CLAIMS

1. An integrated microfluidic photoionization detector (PID) comprising:

a microfluidic ionization chamber having an inlet that receives a fluid sample and an outlet through which the fluid sample exits the microfluidic ionization chamber, wherein the microfluidic ionization chamber comprises one or more microfluidic channels that define a first pattern;

a first electrode and a distinct second electrode in electrical communication with the microfluidic ionization chamber;

an integrated microfluidic ultraviolet radiation chamber that is configured to generate ultraviolet photons; ~~and~~

a first excitation electrode and a second excitation electrode disposed over and in electrical communication with the microfluidic ultraviolet radiation chamber, wherein the first excitation electrode and the second excitation electrode define a second pattern that corresponds to the first pattern of the one or more microfluidic channels of the microfluidic ionization chamber disposed below the microfluidic ultraviolet radiation chamber; and

a transmissive window disposed between the microfluidic ionization chamber and a first side of the microfluidic ultraviolet radiation chamber, the transmissive window defining a plate having one or more ultrathin transmissive regions defined therein each having a thickness of less than or equal to about 500 nm that permit the ultraviolet photons to pass from the microfluidic ultraviolet radiation chamber into the microfluidic ionization chamber.

~~2.~~ 2. The integrated microfluidic photoionization detector (PID) of claim 1, wherein the transmissive window comprises a material selected from the group consisting of: silica, fused silica, silicon, quartz, sapphire, magnesium fluoride, calcium fluoride, lithium fluoride, and combinations thereof.

~~3.~~ 3. The integrated microfluidic photoionization detector (PID) of any of claims 1 to 2, wherein the one or more ultrathin transmissive regions are defined as ~~one or more~~a pattern of select regions on ~~a~~the plate.

~~4.~~ 4. The integrated microfluidic photoionization detector (PID) of any of claims 1 to 3, wherein the ~~transmissive window is disposed on a support plate and the one or more ultrathin transmissive regions are defined within select regions of the support plate.~~

~~5. The integrated microfluidic photoionization detector (PID) of any of claims 1 to 4, wherein the transmissive window~~plate further comprises a stack of layers comprising a first layer and a second layer, wherein the one or more ultrathin transmissive regions are defined within the first layer where the second layer is absent.

5. The integrated microfluidic photoionization detector (PID) of any of claims 1 to 4, wherein the first layer and the second layer comprise silicon dioxide.

~~6.~~ 6. The integrated microfluidic photoionization detector (PID) of any of claims 1 to 5, wherein the transmissive window ~~has a thickness of less than or equal to about 20 μm and in~~is configured to transmit greater than or equal to about 5% of the ultraviolet photons.

~~7.~~ 7. The integrated microfluidic photoionization detector (PID) of any of claims 1 to 6, wherein the one or more ultrathin transmissive regions comprise a material selected from the group consisting of: silica and fused silica and have a thickness of greater than or equal to about 250 nm to less than or equal to about 500 nm.

~~8.~~ 8. The integrated microfluidic photoionization detector (PID) of any of claims 1 to 7, wherein the microfluidic ultraviolet radiation chamber has an inlet that receives an ultraviolet generating fluid.

~~9.~~ 9. The integrated microfluidic photoionization detector (PID) of any of claims 1 to 8, wherein the microfluidic ultraviolet radiation chamber comprises an ultraviolet generating fluid selected from the group consisting of: krypton, argon, helium, and combinations thereof.

~~10.~~ 10. The integrated microfluidic photoionization detector (PID) of any of claims 1 to 9, ~~wherein the microfluidic ionization chamber is one or more microfluidic channels and the integrated microfluidic photoionization detector (PID)~~ further ~~comprises~~comprising a ~~third electrode and a distinct fourth electrode formed in a~~cover layer disposed ~~over and in electrical communication with the~~ on a side of the microfluidic ultraviolet radiation chamber opposite to the transmissive window and the microfluidic ionization chamber, wherein the ~~third electrode and~~ cover layer comprises the ~~fourth~~first excitation electrode ~~define a~~and the second ~~pattern that corresponds to a first pattern of the one or more microfluidic channels of the microfluidic ionization chamber disposed below the microfluidic ultraviolet radiation chamber~~excitation electrode.

~~11.~~ 11. The integrated microfluidic photoionization detector (PID) of any of claims 1 to 10, wherein the microfluidic ionization chamber has a total volume of less than or equal to

about 10 microliters (μL~~) and the microfluidic ultraviolet radiation chamber has a total volume of less than about 10 μL.~~).

~~12.~~ 12. The integrated microfluidic photoionization detector (PID) of any of claims 1 to 11, wherein the first electrode and the distinct second electrode are formed in a layer of electrically conductive material and the one or more microfluidic channels are disposed in the layer to electrically insulate the first electrode from the second distinct electrode.

~~13.~~ 13. A detection system for one or more VOC analytes comprising:

(i) a gas chromatography (GC) unit that comprises at least one gas chromatography column; and

(ii) an integrated microfluidic photoionization detector (PID) disposed downstream of the gas chromatography (GC) unit that comprises:

a microfluidic ionization chamber having an inlet that receives a fluid sample and an outlet through which the fluid sample exits the microfluidic ionization chamber, wherein the microfluidic ionization chamber comprises one or more microfluidic channels that define a first pattern;

a first electrode and a distinct second electrode in electrical communication with the microfluidic ionization chamber;

an integrated microfluidic ultraviolet radiation chamber that is configured to generate ultraviolet photons; ~~and~~

a first excitation electrode and a second excitation electrode disposed over and in electrical communication with the microfluidic ultraviolet radiation chamber, wherein the first excitation electrode and the second excitation electrode define a second pattern that corresponds to the first pattern of the one or more microfluidic channels of the microfluidic ionization chamber disposed below the microfluidic ultraviolet radiation chamber; and

a transmissive window disposed between the microfluidic ionization chamber and the microfluidic ultraviolet radiation chamber, the transmissive window defining a plate having one or more ultrathin transmissive regions defined therein each having a thickness of less than or equal to about 500 nm that permit the ultraviolet photons

to pass from the microfluidic ultraviolet radiation chamber into the microfluidic ionization chamber, wherein the microfluidic photoionization detector (PID) analyzes a sample processed in the gas chromatography (GC) unit.

~~14.~~ 14. The detection system of claim 13, wherein the transmissive window comprises a material selected from the group consisting of: silica, fused silica, quartz, silicon, sapphire, magnesium fluoride, calcium fluoride, lithium fluoride, and combinations thereof.

~~15.~~ 15. The detection system of any of claims 13 to 14, wherein the one or more ultrathin transmissive regions are defined ~~on a~~as a pattern of select regions on the plate.

~~16.~~ 16. The detection system of any of claims 13 to 15, wherein the ~~transmissive window is disposed on a support~~ plate ~~and the one or more transmissive ultrathin regions are defined within select regions of the support plate.~~

~~17. The detection system of any of claims 13 to 16, wherein the transmissive window of the integrated microfluidic photoionization detector (PID)~~ further comprises a stack of layers comprising a first layer and a second layer, wherein the one or more ultrathin transmissive regions are defined within the first layer where the second layer is absent.

17. The detection system of any of claim 16, wherein the first layer and the second layer comprise silicon dioxide.

~~18.~~ 18. The detection system of any of claims 13 to 17, wherein the transmissive window ~~has a thickness of less than or equal to about 20 μm and~~ is configured to transmit greater than or equal to about 5% of the ultraviolet photons.

~~19.~~ 19. The detection system of any of claims 13 to 18, ~~wherein~~further comprising a cover layer disposed on a side of the microfluidic ultraviolet radiation chamber opposite to the transmissive window and the microfluidic ionization chamber ~~is one or more microfluidic channels and the integrated microfluidic photoionization detector (PID) further~~ wherein the cover layer comprises ~~a third~~the first excitation electrode and ~~a distinct fourth~~the second excitation electrode ~~formed in a layer disposed over and in electrical communication with the microfluidic ultraviolet radiation chamber, wherein the third electrode and the fourth electrode define a second pattern that corresponds to a first pattern of the one or more microfluidic channels of the microfluidic ionization chamber disposed below the microfluidic ultraviolet radiation chamber~~.

~~20.~~ 20. The detection system of claim 19, wherein the first electrode and the distinct second electrode are formed in a layer of electrically conductive material and the one or more microfluidic

channels are disposed in the layer to electrically insulate the first electrode from the second distinct electrode.