

CLAIMS

What is claimed is:

1. A field effect transistor (FET) biosensor for virus detection of a selected virus
5 within a sample volume, comprising:
 - a semiconductor substrate;
 - a source electrode on the semiconductor substrate;
 - a drain electrode on the semiconductor substrate and spaced apart from the
source electrode;
 - 10 a gate electrode carried on the semiconductor substrate and located between
the source electrode and the drain electrode, with the gate electrode recessed below
the source electrode and the drain electrode to form an open channel;
 - an insulating layer coupled to a top surface of the gate electrode and a bottom
surface of the source electrode and the drain electrode such that the insulating layer
15 is located between the gate electrode and source electrode and between the gate
electrode and the drain electrode, the insulating layer forming a bottom of the open
channel;
 - a channel material coupled to the insulating layer such that the sample volume
can be oriented within the open channel; and
 - 20 molecular recognition groups oriented within the open channel, the molecular
recognition groups configured to bind with the selected virus to change a current (I_{DS})
between the drain electrode and the source electrode or a channel conductivity at a
selected voltage (V_{GS}) applied to the gate electrode relative to the source electrode to
enable a detection of the selected virus by the FET biosensor based on the change in
25 I_{DS} at the selected voltage or the channel conductivity at the selected voltage.
2. The FET biosensor of claim 1, wherein the insulating layer is comprised of one
or more of silicon dioxide, hafnium dioxide, nitride-oxide, titanium oxide, or
composites thereof.

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3. The FET biosensor of claim 1, wherein the source electrode, gate electrode, and drain electrode are comprised of one or more conductors comprising silver, gold, copper, platinum, aluminum, zinc, cobalt, nickel, tungsten, or ruthenium.
- 5 4. The FET biosensor of claim 1, wherein:
the source, drain, and gate electrodes have a thickness between approximately 50 nanometers (nm) and 250 nm; and
the insulating layer has a thickness of between approximately 5 nm and 20 nm.
- 10 5. The FET biosensor of claim 1, wherein a distance between the source electrode and the drain electrode creates a channel width of approximately 500 nanometers (nm) and 2000 nm.
- 15 6. The FET biosensor of claim 1, wherein the channel material is one or more of:
a zeolite layer formed in the channel and having at least a portion of the molecular recognition groups therein;
a thin gold film having a thickness between approximately 20 and 40 nanometers deposited on the insulating layer in the channel and having at least a portion of the molecular recognition groups functionalized on the thin gold film; or
20 gold nano particles having a diameter between approximately 25 nm and 75 nm, the gold nano particles attached to at least a portion of the molecular recognition groups.
- 25 7. The FET biosensor of claim 1, wherein the sample volume comprises one or more of:
an aptamer buffer solution having between approximately 0.5 micro Mole (uM) and 5 uM concentration;
a stock solution of virus; or
30 a solution of gold nanoparticles functionalized with at least a portion of the aptamers.

8. The FET biosensor of claim 1, wherein the molecular recognition groups are at least one of aptamers, anitgens, and antibodies.
- 5 9. The FET biosensor of claim 1, wherein the selected virus is one or more of:
a SARS-COV-1 virus;
a SARS-COV-2 virus;
a Zika virus; or
a coronavirus.
- 10 10. The FET biosensor of claim 1, wherein at least a portion of the molecular recognition groups are suspended within the open channel in one or more of a dried suspension, a hydrogel, or a dried network of functionalized nanoparticles.
- 15 11. The FET biosensor of claim 1, wherein at least a portion of the molecular recognition groups are functionalized to at least one of the bottom of the open channel, the drain electrode and the source electrode.
- 20 12. The FET biosensor of claim 1, wherein the open channel is configured to receive a drop casted material that includes one or more of the molecular recognition groups, the selected virus, and gold nanoparticles.
- 25 13. A vertical nano gap tunneling current biosensor, comprising:
a semiconductor substrate;
a first electrode oriented on the semiconductor substrate and configured to be connected to a parameter analyzer, the first electrode having a conductive sample surface including molecular recognition groups attached to the surface which are configured to bind with a selected virus, and having an open region located above the first electrode such that the a sample can be introduced onto the surface from
30 outside of the biosensor;
a second electrode spaced from the first electrode with a portion of the electrode protruding into the open region to form a nano-gap between the first electrode and

the second electrode, the nano-gap having a tunneling gap distance to enable a tunneling current between the first electrode and the second electrode when a voltage differential is provided between the first electrode and the second electrode; and

a dielectric layer separating the first electrode and the second electrode,

5 wherein the parameter analyzer is configured to detect a change in the tunneling current through the nano-gap over a range in voltage and the change in the tunneling current is used to identify when the selected virus is bound to the molecular recognition groups.

10 14. The vertical nano gap tunneling current biosensor of claim 13, wherein the semiconductor substrate comprises silicon and a passivation layer is oriented between the semiconductor substrate and the first electrode.

15 15. The vertical nano-gap tunneling current biosensor of claim 13, wherein the molecular recognition groups include at least one of aptamers, antibodies, and antigens.

16. The vertical nano-gap tunneling current biosensor of claim 13, wherein the selected virus is either SARS-CoV-2 or ZIKA.

20 17. The vertical nano-gap tunneling current biosensor of claim 13, wherein the first and second electrodes are formed of gold.

18. The vertical nano-gap tunneling current biosensor of claim 13, wherein the dielectric layer is silicon dioxide.

25 19. The vertical nano-gap tunneling current biosensor of claim 13, further including a hydrophobic layer coated on a top surface of the second electrode.

30 20. The vertical nano-gap tunneling current biosensor of claim 13, wherein the tunneling gap distance is formed to have a selected gap size based on the selected virus and the tunnel gap distance is orthogonal to a plane of the conductive sample surface.

21. A method of detecting a virus, comprising:
exposing a sensor surface to a fluid sample containing a suspected virus, wherein the
sensor surface is modified with aptamers selective for binding to the virus;
measuring an impedance spectrum of the sensor surface;
5 comparing the measured impedance spectrum with an impedance spectrum indicating
the presence of the virus bound to the aptamer; and
outputting a detection signal.
22. The method of claim 21, wherein the impedance of the sensor surface is measured
10 through a pair of electrodes in contact with the sensor surface.
23. The method of claim 22, wherein the pair of electrodes are an interdigital transducer.
24. The method of claim 21, wherein the virus is ZIKV or SARS-CoV-2.
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