CLAIMS:

1. Apparatus for electron irradiation scrubbing, said apparatus comprising:

an anode;

a cathode;

a nanostructure located between said anode and said cathode, said nanostructure being electrically connect to the cathode and configured to field-emit electrons in response to the presence of an electric field between the anode and cathode when a potential difference is established therebetween; and

a housing coupled to said nanostructure and configured for locating the nanostructure so that the nanostructure extends into a container containing gas to be scrubbed such that an interior of said container can be exposed to said electrons.

2. The apparatus of claim 1, wherein the nanostructure is a carbon nanotube (CNT), the apparatus further comprising an additional electron source configured to impinge free electrons onto the CNT to induce stimulated electron field-emission therefrom;

optionally wherein said additional electron source is another nanostructure.

3. The apparatus of either of claim 1 or 2, further comprising an electrical power supply connection operatively coupled to the nanostructure and configured to provide a voltage pulse to the nanostructure.

4. The apparatus of any preceding claim, further comprising:

an array of nanostructures located between the anode and the cathode and electrically connected to the cathode, said array being configured to field-emit electrons in response to the presence of an electric field between the anode and cathode when a potential difference is established therebetween, and comprising said nanostructure;

a substrate on which the array is formed, said substrate optionally being comprised in or electrically connected to the cathode;

a heating element arranged to heat the nanostructure, optionally wherein said heating element is arranged in thermal contact with a side of said substrate reverse to that on which the array is present such that the heating element can conduct heat through the substrate to the array; and

either in addition to or as an alternative to the heating element, a current controlled power supply configured to heat said substrate by Ohmic heating; wherein:

the apparatus optionally further comprises an electrical power supply connection operatively coupled to the nanostructure and configured to provide a voltage pulse to the nanostructure.

5. The apparatus of any preceding claim, wherein:

the nanostructure is at least partially coated in a material having a work function of less than 4 eV, said material optionally comprising caesium or hafnium wherein, when dependent on claim 4, the coating material optionally has a melting point of at least 400°C; and/or

the nanostructure is at least partially coated in a catalytic coating, optionally wherein:

said catalytic coating comprises one or more of vanadium oxide, zinc oxide and tungsten trioxide; and/or

said catalytic coating is applied over a stabilising coating such as titanium dioxide; and/or

the nanostructure is doped with an electron transport enhancing material or electrical conductivity enhancing material;

optionally wherein the apparatus further comprises an array of nanostructures located between the anode and the cathode and electrically connected to the cathode, said array being configured to field-emit electrons in response to the presence of an electric field between the anode and cathode when a potential difference is established therebetween, and comprising said nanostructure, the array comprising a combination of at least two of:

one or more uncoated nanostructures,

one or more nanostructures at least partially coated in a material having a work function of less than 4 eV, and

one or more nanostructures at least partially coated in a catalytic coating.

6. The apparatus of any preceding claim, wherein the nanostructure is hollow, its interior being at least partially filled with a stiffening material, the stiffening material optionally comprising a transition metal such as titanium, iron or copper;

optionally wherein the apparatus further comprises:

an array of nanostructures located between the anode and the cathode and electrically connected to the cathode, said array being configured to field-emit electrons in response to the presence of an electric field between the anode and cathode when a potential difference is established therebetween, and comprising said nanostructure; and

a substrate on which the array is formed;

wherein:

the stiffening material comprises a material the substrate comprises, and optionally carbon; and

optionally, the substrate comprises titanium and the stiffening material comprises titanium carbide.

7. A system for electron irradiation scrubbing of flue gases, said system comprising:

at least four arrays of nanostructures located between the anode and the cathode and electrically connected to the cathode, said arrays being configured to field-emit electrons in response to the presence of an electric field between the anode and cathode when a potential difference is established therebetween and comprising said nanostructure, each array being formed on an electrically conductive substrate;

an electrical power supply;

electrical connections connecting said substrates, said power supply and ground in such a way that each substrate is at a different electrical potential; and

one or more housings coupled to the substrates and configured for locating said arrays such that their nanostructures extend into the container

containing gas to be scrubbed such that an interior of said container can be exposed to electrons field-emitted by the arrays;

wherein the substrates are arranged such that, for all the substrates except that at the highest electrical potential, a straight line path exists from a surface of each array defined by free ends of nanostructures forming that array to a corresponding surface of the array formed on the substrate at the next highest potential;

optionally wherein the substrates are arranged in a double zigzag pattern.

8. A ship comprising the apparatus of any of claims 1 to 6, or the system of claim 7, wherein the container is configured to contain emissions from said ship.

9. An electron irradiation scrubbing method to be performed with the apparatus of claim 1, any of claims 2 to 6 as dependent thereon, or the system of claim 7 as dependent thereon, the method comprising:

establishing a potential difference between the anode and the cathode such that the nanostructure is exposed to an electric field, resulting in field-emission of electrons by said nanostructure; and

exposing the gas to be scrubbed to said electrons.

10. The method of claim 9, wherein the nanostructure is a carbon nanotube (CNT), further comprising exposing the CNT to a free electron to induce stimulated electron field-emission from the CNT;

wherein said free electron was optionally emitted from an additional electron source by field-emission or stimulated field-emission, said additional electron source being another nanostructure.

11. The method of either of claims 9 or 10, further comprising providing a voltage pulse to the nanostructure, said pulse optionally having a magnitude lower than a breakdown voltage of said gas;

wherein said voltage pulse optionally:

has an absolute amplitude of from 100 V to 5 kV; and/or

has a duration of from 1 μs to 1 ms; and/or

is repeated periodically, optionally with a frequency of from 100 Hz to 500 kHz, optionally with a duty cycle of less than 50%.

12. The method of any of claims 9 to 11, wherein said nanostructure is arranged to generate said electron beam in an environment at an absolute pressure of no less than 80 kPa.

13. The method of any of claims 9 to 12, further comprising heating the nanostructure during said field-emission;

wherein the nanostructure is optionally heated to between 200 and 1000°C, optionally to between 300 and 900°C, optionally to between 400 to 800°C, optionally to between 400 and 600°C.

14. The method of any of claims 9 to 13, further comprising:

prior to exposing said gas to said electrons, mixing the gas with ammonia to form a gas mixture; and

subsequent to exposing said gas mixture to the electrons, collecting a powder produced thereby.