

CLAIMS

1. A dielectric barrier electrical discharge apparatus, comprising:
at least two electrodes arranged in use to provide at least one anode
and at least one cathode, an electric field thereby being establishable
5 therebetween, the at least two electrodes being separated to allow a fluid to be
present between the electrodes in use, wherein
at least one of the electrodes has a dielectric portion connected to at
least part of said electrode, and a sub-macroscopic structure being connected to
one of the at least two electrodes or to the dielectric portion, wherein in response
10 to the presence of the electric field between the electrodes, the sub-macroscopic
structure is arranged to field-emit electrons and electrical discharge is
establishable between the dielectric portion and one of the at least two
electrodes.
2. The apparatus according to claim 1, wherein the sub-macroscopic
15 structure is electrically connected to at least one of the electrodes.
3. The apparatus according to claim 2, wherein the or each electrode to
which the sub-macroscopic structure is electrically connected is arranged in use
to provide a cathode.
4. The apparatus according to claim 1, wherein the apparatus is for
20 scrubbing methane in waste gases and the at least two electrodes comprise a
first electrode and a second electrode, the first and second electrodes being
arranged in use to provide the anode and the cathode, the dielectric portion
being connected to the first electrode and the sub-macroscopic structure being
connected to the first or second electrode or to the dielectric portion, the
25 apparatus further comprising:
a housing coupled to the electrodes, the electrodes being located on the
housing so that the sub-macroscopic structure and the dielectric portion each
extend into a container containing gas to be scrubbed such that an interior of
said container can be exposed to said electrons and electrical discharge.

5. An apparatus for scrubbing methane in waste gases, the apparatus comprising:
- a first electrode and a second electrode, the first and second electrodes being arranged in use to provide an anode and a cathode;
 - 5 a dielectric portion connected to the first electrode and a sub-macroscopic structure connected to the first or second electrode or to the dielectric portion, wherein, in response to the presence of an electric field between the electrodes, the sub-macroscopic structure is arranged to field-emit electrons and electrical discharge is establishable between the dielectric and the
 - 10 second electrode; and
 - a housing coupled to the electrodes, the electrodes being located on the housing so that the sub-macroscopic structure and the dielectric portion each extend into a container containing gas to be scrubbed such that an interior of said container can be exposed to said electrons and electrical discharge.
- 15 6. The apparatus according to claim 4 or claim 5, wherein the first electrode is arranged in use to provide the anode.
7. The apparatus according to claim 4, claim 5 or claim 6, wherein the second electrode is arranged in use to provide the cathode.
8. The apparatus according to any one of claims 4 to 7, wherein the sub-
- 20 macroscopic structure is electrically connected to one of the electrodes.
9. The apparatus according to claim 8, wherein the sub-macroscopic structure is electrically connected to the second electrode.
10. The apparatus according to any one of the preceding claims, wherein the dielectric portion is a coating on at least part of a surface of the or each
- 25 electrode to which the dielectric portion is connected.
11. The apparatus according to any one of the preceding claims, wherein the dielectric portion is one or more of mica, quartz, alumina, titania, barium titanate, fused silica, titania silicate, silicon nitride, hafnium oxide or a ceramic.

12. The apparatus according to any one of the preceding claims, wherein the sub-macroscopic structure is a nanostructure, and preferably the nanostructure has an aspect ratio of length to width of at least 1,000.
13. The apparatus according to any one of claims 1 to 11, wherein the sub-
5 macroscopic structure is a microstructure, and preferably the microstructure has an aspect ratio of length to width of at least 5.
14. The apparatus according to any one of the preceding claims, wherein the electrodes are arranged to be between 20 degrees Celsius (°C) and 500 °C, and preferably between 100 °C and 400 °C, such as at 150 °C.
- 10 15. The apparatus according to any one of the preceding claims, further comprising a power supply connected to at least one of the electrodes, the power supply being arranged in use to provide a voltage pulse to said at least one electrode.
16. The apparatus according to claim 15, wherein the power supply is
15 arranged in use to provide a voltage pulse having at least one of the following:
a duration between 1 nanosecond (ns) and 1 millisecond (ms); and
a repeat periodicity of between 100 Hertz (Hz) and 500 kHz, the pulse repetition preferably forming a pulse train with a duty cycle of less than 50%.
17. A system for scrubbing methane in gas, the system comprising:
20 an apparatus according to any one of the preceding claims, the apparatus comprising electrodes separated to allow a gas to be present between the electrodes in use; and
a conduit connected to the apparatus and arranged in use to provide gas to the apparatus such that the gas passes between the electrodes, wherein
25 an electric field is establishable between the electrodes, the electric field being configured to cause electrical discharge between the electrodes to which the gas is exposed in use.

18. The system according to claim 17, further comprising an engine, wherein engine is connected to the conduit, the conduit being arranged in use to pass gas from the engine to the apparatus.
19. The system according to claim 18, wherein the engine uses LNG.
- 5 20. The system according to claim 18 or 19, wherein the conduit is connected to an exhaust outlet of the engine.
21. A method of scrubbing methane from a gas, the method comprising:
establishing an electric field between a first electrode to which a dielectric portion is connected and a second electrode, a sub-macroscopic
10 structure being connected to the first electrode, second electrode or dielectric portion, the electric field causing the sub-macroscopic structure to field emit electrons and electrical discharge to occur between the dielectric and the second electrode; and
exposing gas to be scrubbed to the electrical discharge and electrons.
- 15 22. Electrical discharge for use in scrubbing methane from a gas.
23. The electrical discharge according to claim 22, wherein the electrical discharge is barrier electrical discharge.
24. The electrical discharge according to claim 22 or 23, wherein the electrical discharge is dielectric barrier electrical discharge.
- 20 25. The electrical discharge according to any one of the preceding claims, wherein the gas is a waste gas.
26. The electrical discharge according to any one of the preceding claims, wherein the gas is gas from a Liquefied Natural Gas (LNG) engine.
27. Barrier electrical discharge for use in scrubbing methane in waste
25 gases.
28. Dielectric barrier electrical discharge for use in scrubbing methane in waste gases.

29. Use of electrical discharge in scrubbing methane from a gas.
30. The use according to claim 29, wherein the electrical discharge is barrier electrical discharge.
31. The use according to claim 29 or 30, wherein the electrical discharge is dielectric barrier electrical discharge.
32. The use according to any one of claims 29 to 31, wherein the gas is a waste gas.
33. The use according to any one of claims 29 to 32, wherein the gas is gas from an LNG engine.
34. Use of barrier electrical discharge in scrubbing methane in waste gases.
35. Use of dielectric barrier electrical discharge in scrubbing methane in waste gases.
36. A method of scrubbing methane in a gas with electrical discharge.
37. The method according to claim 36, wherein the electrical discharge is barrier electrical discharge.
38. The method according to claim 36 or claim 37, wherein the electrical discharge is dielectric barrier electrical discharge.