CLAIMS

~~What is claimed is:~~

1. A structure comprising a substrate comprising an activated adsorbent material and a metal species deposited thereon, wherein the metal species comprises a metal, a metal oxide, a metal oxide phosphate, a multi-metal oxide, a perovskite, a metal sulfide, a metal nitride, a metal phosphide, an organometallic compound, or a combination thereof.

2. The structure of claim 1, wherein the metal species deposited thereon is a film, layer, or coating.

3. The structure of claim 1 or 2, wherein other than activation, the activated adsorbent material is not additionally modified.

4. The structure of any of claims 1-3, wherein the activated adsorbent material comprises activated carbon, carbon charcoal, nanostructured carbon, expanded graphite, graphene, zeolites, clays, porous polymers, porous alumina, porous silica, molecular sieves, kaolin, titania, ceria, or a combination thereof.

5. The structure of any of claims 1-4, wherein the activated adsorbent material comprises an activated carbon in a powder, granular, pellet-, monolith, or honeycomb form.

6. The structure of claim 5, wherein the activated carbon is derived from at least one of wood, wood dust, wood flour, cotton linters, peat, coal, coconut, lignite, carbohydrates, petroleum pitch, petroleum coke, coal tar pitch, fruit pits, fruit stones, nut shells, nut pits, sawdust, palm, vegetables, a synthetic polymer, natural polymer, lignocellulosic material, or a combination thereof.

7. The structure of claim 5 or 6, wherein the activated carbon is activated using an activating comprising at least one of phosphoric acid, sulfuric acid, boric acid, nitric acid, oxygenated acids, steam, air, peroxides, alkali hydroxides, metal chlorides, ammonia, carbon dioxide, or a combination thereof.

8. The structure of any of claims 1-7, wherein the activated adsorbent material is

characterized by a mesoporous pore size, ~~macroporous pore size, or a combination thereof~~.

9. The structure of any of claims 1-8, wherein the activated adsorbent material is characterized by a nitrogen B.E.T. surface area from about 600 to about 2500 ~~, or from about 800 to about 1800, or about 1000 to about 1600~~ square~~d~~ meters per gram.

10. The structure of any of claims 5-7, wherein the activated carbon has a bulk oxygen to carbon ratio of less than or equal to about 0.25 at a depth less than 5 nm ~~of less than or equal to about 0.25~~.

11. The structure of any of claims 5-7 or 10, wherein the activated carbon has a bulk phosphorous to carbon ratio of less than or equal to about 0.10 at a depth less than 5 nm ~~of less than or equal to about 0.10~~.

12. The structure of any of claims 5-7 10 or 11, wherein the activated carbon has a bulk nitrogen to carbon ratio at a depth less than 5 nm of less than or equal to about 0.15.

13. The structure of any of claims 5-7 or 10-12, wherein the activated carbon has a surface oxygen to carbon ratio of less than or equal to about 1, based on the total number of surface carbons.

14. The structure of any of claims 5-7 or 10-13, wherein the activated carbon has at least one of (i) surface phosphorous to carbon ratio of less than or equal to about 0.33, based on the total number of surface carbons, (ii) surface nitrogen to carbon ratio of less than or equal to about 0.5, based on the total number of surface carbons or (iii) surface oxygen of oxidized phosphorous to phosphorous ratio of less than or equal to about 1.0, based on the total number of surface phosphorous atoms.

~~15. The structure of any of claims 5-7 or 10-14, wherein the activated carbon has a surface nitrogen to carbon ratio of less than or equal to about 0.5, based on the total number of surface carbons.~~

~~16. The structure of any of claims 5-7 or 10-15, wherein the activated carbon has a surface oxygen of oxidized phosphorous to phosphorous ratio of less than or equal to about~~

~~1.0, based on the total number of surface phosphorous atoms.~~

~~17. The structure of any of claims 1-16, wherein the metal species is derived from a metal species precursor comprising at least one metal and at least one ligand.~~

~~18. The structure of any of claims 1-17, wherein the metal species comprises a metal, a metal oxide, a metal oxide phosphate, a multi metal oxide, a perovskite, a metal sulfide, a metal nitride, a metal phosphide, an organometallic compound, or a combination thereof.~~

~~19.~~15. The structure of any of claims 1-1~~4~~8, wherein the metal species comprises titanium oxide.

~~20.~~16. The structure of any of claims 1-1~~4~~9 and 15, wherein the metal species comprises palladium.

~~21.~~17. The structure of any of claims 1-14~~2~~0, 15 and 16, wherein the structure comprises from about 0.5 to about 50 wt% of the metal species, based on the total weight of the structure.

~~22. A method for preparing a structure according to the steps comprising:~~

~~a. providing an activated adsorbent material in a reactor;~~

~~b. administering at least one atomic layer deposition cycle to deposit a metal species, wherein the administering at least one atomic layer deposition cycle comprises:~~

~~i. introducing a first precursor gas into the reactor to provide a metal species precursor deposited on a surface of the activated adsorbent material;~~

~~ii. introducing a second precursor gas into the reactor to provide the structure.~~

~~23. The method of claim 22, wherein step b is performed 2 to 10 times.~~

~~24. The method of claim 22 or 23, further comprising a step after step (b)(i), after step (b)(ii), or a combination thereof comprising purging the reactor.~~

~~25. The method of any of claims 22-24, wherein the activated adsorbent material comprises activated carbon, carbon charcoal, nanostructured carbon, expanded graphite, graphene, zeolites, clays, porous polymers, porous alumina, porous silica, molecular sieves, kaolin, titania, ceria, or a combination thereof.~~

~~26. The method of any of claims 22-25, wherein the first precursor gas comprises at least one metal and at least one ligand.~~

~~27. The method of any of claims 22-26, wherein the first precursor gas comprises a metal halide, a metal oxyhalide, an organometallic compound, or a combination thereof.~~

~~28. The method of any of claims 22-27, wherein the second precursor gas is capable of displacing a ligand of the metal species precursor deposited on the surface of the activated adsorbent material.~~

~~29. The method of any of claims 22-28, wherein the second precursor gas comprises H_2O, H_2O_2, O_2, O_3, N_2O, NO, NO_2, NH_3, ammonia, 1,1-dimethylhydrazine, tert-butylamine, or allylamine, an alcohol, PH_3, $P(O)OMe_3$, hydrogen sulfide, H_2, ambient air, formalin, or a combination thereof.~~

~~30. The method of any of claims 22-29, wherein the activated adsorbent material is derived from at least one of wood, wood dust, wood flour, cotton linters, peat, coal, coconut, lignite, carbohydrates, petroleum pitch, petroleum coke, coal tar pitch, fruit pits, fruit stones, nut shells, nut pits, sawdust, palm, vegetables, a synthetic polymer, natural polymer, lignocellulosic material, or a combination thereof.~~

~~31. The method of any of claims 22-30, wherein the activated adsorbent material is characterized by a nitrogen B.E.T. surface area from about 600 to about 2500, or from about 800 to about 1800, or about 1000 to about 1600 squared meters per gram.~~

~~32. The method of any of claims 22-31, wherein the absorbent material comprises activated carbon in a powder, granular, pellet , monolith, or honeycomb form.~~

~~33. The method of claim 32, wherein the activated carbon has a bulk oxygen to carbon ratio at a depth less than 5 nm of less than or equal to about 0.25.~~

~~34. The method of claim 32 or 33, wherein the activated carbon has a bulk phosphorous to carbon ratio at a depth less than 5 nm of less than or equal to about 0.10.~~

~~35. The method of any of claims 32-34, wherein the activated carbon has a bulk nitrogen to carbon ratio at a depth less than 5 nm of less than or equal to about 0.15.~~

~~36. The method of any of claims 32-35, wherein the activated carbon has a surface oxygen to carbon ratio of less than or equal to about 1.0, based on the total number of surface carbons.~~

~~37. The method of any of claims 32-36, wherein the activated carbon has a surface phosphorous to carbon ratio of less than or equal to about 0.33 based on the total number of surface carbons.~~

~~38. The method of any of claims 32-37, wherein the activated carbon has a surface nitrogen to carbon ratio of less than or equal to about 0.5, based on the total number of surface carbons.~~

~~39. The method of any of claims 32-38, wherein the activated carbon has a surface oxygen of oxidized phosphorous to phosphorous ratio of less than or equal to about 1.0, based on the total number of surface phosphorous atoms.~~

~~40.~~18. A~~The~~ method for preparing a structure~~of any of claims 32-39~~ comprising:

a. providing an activated carbon powder in a reactor;

b. administering at least one atomic layer deposition cycle to deposit ~~the~~a metal species comprising ~~titanium oxide~~ metal precursor, wherein the administering at least one

atomic layer deposition cycles comprises:

i. introducing ~~$TiCl_4$~~ metal precursor gas into the reactor to provide ~~titanium chloride~~metal precursor deposited on a surface of the activated carbon powder;

ii. introducing water vapor or ambient air into the reactor to provide the ~~titanium~~ metal oxide deposited on the surface of the activated carbon powder.

~~41. The method of claim 22, wherein at least one of:~~

~~a. the activated adsorbent material is an activated carbon powder;~~

~~b. the metal species comprises palladium;~~

~~c. the first precursor gas is palladium hexafluoro-acetylacetone;~~

~~d. the second precursor gas is formalin or ambient air; or~~

~~e. a combination thereof~~

~~42. A method of comprising:~~

~~a. providing an activated carbon powder in a reactor;~~

~~b. administering at least one atomic layer deposition cycle to deposit a metal species comprising palladium, wherein the administering at least one atomic layer deposition cycle comprises:~~

~~i. introducing bis(2,2,6,6-tetramethyl-3,5-heptanedionato)palladium(II) into the reactor to provide a palladium intermediate deposited on a surface of the activated carbon powder; and~~

~~ii. introducing ambient air into the reactor to provide the palladium deposited on the surface of the activated carbon powder.~~

19. The method of claim 14, wherein the activated carbon is derived from at least one of wood, wood dust, wood flour, cotton linters, peat, coal, coconut, lignite, carbohydrates, petroleum pitch, petroleum coke, coal tar pitch, fruit pits, fruit stones, nut shells, nut pits, sawdust, palm, vegetables, a synthetic polymer, natural polymer, lignocellulosic material, or a combination thereof.

20. The method of claim 14 or 15, wherein the activated carbon is activated using an activating comprising at least one of phosphoric acid, sulfuric acid, boric acid, nitric acid, oxygenated acids, steam, air, peroxides, alkali hydroxides, metal chlorides, ammonia, carbon dioxide, or a combination thereof.

21. The method of any of claims 14-16, wherein the activated carbon is characterized by a mesoporous pore size, macroporous pore size, or a combination thereof.

22. The method of any of claims 14-17, wherein the activated carbon is characterized by a nitrogen B.E.T. surface area from about 600 to about 2500 square meters per gram.

23. The method of any of claims 14-18, wherein the activated carbon has a bulk oxygen to carbon ratio of less than or equal to about 0.25 at a depth less than 5 nm.

24. The method of any of claims 14-19, wherein the activated carbon has a bulk phosphorous to carbon ratio of less than or equal to about 0.10 at a depth less than 5 nm.