CLAIMS

1. A system for plasma-based remediation, comprising:

a flow reactor,

in which the flow reactor comprises an internal chamber and an electrode at least partially disposed within the internal chamber, the internal chamber being configured to be fluidly coupled to a gas source such that a gas from the gas source flows into the internal chamber of the flow reactor,

in which the gas comprises a concentration of a first chemical compound,

in which the first chemical compound is selected from the group consisting of NOx, SOx, and combinations thereof;

a pulse generator electrically coupled to the electrode of the flow reactor, the pulse generator being configured to deliver electrical pulses to the electrode to thereby form a non-thermal plasma from the gas, the first chemical compound being converted to a second chemical compound in the non-thermal plasma; and

a water source fluidly coupled to the internal chamber of the flow reactor, the water source being configured to inject water into the internal chamber of the flow reactor to form •OH (hydroxyl radical) molecules from at least a first portion of the injected water when the electrical pulses are delivered to the electrode, the •OH molecules reacting with the second chemical compound in the non-thermal plasma so as to convert the second chemical compound into a water soluble chemical compound, and at least a second portion of the injected water removing the water soluble chemical compound from the flow reactor, thereby reducing the concentration of the first chemical compound in the gas.

2. A system according to Claim 1, in which the electrode is selected from the group consisting of a three-wire electrode, a four-wire electrode, and an extruded electrode, in which the extruded electrode includes a central portion and at least one arm extending from the central portion.

3. A system according to Claim 1, in which NOx is NO and in which SOx is SO_2.

4. A system according to Claim 3, in which the second chemical compound is NO_2 or HSO_3.

5. A system according to Claim 4, in which the water soluble chemical compound is HNO_3 or H_2SO_4.

6. A system according to Claim 1, in which the pulse generator is a solid-state nanosecond high voltage pulse generator, and in which the electrical pulses are high voltage nanosecond electrical pulses.

7. A system according to Claim 1, in which the gas is an exhaust gas from combustion of a fuel.

8. A system according to Claim 1, in which the gas source is a combustion engine.

9. A method for plasma-based remediation, comprising:

receiving a gas from a gas source into an internal chamber of a flow reactor,

in which the gas comprises a concentration of a first chemical compound,

in which the first chemical compound is selected from the group consisting of NOx, SOx, and combinations thereof;

delivering electric pulses to an electrode positioned in the internal chamber such that a non-thermal plasma is formed from the gas,

in which the first chemical compound is converted to a second chemical compound in the non-thermal plasma;

injecting water into the internal chamber of the flow reactor in the presence of the non-thermal plasma,

in which $^{\bullet}OH$ (hydroxyl radical) molecules are formed from at least a first portion of the injected water when the electrical pulses are delivered to the electrode, and

in which the $^{\bullet}OH$ molecules react with the second chemical compound so as to convert the second chemical compound into a water soluble chemical compound; and

removing at least a second portion of the injected water from the flow reactor,

in which the second portion of the injected water comprises the water soluble compound, thereby reducing the concentration of the first chemical compound in the gas.

10. A method according to Claim 9, in which the electrode is selected from the group consisting of a three-wire electrode, a four-wire electrode, and an extruded electrode, in which the extruded electrode includes a central portion and at least one arm extending from the central portion.

11. A method according to Claim 9, in which NOx is NO, and in which SO_X is SO_2.

12. A method according to Claim 11, in which the second chemical compound is NO_2 or HSO_3.

13. A method according to Claim 12, in which the water soluble chemical compound is HNO_3 or H_2SO_4.

14. A method according to Claim 9, in which the electric pulses are delivered by a pulse generator, and in which the pulse generator is a solid-state nanosecond high voltage pulse generator, and in which the electrical pulses are high voltage nanosecond electrical pulses.

15. A method according to Claim 9, in which the gas is an exhaust gas from combustion of a fuel.

16. A plasma reactor for plasma-based remediation, comprising:

a flow reactor comprising an internal chamber;

a gas input port coupled to the flow reactor, the gas input port being configured to fluidly couple a gas source to the flow reactor such that a gas can flow into the internal chamber of the flow reactor;

an electrode at least partially disposed within the internal chamber of the flow reactor;

a pulse generator electrically coupled to the electrode, the pulse generator being configured to deliver electrical pulses to the electrode to thereby form a non-thermal plasma from the gas;

a water inlet port coupled to the flow reactor, the water inlet port being configured to fluidly couple a water source to the internal chamber of the flow reactor, the water source being configured to inject water into the internal chamber of the flow reactor in the presence of the non-thermal plasma;

a gas outlet port coupled to the flow reactor, the gas outlet port being configured to remove the gas from the internal chamber of the flow reactor; and

a water output port coupled to the flow reactor, the water output port being configured to remove the water from the internal chamber of the flow reactor.

17. A plasma reactor according to Claim 16, in which the electrode is selected from the group consisting of a three-wire electrode, a four-wire electrode, and an extruded electrode, in which the extruded electrode includes a central portion and at least one arm extending from the central portion.

18. A plasma reactor according to Claim 16, in which the pulse generator is a solid-state nanosecond high voltage pulse generator, and in which the electrical pulses are high voltage nanosecond electrical pulses.

19. A plasma reactor according to Claim 16, in which the gas is an exhaust gas from combustion of a fuel.

20. A plasma reactor according to Claim 16, in which the gas source is a combustion engine.

CLAIMS

1. A system for plasma-based remediation, comprising:

a flow reactor,

in which the flow reactor comprises an internal chamber and an electrode at least partially disposed within the internal chamber, the internal chamber being configured to be fluidly coupled to a gas source such that a gas from the gas source flows into the internal chamber of the flow reactor,

in which the electrode is selected from the group consisting of a three-wire electrode, a four-wire electrode and an extruded electrode, in which the extruded electrode includes a central portion and at least one arm extending from the central portion,

in which the gas comprises a concentration of a first chemical compound,

in which the first chemical compound is selected from the group consisting of NOx, SOx, and combinations thereof;

a pulse generator electrically coupled to the electrode of the flow reactor, the pulse generator being configured to deliver electrical pulses to the electrode to thereby form a non-thermal plasma from the gas, the first chemical compound being converted to a second chemical compound in the non-thermal plasma; and

a water source fluidly coupled to the internal chamber of the flow reactor, the water source being configured to inject water into the internal chamber of the flow reactor to form •OH (hydroxyl radical) molecules from at least a first portion of the injected water when the electrical pulses are delivered to the electrode, the •OH molecules reacting with the second chemical compound in the non-thermal plasma so as to convert the second chemical compound into a water soluble chemical compound, and at least a second portion of the injected water removing the water soluble chemical compound from the flow reactor, thereby reducing the concentration of the first chemical compound in the gas.

2. A system according to Claim 1, in which NOx is NO and in which SOx is SO_2.

3. A system according to Claim 2, in which the second chemical compound is NO_2 or HSO_3.

4. A system according to Claim 3, in which the water soluble chemical compound is HNO_3 or H_2SO_4.

5. A system according to Claim 1, in which the pulse generator is a solid-state nanosecond high voltage pulse generator, and in which the electrical pulses are high voltage nanosecond electrical pulses.

6. A system according to Claim 1, in which the gas is an exhaust gas from combustion of a fuel.

7. A system according to Claim 1, in which the gas source is a combustion engine.

8. A method for plasma-based remediation, comprising:

receiving a gas from a gas source into an internal chamber of a flow reactor,

in which the gas comprises a concentration of a first chemical compound,

in which the first chemical compound is selected from the group consisting of NOx, SOx, and combinations thereof;

delivering electric pulses to an electrode positioned in the internal chamber such that a non-thermal plasma is formed from the gas,

in which the electrode is selected from the group consisting of a three-wire electrode, a four-wire electrode and an extruded electrode, in which the extruded electrode includes a central portion and at least one arm extending from the central portion.

in which the first chemical compound is converted to a second chemical compound in the non-thermal plasma;

injecting water into the internal chamber of the flow reactor in the presence of the non-thermal plasma,

in which $^{\bullet}OH$ (hydroxyl radical) molecules are formed from at least a first portion of the injected water when the electrical pulses are delivered to the electrode, and

in which the •OH molecules react with the second chemical compound so as to convert the second chemical compound into a water soluble chemical compound; and

removing at least a second portion of the injected water from the flow reactor,

in which the second portion of the injected water comprises the water soluble compound, thereby reducing the concentration of the first chemical compound in the gas.

9. A method according to Claim 8, in which NOx is NO, and in which SOx is SO_2.

10. A method according to Claim 9, in which the second chemical compound is NO_2 or HSO_3.

11. A method according to Claim 10, in which the water soluble chemical compound is HNO_3 or H_2SO_4.

12. A method according to Claim 8, in which the electric pulses are delivered by a pulse generator, and in which the pulse generator is a solid-state nanosecond high voltage pulse generator, and in which the electrical pulses are high voltage nanosecond electrical pulses.

13. A method according to Claim 8, in which the gas is an exhaust gas from combustion of a fuel.

14. A plasma reactor for plasma-based remediation, comprising:

a flow reactor comprising an internal chamber;

a gas input port coupled to the flow reactor, the gas input port being configured to fluidly couple a gas source to the flow reactor such that a gas can flow into the internal chamber of the flow reactor;

an electrode at least partially disposed within the internal chamber of the flow reactor;

in which the electrode is selected from the group consisting of a three-wire electrode, a four-wire electrode and an extruded electrode, in which the extruded electrode includes a central portion and at least one arm extending from the central portion.

a pulse generator electrically coupled to the electrode, the pulse generator being configured to deliver electrical pulses to the electrode to thereby form a non-thermal plasma from the gas;

a water inlet port coupled to the flow reactor, the water inlet port being configured to fluidly couple a water source to the internal chamber of the flow reactor, the water source being configured to inject water into the internal chamber of the flow reactor in the presence of the non-thermal plasma;

a gas outlet port coupled to the flow reactor, the gas outlet port being configured to remove the gas from the internal chamber of the flow reactor; and

a water output port coupled to the flow reactor, the water output port being configured to remove the water from the internal chamber of the flow reactor.

15. A plasma reactor according to Claim 14, in which the pulse generator is a solid-state nanosecond high voltage pulse generator, and in which the electrical pulses are high voltage nanosecond electrical pulses.

16. A plasma reactor according to Claim 14, in which the gas is an exhaust gas from combustion of a fuel.

17. A plasma reactor according to Claim 14, in which the gas source is a combustion engine.