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Physics

FAST DETECTION TECHNIQUE OF SARS-COV-2 BASED ON RAMAN AND FT-IR SPECTROSCOPY

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ABSTRACT Very recently, Coronavirus (COVID-19) disease is intense human easy transmissible disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The World Health Organization (WHO) has referred the COVID-19 outbreak as a pandemic based on the worldwide rapid increase in the rate of human infection. The specific medicines or vaccines for COVID-19 are not available, so that, early diagnosis and management are important for comprising the outbreak. Therefore, amidst COVID-19 pandemic, ultra advanced diagnostic procedures are very importance. Low-Frequency Raman (LFR) Spectroscopy affords a robust theoretical scientific technique for advancement of a non-invasive diagnostic instrument for detecting the affected specimens or patients directly. In this paper, a fast detection technique based on Raman and FT-IR Spectroscopy is proposed for of the COVID-19 and other viral substances, boosting the fundamental future research works.

KEYWORDS : SARS-CoV-2; Pandemic; Raman spectroscopy; FT-IR spectroscopy

INTRODUCTION

COVID-19 is very harmful human pathogens. At December, 2019, it was identified as the cause of a cluster of pneumonia cases in Wuhan, China. It speedily spread out as an epidemic throughout China, followed by almost all other countries around the world. WHO announced the disease COVID-19 i.e., coronavirus disease 2019 in February 2020, [1]. The virus of COVID-19 is SARS-CoV-2. An emergency guidance has been released by WHO and United States (US) Centers for Disease Control and Prevention. This theme has been explained by the virology, epidemiology, clinical features for diagnosis, and prevention of COVID-19. This paper introduces the possibility of applicability the vibrational spectroscopy techniques i.e., Raman and Fourier-transform infrared (FT-IR) spectroscopy for medicare especially for COVID-19 patients. The techniques are very much reliable to detect the virus and can help in the early and fast diagnosis to curb the pandemic. Very recently COVID-19 is biggest biological hazard for our healthcare, economic, political, social sectors, etc. The developed or under development countries could have to get advantage from this technologies for high throughput COVID-19 to prevent the virus outbreak worldwide [2].

The SARS-CoV-2 can be sprayed very easily by cough, sneeze, droplet inhalation and contact routes like oral, nasal contact, eye mucous membranes, etc. The virus has been examined to be present on human biofluids [3]. Biofluids are blood, saliva, tears, sputum, etc. They carry specific disease biomarkers like carbohydrates, proteins, lipids, nucleic acids, hormones, carotenoids, etc. Biomarkers are present in coronaviruses, as their formation contains a single strand of positive-sense RNA carried by structural proteins/glycoprotein and lipids of their matrix, nucleocapsid and envelope. Also, the S protein of coronavirus can bind to the host cell-membrane of receptors to ease viral entry into cells including the human angiotensin converting enzyme-2 (ACE2) receptor. In our observation, these biomarkers create special types of SERS spectra in the field of view of the vibrational spectroscopy for identification instantly.

STRUCTURE OF SARS-CoV-2

The WHO declared COVID-19 as a pandemic on March 11, 2020 [4]. COVID-19 coronavirus SARS-CoV-2 belongs to the Betacoronavirus genus coming from bats. Betacoronaviruses can infect mammals, are zoonotic pathogens. It can cause severe respiratory disease in humans body. Other viruses in this family are SARS coronavirus and MERS coronavirus. SARS-CoV-2 has approximately 79% sequence identity to SARS-CoV and 50% to MERS-CoV [5].

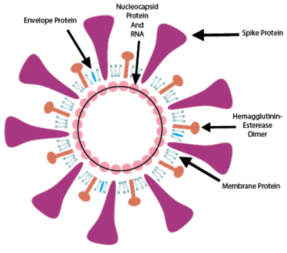

Figure 1: structure of COVID-19 virus

SARS-CoV-2 uses receptor ACE2 for infection in humans. The structure of SARS-CoV-2 constitutes of the following: a spike protein (S), hemagglutinin-esterase dimer (HE), a membrane glycoprotein (M), an envelope protein (E) a nucleoclapid protein (N) and RNA as seen in the figure below [6]. Spike protein (S) is heavily glycosylated. It utilizes an N-terminal signal sequence for gaining access to the ER and intermediate to host receptors [7]. RNA is the genome of the virus. Nucleocapsid protein (N) attaches to RNA and is heavily phosphorylated. Envelope protein (E) is base in small quantities within the virus. It is not needed for replication but it is necessary for pathogenesis. Membrane protein (M) is the most abundant structural protein. It does not require signal sequence but it is as a dimer in the virion. Hemagglutinin-esterase dimer protein (HE) exists in a subset of betacoronaviruses [8, 9].

RAMAN AND FT-IF SPECTROSCOPY

Raman and FT-IF Spectroscopy are famous branch of spectroscopy in which concerned Raman spectra are used for studying pure vibrational, pure rotational and rotation-vibration energy changes in the ground level of molecules. The collision of incident light quanta with the molecule is induced the molecule to undergo the change in Raman spectroscopy. The advanced technique based on Raman and FT-IR spectroscopy is Single-molecule spectroscopy (SMS) which detects one molecule within a crystal or a cell by optical excitation. It gives real-time, non-destructive and non-invasive analysis of biological tissues and biofluids samples [10, 11]. Raman spectroscopy is very unique and can be applied to analyze the virus binding on ACE2 receptors of host cells or to analyze biofluids directly. The vibrational spectroscopy can be widely employed for low cost-effective mass screening at clinics, hospitals, airports, etc. due to portability and low-noise measurements. The effective molecular specificity and water-free signals of Raman spectroscopy permits the technique to be exploited for biochemical profiling of cells in biofluids [12, 13]. Therefore, we would like to reinforce the potential of COVID-19 studies using the proposed techniques described in this paper.

WORKING PROCEDURE AND RESULTS

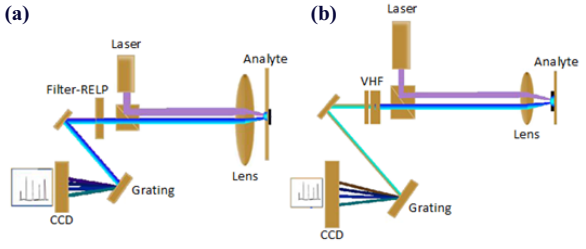

Figure 2: schematics of optical set up: (a) Regular Spontaneous Raman Spectroscopy (b) Low-Frequency Raman Spectroscopy

If it dispersed in a host-matrix then the host/virus-guest dispersion will be taken as spin-casted or drop-casted on a glass microscope slide [19]. For this study, all the Raman Spectroscopy measurements may be

performed in a micro-Raman configuration, consisting of microscope combined with laser light excitation, appropriate collection optics, and spectrometer. The optical set up of regular Raman spectroscopic measurements is demonstrated in Figure 2(a). The set up presented corresponds to a reflection geometry which consists of an excitation laser of wavelength $\lambda = 532$ nm. It is focused on the analyte using a microscope objective lens.

The decoupled Raman signal beam is allowed to go through a Razor Edge Long Pass Filter (Filter-RELP) to block out the laser excitation from passing into and saturating the detector. The Raman signal beam is then coupled into an imaging spectrometer with an EM-CCD camera. Here the optical grating resolves the spectrum and projects it onto a CCD [20].

For Low-Frequency Raman Spectroscopy (LFR), the optical setup that employs the special Very high frequency (VHF) type of laser is used for blocking filters to enable the probing of spectral shifts as low as 5 cm-1.

The schematic LFR is presented in Figure 2(b). Figure 3 shows typical averaged SERS spectra of single viral cell analysis. The indicated results of nanostructure for COVID-19 will be compared with that of other Coronaviruses and other viruses. We will also compare the various viruses to their host-matrices and buffers [21].

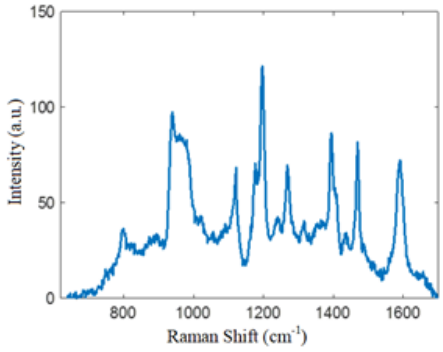

Figure 3: SERS spectra

CONCLUSION

The aim of this paper is to provide a complete alternative to existing SERS based Raman technique of fast detecting viruses. The successful and significant assuaging of SERS signal intensities in the presence of SARS-CoV-2 spike proteins proved its capability in capturing and recognizing SARS-CoV-2. It can be further improved by fabrication implementation, database set-up and algorithm optimization. It has a bright future and huge potential as a rapid and on-site diagnostic tool for SARS-CoV-2 and other viruses to confirm patients determine community cases and track environmental viral sources in pandemics.

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