Claims

1. An electro-Fenton apparatus comprising:

a cathode; and

an anode, wherein

the cathode is a non-graphene carbon substrate coated with graphene or is graphene;

the graphene has a sheet resistance of from 4.0 to 5.5 kΩ sq^{-1}; and

when the cathode is a non-graphene carbon substrate coated with graphene the graphene coating comprises a graphene and a binder material where the weight ratio of graphene to binder material is from 1:1 to 1:10.

2. The apparatus of Claim 1, wherein:

(a) the graphene has a sheet resistance of from 4.4 to 5.1 kΩ sq^{-1}; and/or

(b) the graphene-coated cathode has a resistance value of less than or equal to 3.0 Ω, such as less than or equal to 0.2 Ω, such as less than or equal to 0.1 Ω; and/or

(c) the graphene-coated cathode, when compared to an equivalent uncoated cathode, has a decrease in its resistance value of greater than or equal to 90%, such as greater than or equal to 92.8%; and/or

(d) the cathode has an electroactive surface area of from 2,000 cm^2 to 10,000 cm^2, such as from 3,500 cm^2 to 5,000 cm^2 (e.g. 4,665 cm^2); and/or

(e) the cathode has an electroactive surface area of greater than or equal to 1000% in comparison to an equivalent uncoated cathode; and/or

(f) the binder material is a fluorocarbon polymer.

3. The apparatus of Claim 1, wherein:

(a) when the cathode is a non-graphene carbon substrate coated with graphene, the non-graphene carbon substrate is selected from the group consisting of a carbon cloth, a carbon felt, a carbon fiber wire, graphite or a carbon fiber brush; or

(b) when the cathode is graphene, the graphene is in the form of a graphene foam, a monolayer of graphene on a substrate or a multilayer graphene.

4. The apparatus of Claim 3, wherein the non-graphene carbon substrate is a carbon cloth (e.g. carbon cloth treated with polytetrafluoroethylene) or a carbon fiber brush.

5. The apparatus of Claim 1, wherein the anode is a boron doped diamond anode.

6. The apparatus of Claim 5, wherein the boron doped diamond anode comprises a boron doped diamond coating on a substrate, optionally wherein the substrate for the boron doped diamond coating is selected from one or more of the group consisting of tantalum, tungsten, silicon, titanium and niobium.

7. An electro-Fenton process to treat a wastewater, comprising:

contacting a wastewater with a cathode and an anode in a vessel under electro-Fenton conditions, wherein:

the cathode is a non-graphene carbon substrate coated with graphene or is graphene,

the graphene has a sheet resistance of from 4.0 to 5.5 kΩ sq^{-1}; and

when the cathode is a non-graphene carbon substrate coated with graphene the graphene coating comprises a graphene and a binder material where the weight ratio of graphene to binder material is from 1:1 to 1:10,

optionally wherein the process further comprises adding a catalytic amount of an iron (II) salt to a wastewater in need thereof.

8. The process of Claim 7, wherein:

(a) the graphene has a sheet resistance of from 4.4 to 5.1 kΩ sq^{-1}; and/or

(b) the cathode has a resistance value of less than or equal to 3.0 Ω, such as less than or equal to 0.2Ω, such as less than or equal to 0.1 Ω; and/or

(c) the graphene-coated cathode, when compared to an equivalent uncoated cathode, has a decrease in its resistance value of greater than or equal to 90%, such as greater than or equal to 92.8%; and/or

(d) the cathode has an electroactive surface area of from 2,000 cm^2 to 10,000 cm^2, such as from 3,500 cm^2 to 5,000 cm^2 (e.g. 4,665 cm^2); and/or

(e) the cathode has an electroactive surface area of greater than or equal to 1000% in comparison to an equivalent uncoated cathode.

9. The process of Claim 7, wherein:

(a) when the cathode is a non-graphene carbon substrate coated with graphene, the non-graphene carbon substrate is selected from the group consisting of a carbon cloth, a carbon felt, a carbon fiber wire, graphite or a carbon fiber brush; or

(b) when the cathode is graphene, the graphene is in the form of a graphene foam, a monolayer of graphene on a substrate or a multilayer graphene.

10. The process of Claim 9, wherein the non-graphene carbon substrate is a carbon cloth or a carbon fiber brush.

11. The process of Claim 7, wherein the anode is a boron doped diamond anode.

12. The process of Claim 11, wherein the boron doped diamond anode comprises a boron doped diamond coating on a substrate, optionally wherein the substrate is selected from one or more of the group consisting of tantalum, tungsten, silicon, titanium and niobium.

13. Use of a non-graphene carbon substrate coated with graphene or graphene as a cathode in an electro-Fenton process, wherein:

the graphene has a sheet resistance of from 4.0 to 5.5 kΩ sq^{-1}; and

when the use is a use of a non-graphene carbon substrate coated with graphene as a cathode in an electro-Fenton process, the graphene coating comprises a graphene and a binder material where the weight ratio of graphene to binder material is from 1:1 to 1:10.

14. The use of Claim 13, wherein the electro-Fenton process relates to the treatment of a wastewater.

15. The use of Claim 13, wherein:

(a) the graphene has a sheet resistance of from 4.4 to 5.1 kΩ sq^{-1}; and/or

(b) the graphene-coated cathode has a resistance value of less than or equal to 3.0 Ω, such as less than or equal to 0.2Ω, such as less than or equal to 0.1 Ω; and/or

(c) the graphene-coated cathode, when compared to an equivalent uncoated cathode, has a decrease in its resistance value of greater than or equal to 90%, such as greater than or equal to 92.8%; and/or

(d) the cathode has an electroactive surface area of from 2,000 cm^2 to 10,000 cm^2, such as from 3,500 cm^2 to 5,000 cm^2 (e.g. 4,665 cm^2); and/or

(e) the cathode has an electroactive surface area of greater than or equal to 1000% in comparison to an equivalent uncoated cathode.

16. The use of Claim 13, wherein:

(a) when the cathode is a non-graphene carbon substrate coated with graphene, the non-graphene carbon substrate is selected from the group consisting of a carbon cloth, a carbon felt, a carbon fiber wire, graphite or a carbon fiber brush; or

(b) when the cathode is graphene, the graphene is in the form of a graphene foam, a monolayer of graphene on a substrate or a multilayer graphene (e.g. from 2 to 800 layers).

17. The use of Claim 16, wherein the non-graphene carbon substrate is a carbon cloth or a carbon fiber brush.

18. The use of Claim 13, wherein the use further comprises the use of a boron doped diamond anode.

19. The use Claim 18, wherein the boron doped diamond anode comprises a boron doped diamond coating on a substrate, optionally wherein the substrate is selected from one or more of the group consisting of tantalum, tungsten, silicon, titanium and niobium.

20. The apparatus according to any one of Claims 1 to 6, wherein the cathode is a non-graphene carbon substrate coated with graphene; or

the process according to any one of Claims 7 to 12, wherein the cathode is a non-graphene carbon substrate coated with graphene; or

the use according to any one of Claims 13 to 19, wherein the use is a use of a non-graphene carbon substrate coated with graphene as a cathode in an electro-Fenton process.