[0010] The present invention seeks to provide an edge-functionalised graphene platelet structure which substantially retains the beneficial properties of pure graphene but is also capable of being stored in higher concentrations than existing graphene structures.

Summary

[0011] The present disclosure provides a dispersible graphene platelet including: a base layer of graphene; at least one discontinuous graphene layer stacked on the base layer; wherein the at least one discontinuous layer has a smaller surface area than the base layer; and, wherein the edge regions of the base layer and the at least one discontinuous layer are at least partially functionalised.

[0011a] In one aspect, the present disclosure provides a dispersible graphene platelet comprising: a base layer of graphene; at least one discontinuous graphene layer stacked on the layer it is stacked upon; wherein each discontinuous layer has a smaller surface area than the base layer; wherein each base layer and each discontinuous layer is defined by a central region and an edge region; and wherein edge regions of the base layer and the at least one discontinuous layer are at least partially functionalized and the central regions of the base layer and discontinuous layer/s are unfunctionalized; and wherein the platelet is able to form a stable dispersion in water at concentrations up to 10 mg/mL for at least 3 months, to form a stable suspension in water at concentrations over 100 mg/mL for at least 6 hours, or to form a stable suspension in organic solvents at concentrations of 50 mg/mL for at least 6 hours.

[0012] In certain examples of the first aspect, the platelet is able to form a stable dispersion in water at concentrations up to 700 mg/mL.

[0013] In certain examples of the first aspect, the electrical conductivity of the platelet is approximately 900 S/cm.

[0014] In certain examples of the first aspect, the platelet is further functionalised by the addition of metal ions to at least one of the functionalised edges or the surface.

[0015] In certain examples of the first aspect, the metal ions are selected from Fe, Cu, Co, and Sn.

[0016] According to a second example, there is provided a polymer-matrix composite material comprising a polymer; and graphene platelets according to the first aspect.

[0016a] According to a second aspect, there is provided a polymer-matrix composite material comprising a polymer selected from alginate, chitosan, polyvinyl alcohol (PVA), polyethylene glycol (PEG), polyurethane (PU), polyethyleneimine (PEI), polyvinylidene fluoride (PVDF), polydimethylsiloxane (PDMS) and poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS); and graphene platelets according to the first aspect.

[0017] In certain examples of the second aspect, the polymer is selected from alginate, chitosan, PVA, PEG, PU, PEI, PVDF, PDMS or PEDOT PSS.

[0018] According to a third example, there is provided an electrode for electrochemical processes comprising; graphene platelets according the first aspect; and a binder.

[0018a] According to a third aspect, there is provided an electrode for electrochemical process comprising; graphene platelets according to the first aspect; and a binder selected from Nafion and polyvinylidene fluoride (PVDF).

[0019] In certain examples of the third aspect, the binder is selected from Nafion and PVDF.

[0020] According to a fourth aspect, there is provided a method for producing an electrode according to the third aspect, comprising: creating a mixture containing graphene platelets according to the first aspect and a binder; and coating the mixture onto an electrode substrate.

[0021] According to a fifth example, there is provided a method for producing dispersible graphene platelets including the steps of:

a. suspending graphite or graphene in a solution containing an organic nitrile (such as acetonitrile), an ester (such as ethyl acetate) and water; and

b. reacting the solution containing suspended graphite or graphene with an oxidant (such as ruthenium tetroxide) to at least partially functionalise edge regions of the graphite or graphene.

[0021a] According to a fifth aspect, there is provided a method for producing dispersible graphene platelets including the steps of:

a. suspending graphene in a solution containing methyl cyanide, ethyl acetate and water; and

b. reacting the solution containing suspended graphene with sodium periodate and ruthenium trichloride to at least partially functionalise edge regions of the graphite or graphene without modifying an inner structure of the graphene.

[0022] In certain examples of the fifth aspect, the method further comprises the step of: cooling the resultant solution obtained in step b. in an ice bath.

[0023] In certain examples of the fifth aspect, the method further comprises the step of: homogenising the resultant solution obtained in step b.

[0024] In certain examples of the fifth aspect, the homogenisation is conducted at 20000 rpm up to 2 hours.

[0025] In certain examples of the fifth aspect, the method further comprises the step of: ultrasonicating the resultant solution obtained in step b.

[0026] In certain examples of the fifth aspect, the method further comprises the step of: filtering the resultant solution obtained in step b to produce a filtered solid.

[0027] In certain examples of the fifth aspect, the method further comprises the step of: washing the filtered solid.

[0028] In certain examples of the fifth aspect, washing includes washing the filtered solid with HCl and water.

[0029] In certain examples of the fifth aspect, the filtered solid is washed with HCl until a filtrate produced by washing the filtered solid is colourless and then with water until the filtrate is neutral.

[0041] According to a sixth example, there is provided a dispersible graphene platelet according to the first aspect, produced by a method according to the fifth aspect.

[0041a] According to a seventh example, there is provided a method for producing dispersible graphene platelets including the steps of: suspending graphite or graphene in a solution; and, contacting the solution containing suspended graphite or graphene with an oxidant to at least partially functionalise edge regions of the graphite or graphene.

Brief Description of the Figures

[0042] FIGURE 1 shows a schematic representation of a dispersible graphene platelet.

[0043] FIGURE 2 shows a low magnification bright field TEM image of a single dispersible graphene platelet.

[0044] FIGURE 3 shows a high magnification bright field TEM image of the edge of a dispersible graphene platelet.

[0045] FIGURE 4 shows an SEM image of a dispersible graphene platelet at 5000x magnification.

[0046] FIGURE 5A shows a Raman spectrum for a sample of graphene platelets.

[0047] FIGURE 5B shows a Raman spectrum for 99.9999% graphite.

[0048] FIGURE 6A shows an expanded 2D band from the Raman spectrum of the edges of a dispersible graphene platelet.

[0049] FIGURE 6B shows an expanded 2D band from the Raman spectrum of the basal plane of a dispersible graphene platelet.

[0050] FIGURE 7A shows the XRD spectrum for a sample of graphene platelets.

[0051] FIGURE 7B shows the XRD spectrum for both 99.9999% graphite and graphene platelets.

[0052] FIGURE 8 shows an XPS spectrum for a sample of graphene platelets.

[0053] FIGURE 9 shows a graph of the titration of a dispersion of the graphene platelets.

The claims defining the invention are as follows:

1. A dispersible graphene platelet comprising:

   a base layer of graphene;

   at least one discontinuous graphene layer stacked on the base layer;

   wherein each discontinuous layer has a smaller surface area than the layer it is stacked upon;

   wherein each base layer and each discontinuous layer is defined by a central region and an edge region; and

   wherein edge regions of the base layer and the at least one discontinuous layer are at least partially functionalised and the central regions of the base layer and discontinuous layer/s are unfunctionalised; and

   wherein the platelet is able to form a stable dispersion in water at concentrations up to 10 mg/mL for at least 3 months, to form a stable suspension in water at concentrations over 100 mg/mL for at least 6 hours, or to form a stable suspension in organic solvents at concentrations of 50 mg/mL for at least 6 hours.

2. The platelet according to claim 1, wherein the electrical conductivity of the platelet is approximately 900 S/cm.

3. The platelet according to claim 1 or claim 2, wherein the platelet is further functionalised by the addition of metal ions selected from Fe, Cu, Co and Sn to the functionalised edges of the platelet.

4. A polymer-matrix composite material comprising

   a polymer selected from alginate, chitosan, polyvinyl alcohol (PVA), polyethylene glycol (PEG), polyurethane (PU), polyethyleneimine (PEI), polyvinylidene fluoride (PVDF), polydimethylsiloxane (PDMS) and poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS); and

   graphene platelets according to any one of claims 1 to 3.

5. An electrode for electrochemical processes comprising;

   graphene platelets according to any one of claims 1 to 3; and

a binder selected from Nafion and polyvinylidene fluoride (PVDF).

6. A method for producing an electrode according to claim 5, comprising:
   creating a mixture containing graphene platelets according to any one of claims 1 to 3 and a binder; and
   coating the mixture onto an electrode substrate.

7. A method for producing dispersible graphene platelets including the steps of:
   a. suspending graphene in a solution containing methyl cyanide, ethyl acetate and water; and,
   b. reacting the solution containing suspended graphene with sodium periodate and ruthenium trichloride to at least partially functionalise edge regions of the graphite or graphene without modifying an inner structure of the graphene.

8. The method according to claim 7, further comprising the step of:
   cooling and homogenising the resultant solution obtained in step b. in an ice bath wherein the homogenisation is conducted at up to 20000 rpm up to 2 hours.

9. The method according to claim 7 or claim 8, further comprising the step of:
   ultrasonicating the resultant solution obtained in step b.

10. The method according to any one of claims 7 to 9, further comprising the step of:
    filtering the resultant solution obtained in step b to produce a filtered solid, and washing the filtered solid with HCl and water or an organic solvent.

11. The method according to any one of claims 7 to 10, wherein the filtered solid is dried in vacuo to produce a dried powder.

12. The method according to any one of claims 7 to 10, wherein the filtered solid is freeze dried to produce a dried powder.

13. The method according to claim 11 or claim 12, wherein the dried powder is dispersed in water and sonicated for up to 30 minutes, and a resulting mixture is allowed to settle for up to 48 hours to produce a solid and a supernatant, and decanting and filtering the supernatant to produce a graphene powder, which is washed with an organic solvent and dried.

14. The method according to claim 11 or claim 12 wherein the dried powder is dispersed in water and sonicated for up to 30 minutes, and a resulting mixture is centrifuged to produce a solid and a supernatant.

15. The method according to any one of claims 7 to 14, wherein ruthenium tetroxide is provided via the reaction of sodium periodate with ruthenium trichloride added to the solution containing suspended graphene.

16. The method according to any one of claims 10 to 15, wherein the filtered solid is then dispersed in a solution containing metal ions selected from Fe, Cu, Co and Sn, to bind metal ions to at least one of a surface or a functionalised edge of the platelet.