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RAPID DETECTION OF COVID-19 CAUSATIVE VIRUS (SARS-COV-2) USING FET-BASED BIOSENSOR

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ABSTRACT

As the whole world is facing a newly emerging human infectious disease called Coronavirus disease 2019 (COVID-19) caused by coronavirus 2 (2019-nCoV). There is rapid and fast rate of increase of infection, this COVID-19 outbreaks as a pandemic by WHO. There is no specific vaccine for this disease are yet available, so there must be rapid detection and diagnosis of COVID-19 in this short period of time. Here, we report a field effect transistor (Bio-FET)-based bio sensing device for detecting SARS-CoV-2 in collected samples. The sensor is able to detect the spike protein molecules of coronavirus 2 on the surface which is further processed by electronics systems and gives final result. This device is a highly sensitive immunological diagnostic method for COVID-19 that requires no sample pretreatment.

KEYWORDS: FET, biosensor, COVID-19,2019-nCoV, SARS-CoV-2 .

I. INTRODUCTION

There is rapid growth of COVID-19 cases all around the world, so there must be large amounts of testing kits requires for samples to be tested by the use of conventional testing kits which also takes long period of time. By introducing new methods of advanced electronics systems, we can increase the rate of testing of samples from persons/individual.

Coronaviruses causes mild to moderate upper respiratory tract illnesses in both humans and animal. For emerging pathogens, real-time reverse transcription polymerase chain reaction (RT-PCR) for the DNA amplification is the primary means of diagnosis. The rate of COVID-19 transmission is much faster among us. Molecular diagnosis using real time RT-PCR takes at least 3 hrs. Hence, highly sensitive immunological diagnostic methods that directly detect viral antigens in clinical samples without sample preparation steps are necessary for rapid and accurate diagnosis of COVID-19.

Among the many diagnostic methods currently available, field-effect transistor (FET)-based biosensing and bioelectronics devices have ability to make highly sensitive and instantaneous measurement using little amount of sample/analytes.

II. LITERATURE REVIEW

- By the application of certain types of electronics system, the vital component in this nCoV- biosensor testing instrument is transducer which can be able to detect the SARS-CoV-2 easily.
- The experts all around the world in the field of electronics, biomedical sciences and biotechnology are continuously developing this device for the proper working.

III. WORKING PRINCIPLE

FET biosensors are based on the interactions of specific antibodies with a specific antigen (SARS-CoV-2). Antigen detect the binding of antibodies to the antigen by immobilizing the reaction on the surface of a transducer that converts the surface change parameters into detectable electrical signal. These variations in voltage and current is created by the resistance developed on the surface of the bio receptors, Which is further processed by signal processing unit and gives final result.

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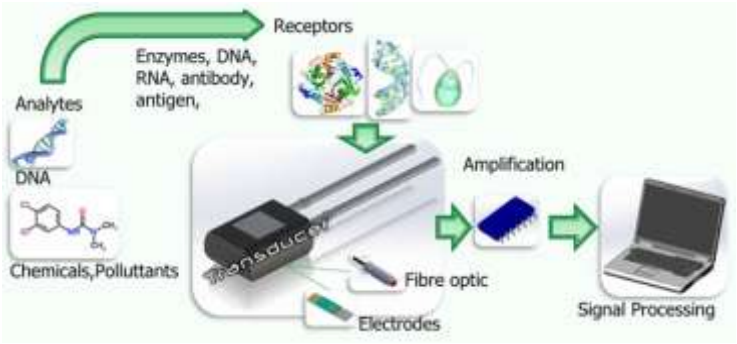

Fig-1: Schematic diagram

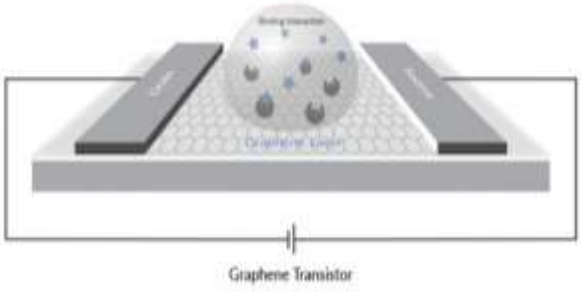

Fig-2: Graphene layered FET sensor

IV. FET BASED BIOSENSOR

FET-based biosensors are semiconductor devices which is useful in rapid testing and on-site detection. In this FET-biosensor, there is a layer of graphene, all of which are exposed on its surface. Graphene-based FET biosensors can detect surrounding changes on their surface and provides on optimal sensing environment for ultrasensitive low-noise detection.

Fig-3: Graphene FET array

A graphene-based biosensing device functionalized with SARS-CoV-2 spike antibody(COVID-19 FET sensor) for use as a SARS-CoV-2 virus detection platform. SARS-COV-2 spike antibody was immobilized onto the fabricated device through 1-pyrenebutyric acid N-hydroxysuccinimide ester (PBASE), an efficient interface coupling agent used as a probe linker. COVID-19 FET sensor detects target SARS-CoV-2 antigen protein with a limit of detection (LOD) of 1 fg/mL. This sensor could distinguish a large signal distortion/variations with SARS-CoV-2 virus.

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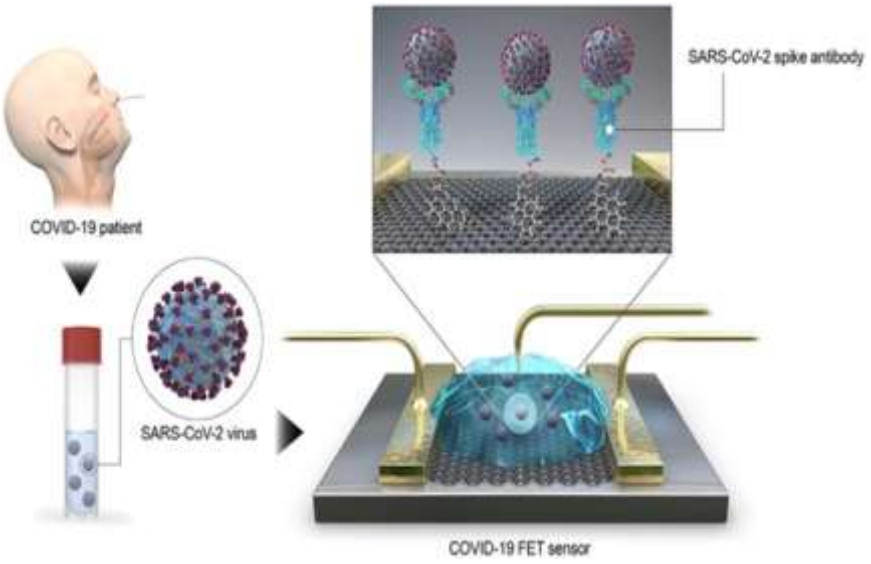

Fig-4: COVID-19 FET sensor operation procedure

V. RESPONSE AND OBSERVATIONS OF FET BIOSENSOR

On the surface of graphene FET sensor, the graphene is soaked with a PBASE solution . PBASE is a linker that contains a pyrene group that non-covalently attaches to graphene through π-π (pi-pi) stacking, at the other end is an activated ester which reacts with the means then adding SARS-CoV-2 spike protein antibody which reacts with the linker to form a chemical bond.

After the graphene is attached with antibody, the devices sensitivity were tested, this design uses a buffered water droplets with an electrode as the transistors gate so called aqueous solution gated FET. Now if a voltage is applied across the source and drain electrodes a current flow through the graphene layer can be measured as a function of the gate voltage.

Now tested whether the transistor would respond to the spike protein bound to the antibodies of high affinity, this event changes the charge distribution in the immediately vicinity of the graphene layer thus changing its electrical conductivity, the change in conductivity alters the amount of current than can flow between the source and drain electrodes, this device could detect the spike protein down to 1 fg/mL (femtogram per milliliter), a very high sensitivity. The sensors had no response for the spike proteins of other viruses viz. SARS and MERS virus.

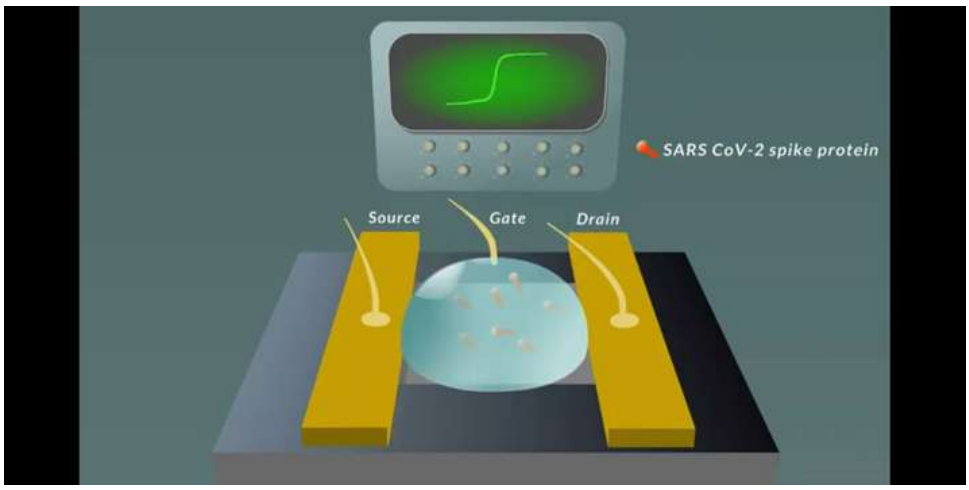

Fig-5: SARS-CoV-2 spike protein response.

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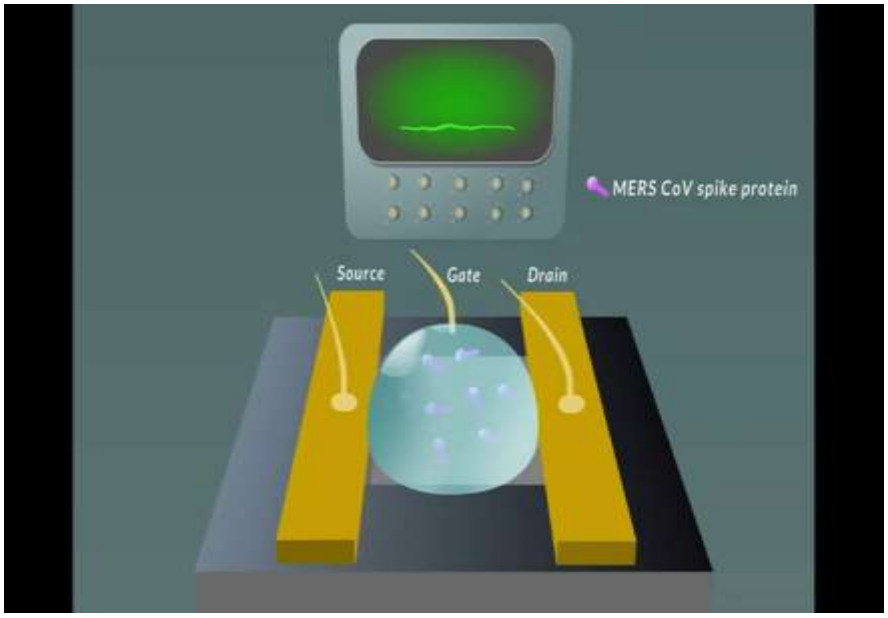

Fig-6: MERS CoV spike protein response

Then actual swab sample collected from COVID-19 patient placed on G-FET sensor could detect the virus. The higher the concentration of SARS-CoV-2 virus in the sample, the greater signal response we saw in this biosensor. For negative control experiment also: a swab sample from a healthy, uninfected person showed no response. This critical experiment demonstrated proof of concept that the device could be used to distinguish between healthy and infected people with COVID-19 disease.

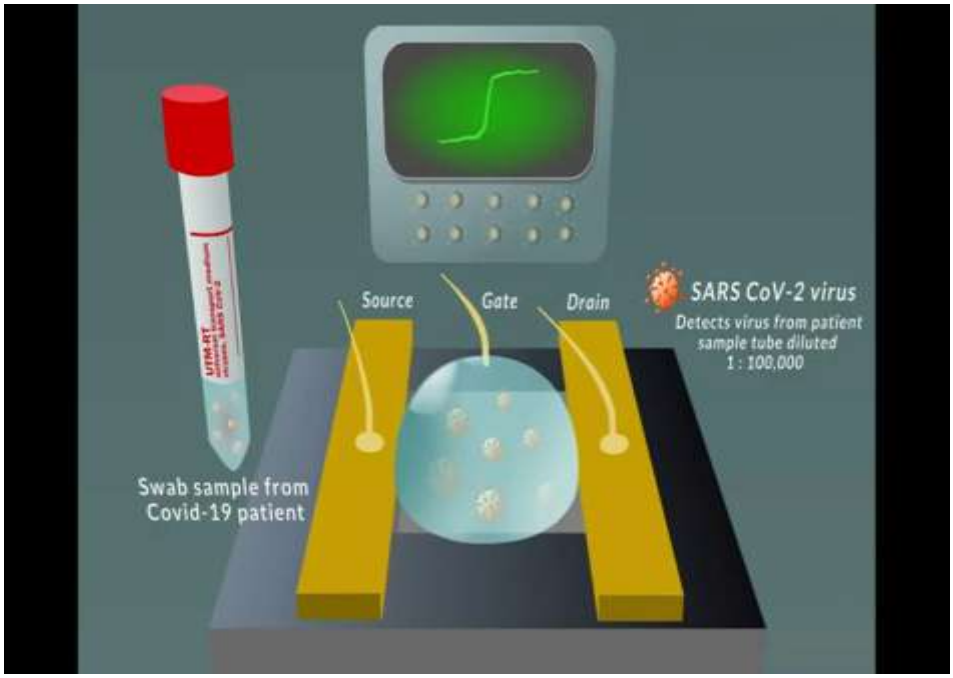

Fig-7: Swab sample response from COVID-19 patient

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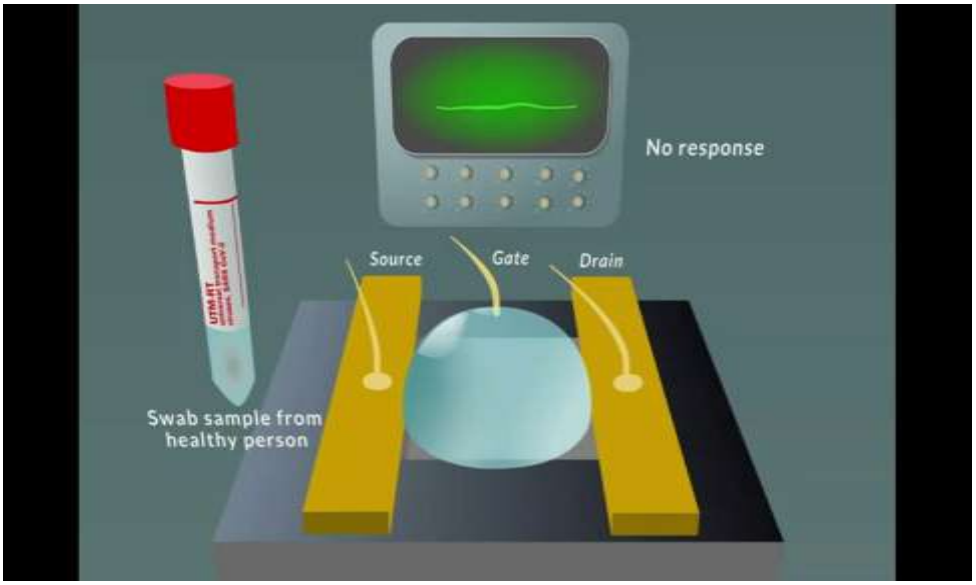

Fig-8: Swab sample response from healthy person

VI. TOWARDS MAKING THIS DEVICE IN USE

After the proper research and analysis from the observations of Bio-FET sensor responses for SARS-CoV-2 virus, this device can be made for virus detection with the help of highly sensitive graphene layered Bio-FET transistor as a highly sensitive transducer, for the signal response on the action of virus there is fluctuations in current and voltages which can be detected by analog electronics circuits and ICs and further the signal will be converted into digital form to show direct confirmation of COVID-19 patient on display module and oscilloscope.

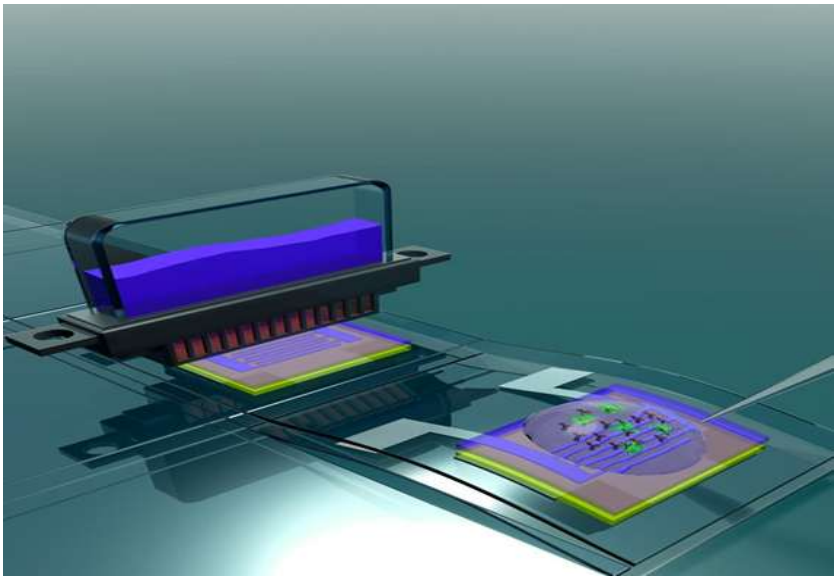

Fig-9: Fabrication of graphene based FET biosensor

Fig-10: FET based biosensor instrument manufactured by matsumoto lab and muRata co. ltd.

VII. CONCLUSION

During the COVID-19 pandemic, the development of highly sensitive and rapid biosensing devices has become increasingly important. The COVID-19 FET sensor in which the SARS-CoV-2 spike antibody is conjugated to a graphene sheet, which is used as the sensing area. The sensor was able to detect SARS-CoV-2 virus in clinical samples. Furthermore, the device exhibited no measurable cross-reactivity with MERS-CoV antigen. Therefore, this functionalized graphene-based sensor platform provides simple, rapid, and highly responsive detection of the SARS-CoV-2 virus in clinical samples. Moreover, this technology could be adapted for diagnosis of other emerging viral diseases.

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