs collect viral particles from the upper respiratory tract, which constitute a site of H1N1 virus replication during infection. Before sending the samples for analysis, they are first placed in vials with other substances collected for the same purpose. The application of polymer-coated microcavity biosensors is effective in improving the detection sensitivity of these samples. It enhances the capacity for detecting low viral load by enhancing the binding affinity with the virus particles due to the polymer coating. The structure of the presented sensor is based on the microcavity that provides the additional improvement of the sensitivity. When integrated with conventional sampling methods, this biosensor technology can produce swift and precise affirmation of H1N1 in the respiratory system thereby enhancing the diagnostic process and establishing timely and appropriate public health intervention measures.

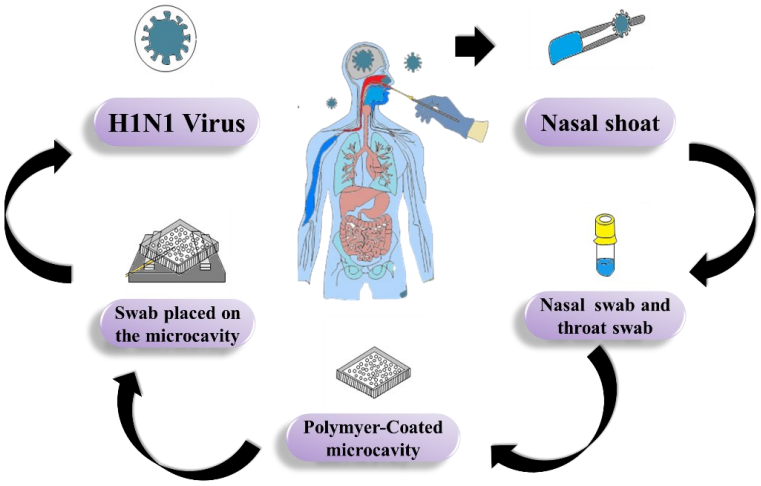

Figure 2. Process of detecting virus through swab.

3.1. Micro cavity structure

The biosensor's detection process relies on the microcavity where light and matter interactions are controlled to efficiently and selectively detect the H1N1 influenza virus. In this work, we employed a highly specific micro-cavity structure that was designed to enhance resonant phenomena and optimize the confinement of the light. Hence, silica and other high-quality dielectric materials were used in the fabrication of the microcavity owing to their superior optical transparency and low light absorption. The geometry of the microcavity can be spheric, cylindrical, or planar each kind of geometry provides specific advantages concerning the optical confinement and resonance. For instance, perfect internal reflection enables spherical microcavities, the WGM resonators, to imprison the light, and thereby enhance the sensing duration of the virus-coated surface.

The size of the microcavity was further controlled to match certain resonance frequencies with predetermined optical properties of viral samples. The actual structures that were created for the tubing were flat geometries and were produced using state-of-the-art techniques such as reactive ion etching and lithography for the flat geometries and especially advanced polishing for the necessary spherical geometries. These procedures eliminated all the scattering losses and also improved the resonance quality (Q-factor) by making the microcavity surfaces very smooth. The small changes in refractive index, as in the case of binding of H1N1 virus particles, were also noticeable in terms of the changes in cavity spacing, or diameter, which made it easily possible to achieve the optimum resonant cavity spacing. This enhanced the resonance sensitivity. The performance or ability of the microcavity to optically identify small hinted concentrations of viruses in a sample can be significantly affected by any shift in its geometry or morphology; thus, this level of sensitivity is crucial.

3.2. Polymer coating

The layer that has been applied to the microcavity biosensor is the polymer coating as it plays the role of increasing the binding parameter values for the H1N1 influenza virus and also enhances the antibodies' immobilization. The biocompatible material for this study is polyethylene glycol (PEG) or polystyrene since this material

has suitable surface properties and affords specific interactions with biomolecules. A spin-coating technique was employed to ensure that the polymer can coat the microcavity surface uniformly and maintain a specific thickness ranging from 100 to 500 nanometers in general. This thickness was selected to meet the constraint on the thickness necessary to maintain the optical properties of the microcavity and simultaneously expose the appropriate surface area to binding. To enhance the hydrophilicity of the microcavity surface mesh and enhance the polymer layer's adhesion, the surface was washed before coating, including plasma treatment. After the coating of the surface, chemical coupling methods were adopted that helped to immobilize some of the antibodies specific to the H1N1 virus. Stable immobilization of the antibodies was achieved through functionalization of the polymer surface to allow for a direct covalent reaction with the antibodies. There is a high selectivity in which the virus can attach to the well-defined and biocompatible surface thus increasing the sensitivity of the biosensor. Furthermore, the polymer coating offers other functions; for example, resistance to non-specific binding is critical when improving the assay, reliability, and dependability of the biosensor as well as increasing the biosensor's ability to detect low levels of H1N1.

3.3. Polymer-coated microcavity biosensor

The first step in applying the polymer-coated microcavity biosensor to detect influenza is to perform surface preparation. To enhance the hydrophilicity of the microcavity and obtain better polymer coating adhesion, the microcavity should be cleaned and treated properly. During spin coating, an appropriate biocompatible polymer layer for instance PEG is incorporated into the surface of the chip in a layer that enables the immobilization of some specific antibodies that would detect the H1N1 virus. The antibodies attach to form covalent bonds to the polymer layer once the polymer is on the substrate this anchors the surface and securely holds the viral antibodies for viral capture. When the biosensor is established, a specimen that may contain an influenza virus is introduced into the microcavity. To enhance the viral attachment to the immobilized antibodies, the sample is allowed to incubate for a certain time in this step, typically ranging from 30 min to several hours. Non-bound interferences are then washed off the sensor with a buffer solution to help reduce the background count. An optical detecting device that monitors changes in resonance wavelength or intensity proportional to the binding events of the influenza virus to the biosensor is then used to analyze the biosensor. The identification of the H1N1 virus in the sample could be estimated based on the absolute value and comparing the detected changes to the calibration curves given as a result of the real-time PCR reaction, providing a fast highly accurate diagnostic result. **Figure 3** shows a polymer-coated microcavity biosensor to detect influenza.

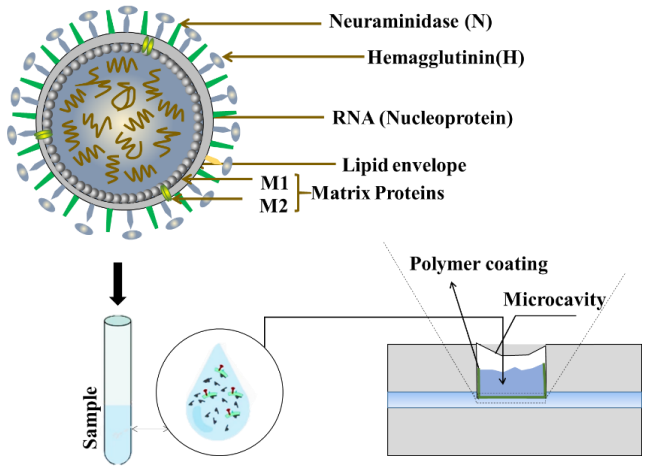

Figure 3. Schematic representation of influenza virus structure and detection using a polymer-coated microcavity biosensor.

3.4. H1N1 influenza virus

H1N1 is a subtype of IAV and is the cause of both, the global pandemic and the severe flu season, it is often referred to as swine flu. It is a part of the Orthomyxoviridae family and is characterized by two glycoproteins on the outer shells, namely, neuraminidase and hemagglutinin that help the virus enter and exit from the host cell. The virus has a different antigenic characterization caused by the "H1" and "N1" referring to specific variants of these proteins. H1N1 spreads especially through droplets produced when infected people agitate their respiratory system either through coughing or sneezing it can also spread through contact with contaminated objects. Fever, cough, sore throat, body pains, and exhaustion are the usual symptoms; however, more severe instances could result in complications like pneumonia, especially in susceptible groups including small children, the elderly, and people with weakened immune systems. The rapid mutation and adaption of H1N1 causes widespread illnesses and poses a major threat to public health. To manage epidemics and stop widespread transmission, early diagnosis is still crucial even with the availability of vaccinations and antiviral therapies.

3.4.1. Haemagglutinin (H)

1) The word haemagglutin comes from its capacity to agglutinate erythrocytes in specific circumstances.
2) Hemadsorption and haemagglutination are carried out by the glycoprotein haemagglutinin, which is made up of the polypeptides H1 and H2. The disulfide link connects these two polypeptides.
3) There are 500 spikes in the Haemagglutinin, each of which is *12 nm* long.
4) The hydrophilic tail end of the triangle-shaped H inserts it into the viral membrane. The binding of vision to host cells is carried out by the distal end, which has five antigenic sites (H1–H5).
5) One of the main influenza virus antigens, haemagglutinin, is the component that causes antigenic variation.
6) HA makes it possible for the virus to attach itself to respiratory epithelial cells and red blood cells mucoprotein receptors.

3.4.2. Neurominidase (N)

1) Neuraminidase, a glycoprotein receptor, plays a crucial role in identifying the influenza virus isolates' subtype.
2) It is made up of four identical monomers and has 100 spikes in the shape of mushrooms. A box-shaped head is used to tap a thin stalk.
3) When the viral replication cycle comes to an end, N is active.
4) The sialidase enzyme neuraminidase eliminates sialic acid from glycol conjugates. It results in the hydrolysis of sialic acid or N-acetyl neuraminic acid residues on red blood cell glycoprotein receptors, which elutes or separates cells that are absorbed by virion particles.
5) The removal of sialic acid residues from viral glycoproteins contributes to the budding process by facilitating the release of virus particles from the surface of infected cells and helps stop virions from self-aggregating.
6) Additionally, it breaks down the mucus layer, making the respiratory tract's epithelial barrier vulnerable to viral infection.

4. Result

The signal from a biosensor varies in response to varying concentrations of the target material, demonstrated by a sensitivity curve. The sensor's efficacy and detection limitations are determined with its assistance. The term "cell viability" describes the health and survival of cells in an experiment; it is frequently assessed to evaluate the effects of environmental factors or therapies. The correlation between time and signal response reveals kinetic features by monitoring the evolution of a sensor's output over time following exposure to the target. The term "virus type" refers to the particular virus being identified, whereas "biosensor type" describes the detection technology such as optical or electrochemical sensors. All of these elements work together to reveal how well a biosensor detects viral infections.

- Wavelength shift vs. virus concentration

The relationship between viral concentration and wavelength shift serves as the sensitivity of polymer-coated biosensors in detecting the influenza H1N1 virus as shown in **Figure 4**. There is no wavelength shift at a concentration of $0\ \mathrm{pg/mL}$, suggesting that the virus is not present. A modest wavelength change of $10\ nm$ is observed when the concentration rises to $250\ \mathrm{pg/mL}$, indicating the biosensor's initial reaction. At increasing doses, this sensitivity keeps growing: the wavelength shift increases to $50\ \mathrm{nm}$ at $500\ \mathrm{pg/mL}$ and to $100\ nm$ at $1000\ \mathrm{pg/mL}$. The biosensor shows a significant wavelength shift of $150\ \mathrm{nm}$ at the highest concentration tested $2500\ \mathrm{pg/mL}$. The biosensor's increased sensitivity is demonstrated by the gradual rise in wavelength shift with increasing viral concentrations, which makes it a useful tool for early H1N1 infection detection.

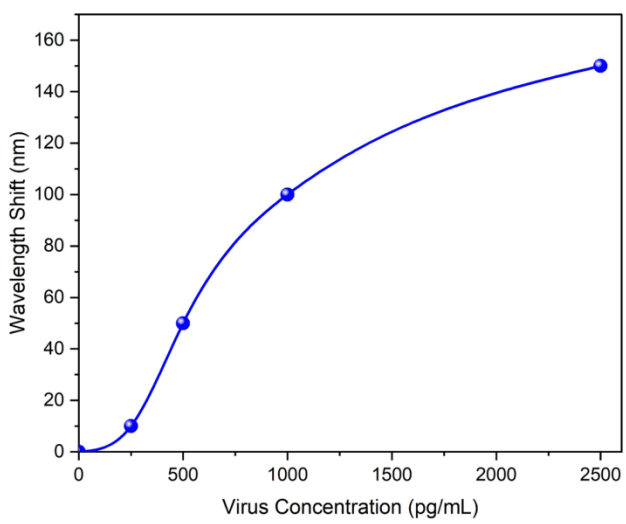

Figure 4. The polymer-coated microcavity biosensor's wavelength shift and virus concentration relationship.

- Cell viability (%) vs. Treatment type

The polymer coated and the standard material treatment techniques are shown in **Figure 5**. From the result, it is clear that the polymer-coated treatment enhances 90 % cell viability which is far better than the standard material which had 75% cell viability. This important difference shows just how effective polymer coatings are in enhancing cellular responses and that enhanced outcomes from their application may be probable in biological cases. Consequently, the evidence presented herein shows that material could be coated with polymers to boost cellular functionality along with treatment outcomes in Medical and biological contexts.

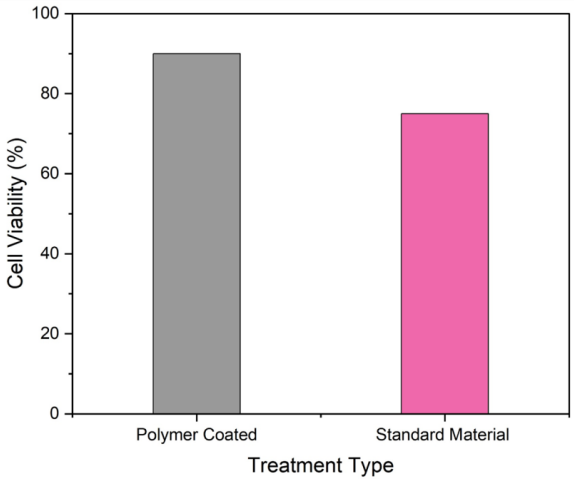

Figure 5. Cell viability performance in polymer coated and the standard material treatment.

- Time (s) vs. signal response

Figure 6 shows the signal response of the biosensor to the target analyte as a time response curve. No binding or detection has yet to take place, as evidenced by the signal response being zero at time zero seconds. The biosensor starts to identify the target over time, demonstrated by the signal response's progressive rise over time. An

early contact is indicated by the signal rising to 0.1 after 10 s. When the response hits 0.3 after 20 s, there is a noticeable increase in signal strength, suggesting successful binding. The response approaches 0.5 after 30 s, indicating that the biosensor is still effectively capturing the target molecules. The biosensor has achieved a nearly ideal detection level when the signal response peaks at 0.8 after 60 s. This data demonstrates the sensor's efficacy for real-time monitoring and early diagnosis in medical settings by highlighting its quick target detection capability.

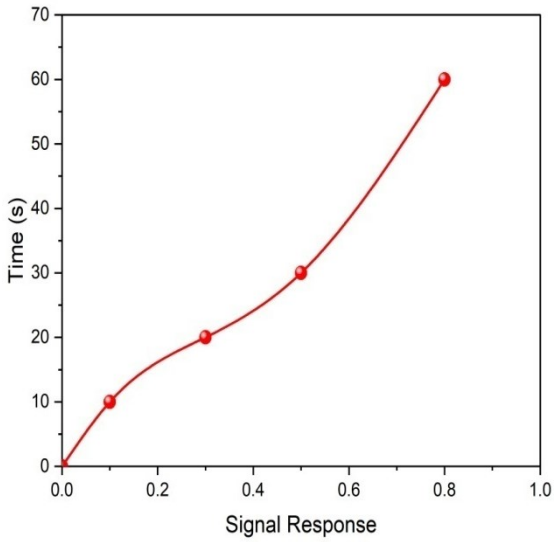

Figure 6. Signal response of the biosensor to the target analyzed as a time response curve.

- Average wavelength shift (nm) vs. virus type

The average wavelength shifts (in nanometers) for the various virus types are shown in **Figure 7**, emphasizing their distinctive features. At 60 nm, H1N1 Influenza has the largest average wavelength shift, indicating that it could have substantial interactions with light or its surroundings that can be evaluated using this shift. The common cold-causing rhinovirus has a smaller wavelength shift of 25 nm, which suggests comparatively fewer interaction effects. The much lower shift of 10 nm for adenovirus, which could trigger several diseases, indicates that its interactions with light are less than those of the other viruses. Finally, the average wavelength shift of the parainfluenza virus is 12 nm, suggesting that its interactions lie in the middle of those of rhinovirus and adenovirus. These numbers can shed insight into the physical characteristics of these viruses, which could be helpful in investigation and diagnosing contexts.

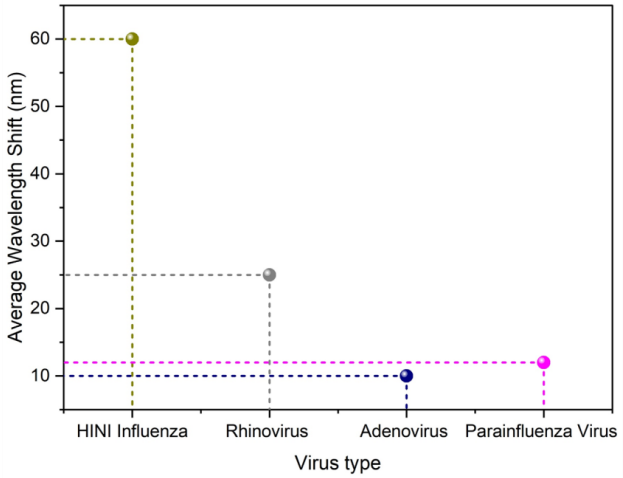

Figure 7. Average wavelength shift for different viruses.

- Binding affinity vs. biosensor type

The efficacy of biosensors, which are analytical tools that translate a biological reaction into an electrical signal, is frequently impacted by the affinity of the biomolecular interactions they enable as demonstrated in **Figure 8**. The dissociation constant (Kd), which measures how firmly a ligand binds to its target biomolecule, is used in this context to quantitatively reflect affinity; lower Kd values imply greater binding. Two different kinds of biosensors one polymer-coated and the other non-coated are compared figure. The polymer-coated biosensor has a moderate to high affinity for its target, as shown by its Kd value of 5. The non-coated biosensor's Kd value of 10 is substantially greater, indicating a significantly lower binding affinity. This sharp variation in Kd values demonstrates how well the polymer coating functions to enhance the sensor-biomolecule interaction, which could result in increased sensitivity and specificity when identifying the target analytes. For applications needing accurate and trustworthy measurements of biomolecular interactions, the polymer-coated biosensor could be more appropriate.

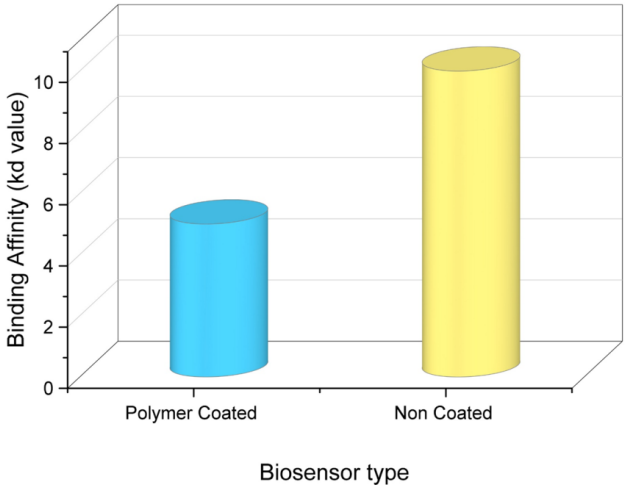

Figure 8. Binding affinity comparison with polymer-coated and non-coated biosensors.

5. Discussion

Electrochemical biosensors for virus detection could be used with contemporary methods such as computer vision and the electrochemical collision approach. These developments enable more efficient and quick viral identification by enhancing the sensitivity, accuracy, and general performance of biosensors. The integration of these cutting-edge techniques improves the usefulness of biosensors, increasing their accuracy in identifying different viruses and providing positive responses for the next public health diagnostics demonstrated in research [26]. The sensor also exhibited a response time of 5 min for the spike protein and the limit of detection (LOD) was determined to be 200 pM for saliva samples containing the S proteins and 500 pM from phosphate buffer saline (PBS) solutions. Furthermore, the sensor identified a pseudovirus in an electrolyte mixture with a LOD of $106\ \text{copies/mL}$ as described in the article [27]. These results demonstrated that the IAV H3N2 could be detected selectively by the binding peptide immobilized hydrogel microsphere (BP-Hyd). An IAV hemagglutinin-labeled antibody was used to index the identified IAV H3N2. With a detection limit of $1.887\ \text{PFU mL}^{-1}$, they were able to detect IAV H3N2 quantitatively and selectively by combining the affinity peptide with hydrogel microspheres in the investigation [28]. A linear detection range of $10\ \text{pM}$ to $100\ \text{nM}$ is attained by the biosensor, with a detection limit of $0.44\ \text{pM}$. It was able to identify the H1N1 virus with high selectivity and reproducibility. When actual samples were analyzed, the biosensor's stability was verified. Its potential for efficient H1N1 virus identification is demonstrated by these performance measures in research [29]. The basics of sound vibrations in sensor technology and microvascular operation, acoustics wave methods suitable for detection and action, piezoelectric elements used to generate acoustic waves, production methods, and challenges in applying acoustic waves methods in biosensing were all thoroughly examined in [30]. The primary focus had been on the last decade's developments in the detection potential of sound waves in a variety of applications, including the detection of infectious microorganisms DNA, protein molecules, sickness markers, acoustofluidic deception, and the division of biological materials like cells. Three primary categories of speciality fibre technologies were presented in [31], multifunctional and multimaterial fibres, lab on fibres, and photonic crystal fibres (PCFs) and optical fibres with other unique architectures. Speciality fibres had been widely employed for both practical applications for a variety of sensing applications. The possible uses for sensors based on fibre. Speciality fiber-based sensors could greatly enhance sensor performance, including sensitivity, as compared to conventional optical fibre sensors. Sensing physical characteristics including temperature, magnetic field, strain, and refractive index had allowed for these kinds of presentations.

6. Conclusion

Seasonal epidemics and occasional pandemics are caused by influenza viruses, which pose a serious threat to global public health. In this work, we provided a new polymer-coated microcavity biosensor for the H1N1 influenza virus's high sensitivity detection. This label-free biosensor leverages a primary microcavity structure optimized for viral samples, enhancing sensitivity. The simulation demonstrates the

exceptional sensitivity of the microcavity resonator in H1N1. The polymer coating enhances binding affinity as 5.0 and promotes the immobilization of certain antibodies; our biosensor effectively detects H1N1 at lower concentrations than traditional diagnostic methods. The sensor's functioning is improved and biocompatibility is granted by using the polymer layer, which opens up potential applications in point-of-care settings. The signal from a biosensor varies with the target concentration, indicated by a sensitivity curve. The sensor's output is tracked over time using time versus signal response. The kind of biosensor is the technology utilized for detection, whereas the type of virus is the virus being identified. These elements evaluate the performance of the sensor. When cell viability reaches 90%, polymer-coated biosensors function better. The polymer-coated microcavity biosensor, while promising for H1N1 detection, has limitations such as sensitivity to environmental factors, potentially reduced selectivity for distinct virus strains and dependency on cell viability for optimal performance. Additionally, its real-time detection capabilities could be improved, and the stability of the polymer coating over time could affect long-term accuracy, limiting its scalability in point-of-care settings. Improving real-time detection capabilities and increasing selectivity for particular influenza strains could improve its diagnostic applications.

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