CLAIMS

What is claimed is the following:

1. A process for preparing graphene nanoribbons, said process comprising:

exposing a plurality of carbon nanotubes to an alkali metal source in the absence of a solvent;

wherein exposing opens the carbon nanotubes parallel to their longitudinal axis; and

after exposing, adding an electrophile to form functionalized graphene nanoribbons.

2. The process of claim 1, wherein the alkali metal source comprises an alkali metal vapor.

3. The process of claim 1, wherein the alkali metal source comprises a molten alkali metal.

4. The process of claim 1, wherein the alkali metal source comprises an alkali metal selected from the group consisting of potassium, rubidium, cesium and combinations thereof.

5. The process of claim 4, wherein the alkali metal comprises potassium.

6. The process of claim 4, wherein the alkali metal is covalently bound to the graphene nanoribbons before the electrophile is added.

7. The process of claim 6, wherein the electrophile displaces the alkali metal from the graphene nanoribbons and introduces a plurality of functional groups to the functionalized graphene nanoribbons.

8. The process of claim 6, further comprising:

transmetalating the alkali metal with a transmetalating species before adding the electrophile;

wherein the transmetalating species comprises at least one element selected from the group consisting of boron, an alkaline earth metal, a transition metal, a rare earth metal, and combinations thereof.

9. The process of claim 8, wherein the transmetalating species comprises at least one element selected from the group consisting of magnesium, zinc, tin, palladium, copper, nickel, and combinations thereof.

10. The process of claim 1, wherein exposing takes place at a temperature between about 50°C and about 500°C.

11. The process of claim 10, wherein exposing takes place at a temperature between about 250°C and about 300°C.

12. The process of claim 1, wherein the carbon nanotubes comprise multi-walled carbon nanotubes.

13. The process of claim 1, wherein the electrophile is selected from the group consisting of water, alcohols, organic halides and synthetic equivalents thereof, aldehydes, ketones, carboxylic acids, carboxylic esters, carboxylic acid chlorides, carboxylic acid anhydrides, enones, nitriles, carbon dioxide, halogens, vinyl monomers, ring-opening monomers and combinations thereof.

14. The process of claim 13, wherein the vinyl monomers are selected from the group consisting of styrene, acrylonitrile, methyl vinyl ketone, alkyl acrylates, alkyl methacrylates, and combinations thereof.

15. The process of claim 1, wherein the electrophile is added in a solvent.

16. The process of claim 1, wherein the electrophile is added neat.

17. The process of claim 1, further comprising:

exfoliating the functionalized graphene nanoribbons to form exfoliated, functionalized graphene nanoribbons.

18. The process of claim 17, wherein exfoliating comprises exposing the functionalized graphene nanoribbons to a superacid solvent.

19. The process of claim 1, further comprising:

oxidizing the functionalized graphene nanoribbons to form oxidized, functionalized graphene nanoribbons.

20. The process of claim 1, further comprising:

defunctionalizing the functionalized graphene nanoribbons to form defunctionalized graphene nanoribbons.

21. The process of claim 20, wherein defunctionalizing comprises a thermal defunctionalization process.

22. A process for preparing graphene nanoribbons, said process comprising:

exposing a plurality of multi-walled carbon nanotubes to a potassium metal source in the absence of a solvent;

wherein exposing opens the multi-walled carbon nanotubes parallel to their longitudinal axis; and

after exposing, adding an electrophile to form functionalized graphene nanoribbons.

23. The process of claim 22, wherein the potassium metal source comprises potassium metal vapor.

24. The process of claim 22, wherein the potassium metal source comprises molten potassium metal.

25. The process of claim 22, wherein exposing takes place at a temperature between about 50°C and about 500°C.

26. The process of claim 25, wherein exposing takes place at a temperature between about 250°C and about 300°C.

27. The process of claim 22, wherein the electrophile is selected from the group consisting of water, alcohols, organic halides and synthetic equivalents thereof, aldehydes, ketones, carboxylic acids, carboxylic esters, carboxylic acid chlorides, carboxylic acid anhydrides, enones, nitriles, carbon dioxide, halogens, vinyl monomers, ring-opening monomers and combinations thereof.

28. The process of claim 22, further comprising:

exfoliating the functionalized graphene nanoribbons to form exfoliated, functionalized graphene nanoribbons.

29. The process of claim 22, further comprising:

oxidizing the functionalized graphene nanoribbons to form oxidized, functionalized graphene nanoribbons.

30. The process of claim 22, further comprising:

defunctionalizing the functionalized graphene nanoribbons to form defunctionalized graphene nanoribbons.

31. Functionalized graphene nanoribbons prepared by the process of claim 1.

32. Exfoliated, functionalized graphene nanoribbons prepared by the process of claim 17.

33. Defunctionalized graphene nanoribbons prepared by the process of claim 20.

CLAIMS

1. A manufacture method of graphene nanoribbons, comprising:

exposing a plurality of carbon nanotubes to an alkali metal source under a non-presence of a solvent to cleave by exposure the carbon nanotubes parallel to a vertical axis thereof; and

adding an electrophile after exposure to form functionalized graphene nanoribbons.

2. The method according to claim 1, wherein the alkali metal source includes an alkali metal vapor.

3. The method according to claim 1, wherein the alkali metal source includes a molten alkali metal.

4. The method according to claim 1, wherein the alkali metal source includes an alkali metal selected from a group consisting of potassium, rubidium, cesium, and a combination thereof.

5. The method according to claim 4, wherein the alkali metal includes potassium.

6. The method according to claim 4, wherein the alkali metal is covalently bonded to the graphene nanoribbons before adding the electrophile.

7. The method according to claim 6, wherein the alkali metal is replaced from the graphene nanoribbons by the electrophile and a plurality of functional groups is introduced to the functionalized graphene ribbons.

8. The method according to claim 6, further comprising: metal exchanging the alkali metal using a metal exchange species before adding the electrophile; wherein

here, the metal exchange species includes at least one type of element selected from a group consisting of boron, an alkaline-earth metal, a transition metal, a rare-earth metal, and a combination thereof.

9. The method according to claim 8, wherein the metal exchange species includes at least one type of element selected from a group consisting of magnesium, zinc, tin, palladium, copper, nickel, and a combination thereof.

10. The method according to claim 1, wherein exposure is performed at a temperature between 50°C and 500°C.

11. The method according to claim 10, wherein exposure is performed at a temperature between 250°C and 300°C.

12. The method according to claim 1, wherein the carbon nanotubes include multiwall carbon nanotubes.

13. The method according to claim 1, wherein the electrophile is selected from a group consisting of water, an alcohol, an organohalide and a synthetic equivalent thereof, an aldehyde, a ketone, carboxylic acid, a carboxylate ester, a carboxylic acid chloride, a carboxylic acid anhydride, an enone, a nitrile, carbon dioxide, a halogen, a vinyl monomer, a ring-opening monomer, and a combination thereof.

14. The method according to claim 13, wherein the vinyl monomer is selected from a group consisting of styrene, acrylonitrile, methyl vinyl ketone, an alkyl acrylate, an alkyl methacrylate, and a combination thereof.

15. The method according to claim 1, wherein the electrophile is added in a solvent.

16. The method according to claim 1, wherein the electrophile is added as-is.

17. The method according to claim 1, further comprising: peeling multiwall functionalized graphene nanoribbons to form peeled functionalized graphene nanoribbons.

18. The method according to claim 17, wherein peeling includes exposing the functionalized graphene nanoribbons to a superacid solvent.

19. The method according to claim 1, further comprising: oxidizing the functionalized graphene nanoribbons to form oxidized functionalized graphene nanoribbons.

20. The method according to claim 1, further comprising: de-functionalizing the functionalized graphene nanoribbons to form de-functionalized graphene nanoribbons.

21. The method according to claim 20, wherein de-functionalization includes a thermal de-functionalization process.

22. A manufacture method of graphene nanoribbons, comprising:

exposing a plurality of multiwall carbon nanotubes to a potassium metal source under a non-presence of a solvent to cleave by exposure the multiwall carbon nanotubes parallel to a vertical axis thereof; and

adding an electrophile after exposure to form functionalized graphene nanoribbons.

23. The method according to claim 22, wherein the potassium metal source includes a potassium metal vapor.

24. The method according to claim 22, wherein the potassium metal source includes a molten potassium metal.

25. The method according to claim 22, wherein exposure is performed at a temperature between 50°C and 500°C.

26. The method according to claim 25, wherein exposure is performed at a temperature between 250°C and 300°C.

27. The method according to claim 22, wherein the electrophile is selected from a group consisting of water, an alcohol, an organohalide and a synthetic equivalent thereof, an aldehyde, a ketone, carboxylic acid, a carboxylate ester, a carboxylic acid chloride, a carboxylic acid anhydride, an enone, a nitrile, carbon dioxide, a halogen, a vinyl monomer, a ring-opening monomer, and a combination thereof.

28. The method according to claim 22, further comprising: peeling the functionalized graphene nanoribbons to form peeled functionalized graphene nanoribbons.

29. The method according to claim 22, further comprising: oxidizing the functionalized graphene nanoribbons to form oxidized functionalized graphene nanoribbons.

30. The method according to claim 22, further comprising: de-functionalizing the functionalized graphene nanoribbons to form de-functionalized graphene nanoribbons.

31. Functionalized graphene nanoribbons manufactured by the method according to claim 1.

32. Peeled functionalized graphene nanoribbons manufactured by the method according to claim 17.

33. De-functionalized graphene nanoribbons manufactured by the method according to claim 20.