Overview of surface plasmon resonance optical sensors for Covid-19 (SARS-CoV-2) detection

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Abstract. The SARS-CoV-2 i.e., the novel severe acute respiratory syndrome corona virus; has caused massive loss of life. Mitigating this pandemic requires rapid inexpensive technologies for testing COVID-19. Optical sensors can be used to detect the Covid-19 virus by the surface Plasmon resonance phenomenon. Surface plasmon resonance sensors have good sensitivity, response times, fine resolution, and limits of detection. This paper, provides a brief overview on the COVID-19 effects, currently used testing technology, and potential of surface plasmon resonance optical sensors use for detecting this virus.

1. Introduction
The corona virus disease (Covid-19) caused a massive global pandemic and have caused a grave loss of lives. COVID-19 has various symptoms making conclusive diagnosis challenging. Covid-19 symptoms are high fever, dry coughing, sore throat, temporary loss of taste and smell, diarrhea, strong headaches, and sudden fatigue, among others[1]. So, conclusive testing methods are needed to stop this pandemic.

The long waiting lines for Covid-19 testing were caused by the lack of equipment for testing technology COVID-19 are a big concern. The current technologies for Covid-19 testing can be described as slow and expensive. For instance, single photon emission computed tomography (SPECT), computed tomography (CTes), positron emission tomography (PET), enzyme-linked immunosorbent assay (ELISA) can be expensive and laborious procedures and they require well-trained staff to conduct them. The more common testing technology reverse-transcription polymerase chain reaction (RT-PCR) is not cost-effective and has long response time. Thus, RT-PCR testing clinics have been overwhelmed with potential patients. Also, RT-PCR testing requires trained professionals, in some cases has been shown to give false-negatives and can be expensive for the public. [2-6]

Optical sensors have been widely used in many applications due to their higher sensitivity, good selectivity, relatively short response times, and good resolution. [7]. Optical surface plasmon resonance sensors using Kretschmann setup coated with graphene and thiol DNA had a sensitivity of 130 degree/RIU in simulations[8]. Another chip optical sensor with spike protein specific Plasmonic chip had a limit of detection of up to 370 vp/mL [9]. Optical sensors can provide results at a much faster times than current technologies with high sensitivity and good limits of detections.
2. Methodology
SPR Kretschmann setup is a surface plasmon sensor structure that has a prism with a very thin metal layer coating. Gold is commonly selected as an SPR coating for good sensitivity and durability. P-polarized (TM) light from a He-Ne laser hits the prism. Then, the light is received by a photo detector. The evanescent field of the light at the prism boundary hits the thin metal layer. when resonance conditions are fulfilled, i.e., P-polarized light, a prism with high refractive index, and a thin uniform metal layer coated on one face of the prism.

Resonance occurs at the surface plasmon resonance angle and the resulting resonance dip can be seen in the output [8, 10]. Surface plasmon resonance sensors need a layer of immobilized biomolecules (such as antibodies) immobilized on the thin metal layer of the prism outer surface. This immobilized bio-molecules layer can bind the pathogen (the virus) to the sensors’ surface [11]. The resulting accumulation of the bound pathogen (virus) cause a change (an increase) in the refractive index of the sensor’s surroundings. Thus, shifting the sensor resonance angle. [12-14]. By recording the shifts of the resonance angle, the pathogen can be detected.

The SPR sensor setup consists of three main components: the laser light source, the prism, and the light detector. The He-Ne laser can be used as light source [15]. The light detector receives the light from the prism. The experiment setup is presented in Figure 1.

![Figure 1. The experiments setup for the pathogen.](image)

3. Results and discussion
Sensitivity, response time, figure of merit, and limit of detection are performance parameters showing the feasibility of using a biosensor. The SPR sensors’ sensitivity is the amount of the shift in the resonance angle divided by the total changes of surroundings’ refractive index. The binding of the pathogen to the layer of the immobilized ligands on the thin metal coating of the prism surface cause a change of the refractive index.

The centre resonance angle of SPR is the angle of the minimum reflectivity. The sensor’s full width of half minimum/maximum (FWHM) is the difference of angles with 3 dBm output. The quality factor of the SPR sensor relates to the FWHM by the following: $Q = \frac{\theta}{\text{FWHM}}$.

The figure of merit of an SPR biosensor is the sensor’s sensitivity to the FWHM of the sensor’s resonance dips ratio; $\frac{S}{\text{FWHM}}$. The Limit of detection is a vital parameter. It is the smallest amount of the pathogen the sensor can detect. Limit of detection can be calculated by $\frac{R}{S_{\text{surf}}}$. R is the resolution of the structure and $S_{\text{surf}}$ is the ratio of the total refractive index change divided by the maximum surface of the mass concentration. $\frac{\Delta n}{\sigma_{\text{max}}}$. The uniformity, thickness and material of the thin metal layer can help improve the sensor’s performance. The refractive index of the prism, the output power of the light source and wavelength can be varied to optimize the sensor.
During this COVID-19 pandemic fight, accurate, cost-effective virus detection methods are vital. Optical sensors can provide accurate, rapid, cost-effective, rapid, and sensitive, technology for the COVID-19 detection. Improving and optimizing this sensors’ structure to achieve the highest sensitivity and best limits of detection is the only way to make SPR biosensors a viable potential choice for detection of this pathogen; the COVID-19 virus.

4. Conclusion
The efforts to control the COVID-19 pandemic are vital to all. This paper gives a brief summary of this virus, the currently used detection technologies, the shortcomings of these technologies, and the potential of optical biosensing technologies development to for Covid-19 detection. Surface plasmon resonance biosensors are the primary focus of this summary due to SPR sensors’ good sensitivity, resolution, response time, and limits of detection.

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