CLAIMS

1. A method of testing a sample, comprising:

acquiring a first Fourier transform infrared (FTIR) spectrum from a surface-enhanced infrared absorption (SEIRA) sensor;

acquiring a second Fourier transform infrared (FTIR) spectrum from a surface-enhanced infrared absorption (SEIRA) sensor bound with a molecule complementary to a target molecule;

acquiring a third FTIR spectrum from the SEIRA sensor after providing the sample to the SEIRA sensor;

determining a first change from the first FTIR spectrum to the second FTIR spectrum;

determining a second change from the second FTIR spectrum to the third FTIR spectrum; and

based on the first change and the second change, determining a presence and/or a concentration of a target molecule in the sample, wherein each of the first change and the second change includes a change in intensity across a range of frequencies.

2. The method according to claim 1, wherein determining of the presence and/or the concentration of the target molecule in the sample comprises determining an area ratio, and wherein the area ratio is a ratio between the area under the first change and the area under the second change, and wherein the area ratio is indicative of a concentration of the target molecule in the sample.

3. The method according to claim 1 or claim 2, wherein determining the presence and/or the concentration of the target molecule in the sample comprises a shift in one or more resonance peak frequencies from the first FTIR spectrum to the second and third FTIR spectrum.

4. The method according to any one of claims 1 to 3, wherein the second FTIR spectrum corresponds to a first binding event between the complementary molecule

and metallic elements of the SEIRA sensor.

5. The method according to any one of claims 1 to 5, wherein the third FTIR spectrum corresponds to a target binding event between the target molecule and the first molecule bound to the SEIRA sensor.

6. The method according to any one of claims 1 to 5, comprising: acquiring each of the first FTIR spectrum, the second FTIR spectrum, and the third FTIR spectrum by measuring a respective reflection spectrum using a microscopic FTIR spectrometer.

7. The method according to any one of claims 1 to 6, comprising: binding one or more first molecules to nano-antennas of the SEIRA sensor, each of the one or more first molecules being selected from complementary molecules of at least one of a plurality of the target molecules.

8. The method according to claim 7, comprising: determining a concentration of each of the plurality of the target molecules based on the respective area ratio obtained from one acquisition of the second FTIR spectrum and third FTIR spectrum.

9. The method according to any one of claims 1 to 8, wherein the target molecule is one or more biomarkers.

10. The method according to any one of claims 1 to 9, wherein the first molecule is a single-stranded deoxyribonucleic acid (ssDNA) molecule, and wherein the target molecule is a micro ribonucleic acid (miRNA) molecule or another ssDNA molecule.

11. The method according to any one of claims 2 to 10, wherein the area ratio is linearly correlatable to any one or both of a reverse transcription-polymerase chain reaction (RT-qPCR) test result and a next-generation sequencing (NGS) test result.

12. A device for testing a sample according to the method recited in any one of claims 1 to 11, comprising:

a plurality of wells, each of the plurality of wells being at least partially circumscribed by a physical barrier to prevent fluidic communication through the physical barrier between the adjacent ones of the plurality of wells; and

a surface-enhanced infrared absorption (SEIRA) sensor disposed in each of the plurality of wells, wherein the SEIRA sensor is configured with a resonant response in a plurality of resonant peak frequencies distributed over a range of frequencies.

13. The device according to claim 12, wherein the SEIRA sensor comprises:

a substrate; and

multiple pairs of nano-antennas disposed on the substrate in a lattice array, wherein any one of the multiple pairs of nano-antennas include:

a shorter nano-antenna; and

a longer nano-antenna, wherein the shorter nano-antenna and the longer nano-antenna are in alignment along an axis of symmetry bisecting one of the multiple pairs of nano-antennas,

wherein, optionally, each of the multiple pairs of nano-antennas is dimensionally configured to exhibit a broadband multi-resonance with various resonance wavelengths;

wherein, optionally, the nano-antennas are dimensionally configured to exhibit a plurality of resonances matching respective absorption regions characteristic of one or more target molecules in the sample;

wherein, optionally, the dimensions of the nano-antennas are determined to produce resonance wavelengths matching characteristic fingerprints of one or more target molecules obtained by the attenuated total reflection FTIR under vacuum condition.

14. The device according to claim 13, wherein the lattice array is characterized by a period of 3 μm, and

wherein the shorter nano-antenna is characterized by a length of 0.8 micrometers (μm), a width of 0.08 μm, and a height of 0.1 μm, and

wherein the longer nano-antenna is characterized by a length of 2.6 μm, a width of 0.4 μm, and a height of 0.1 μm, and

wherein the shortest spacing between the shorter dipole and the longer dipole is 1.5 μm,

wherein the substrate is made of calcium difluoride (CaF_2) and the nano-antennas are made of gold (Au).

15. A method of testing a sample using the device according to claim 12, the sample being a mixed solution of one or more target molecules and one or more non-target molecules, the method comprising:

simultaneously acquiring a first Fourier transform infrared (FTIR) spectrum for each of a first well and a second well, the first well and the second well being selected from the plurality of wells and having dimensionally similar SEIRA sensors disposed therein, each of the SEIRA sensors including multiple pairs of nano-antennas patterned in a lattice array;

binding a first molecule to the multiple pairs of nano-antennas of the first well, the first molecule being complementary to a first target molecule;

binding a second molecule to the multiple pairs of nano-antennas of the second well, the second molecule being complementary to a second target molecule;

simultaneously acquiring a second Fourier transform infrared (FTIR) spectrum for each of the first well and the second well;

providing the mixed solution to the first well and the second well;

simultaneously acquiring a third FTIR spectrum for each of the first well and the second well;

simultaneously determining a presence and/or a concentration of the first target molecule and a presence and/or a concentration of the second target molecule;

determining a first area ratio based on the first FTIR spectrum of the first cell, the second FTIR spectrum of the first cell, and the third FTIR spectrum of the first well; and

determining a second area ratio based on the first FTIR spectrum of the second well, the second FTIR spectrum of the second well, and the third FTIR spectrum of the second well, wherein the first area ratio and the second area ratio are indicative of respective concentrations of different target molecules in the mixed solution.