CLAIMS

1. Adsorbents comprising:

metal oxide particles having a wide pore size distribution as measured by a pore size distribution span 90 value of at least about 1.0; and

polymeric material covalently bonded to surfaces of said metal oxide particles.

2. The adsorbents of claim 1, wherein said metal oxide particles have a median particle size of less than about 150 µm,

preferably less than about 100 µm,

more preferred about 10 to about 50 µm,

in particular about 30 µm.

3. The adsorbents of any one of claims 1 or 2, wherein said metal oxide particles have a median pore size of less than about 2000 Å,

preferably less than about 1000 Å,

more preferred about 100 to about 800 Å,

still more preferred about 150 to about 250 Å,

in particular about 200 Å.

4. The adsorbents of any one of claims 1 to 3, wherein said metal oxide particles have a pore size distribution of from about 30 to about 5000 Å,

preferably about 50 to about 3000 Å.

5. The adsorbents of any one of claims 1 to 4 , wherein said metal oxide particles have a BET particle surface area of at least about 100 m^2/g,

preferably at least about 300 m^2/g,

more preferred at least about 500 m^2/g,

still more preferred about 600 to about 800 m^2/g,

in particular about 700 m^2/g.

6. The adsorbents of any one of claims 1 to 5, wherein said metal oxide particles have a pore volume, as measured by mercury intrusion, of at least about 0.25 ml/g,

preferably at least about 0.50 ml/g,

more preferred at least about 1.00 ml/g,
still more preferred at least about 1.50 ml/g,
in particular about 1.77 ml/g.

7. The adsorbents of any one of claims 1 to 6, wherein said metal oxide particles have a pore size distribution span 90 value of at least about 2.0,
preferably at least about 3.0,
more preferred about 5.0 to about 10.0,
still more preferred about 7.5 to about 8.5,
in particular about 7.8.

8. The adsorbents of any one of claims 1 to 7, further comprising at least one bifunctional moiety extending from said surfaces of said metal oxide particles, each of said at least one bifunctional moiety comprising (i) one or more functional groups capable of bonding to said surfaces, and either (iia) said polymeric material, or (iib) one or more reactive groups capable of bonding to said polymeric material.

9. The adsorbents of claim 8, wherein said at least one bifunctional moiety comprises an epoxy silane.

10. The adsorbents of any one of claims 8 or 9, wherein said at least one bifunctional moiety comprises (3-glycidoxypropyl)-trimethoxysilane.

11. The adsorbents of any one of claims 1 to 10, wherein said polymeric material is covalently bonded to said surfaces via a covalent bond linkage consisting of one or more atoms selected from the group consisting of C, O, Si and N.

12. The adsorbents of any one of claims 1 to 11, wherein said polymeric material comprises a polyelectrolyte,
Preferably said polymeric material comprises polyethyleneimine, polyallylamine, polyvinyl pyridine, polydiallyldimethylammonium chloride (pDADMAC), or a copolymer containing one or more cationic or cationic-forming functional groups, in particular polyethyleneimine.

13. The adsorbents of any one of claims 1 to 12, wherein said adsorbents comprises a reaction product of said metal oxide particles and an aqueous trimethoxysilyl-polyethyleneimine solution.

14. The adsorbents of any one of claims 12 or 13, wherein said polyethyleneimine has (i) a weight average molecular weight, Mw, and (ii) a number average molecular weight, Mn, each of which is less than about 5000,

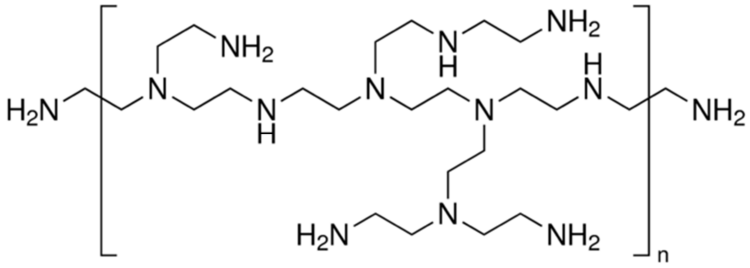
preferably (i) a weight average molecular weight, Mw, and

(ii) a number average molecular weight, Mn, each of which ranges from about 500 to about 2500,

more preferred (i) a weight average molecular weight, Mw, ranging from about 800 to about 2000, and

(ii) a number average molecular weight, Mn, ranging from about 600 to about 1800.

15. The adsorbents of any one of claims 12 to 14, wherein said polyethyleneimine has a structure:



prior to being covalently bonded to said surfaces, and n is a number greater than or equal to 1.

16. The adsorbents of any one of claims 1 to 12, wherein said polymeric material comprises an anionic polyelectrolyte.

17. The adsorbents of any one of claims 1 to 12 and 16, wherein the polymeric material comprises polyacrylic acid, polymethacrylic acid, polystyrene sulfonic acid, nucleic acid, or a copolymer containing one or more anionic or anionic-forming functional groups,

preferably polyacrylic acid, polymethacrylic acid, or a combination thereof,

wherein said polyacrylic acid or said polymethacrylic acid preferably has a weight average molecular weight, Mw, greater than about 50,000,

more preferred about 100,000 to about 250,000.

18. The adsorbents of any one of claims 1 to 17, wherein said polymeric material is present in an amount representing up to about 20.0 wt% of said adsorbents based on a total weight of said adsorbents,

preferably about 1.0 to about 15.0 wt% of said adsorbents based on a total weight of said adsorbents.

19. The adsorbents of any one of claims 1 to 18, wherein less than 100% of said surfaces are bonded to said polymeric material.

20. The adsorbents of any one of claims 1 to 19, wherein said metal oxide particles comprise silica particles.

21. The adsorbents of any one of claims 1 to 20 bound to one or more particular biological compounds,

wherein the one or more particular biological compounds preferably comprise a protein, a polysaccharide, a lipid, a nucleic acid, a metabolites, a mammalian cell, mammalian cell debris, an antibody, a peptide, DNA, RNA, an endotoxin, a virus, a vaccine, an enzyme, or any combination thereof.

22. A method of making the adsorbents of any one of claims 1 to 20, said method comprising:
contacting the metal oxide particles with one or more reactants under reaction conditions that result in the polymeric material covalently bonded to the surfaces of the metal oxide particles.

23. The method of claim 22, wherein the one or more reactants comprise at least one bifunctional compound comprising (i) one or more functional groups capable of bonding the compound to the surfaces of the metal oxide particles, and either (iia) the polymeric material, or (iib) one or more reactive groups capable of bonding to the polymeric material.

24. The method of any one of claims 22 and 23, wherein said contacting step utilizes a reaction mixture free of organic solvent.

25. Use of adsorbents as defined in any of claims 1 to 20 as a bioprocessing clarification agent.

26. Use of the adsorbents according to claim 25, wherein the adsorbents is added to a bioprocessing vessel containing one or more biomolecules, the one or more biomolecules preferably comprising a protein, a polysaccharide, a lipid, a nucleic acid, a metabolites, a mammalian cell, mammalian cell debris, an antibody, a peptide, DNA, RNA, an endotoxin, a virus, a vaccine, an enzyme, or any combination thereof.

27. Use of the adsorbents according to any one of claims 25 or 26, wherein the adsorbents bind to one or more biomolecules that come into contact with the adsorbents.

28. Use of the adsorbents according to any one of claims 25 to 27, wherein the adsorbents is added to a bioprocessing vessel containing at least one of: host cells and cell debris; antibodies, proteins and peptides; nucleic acids, such as DNA and RNA; endotoxins; viruses; vaccines.

29. Use of the adsorbents according to any one of claims 25 to 28, wherein following a binding step in which the adsorbents binds to one or more biomolecules that come into contact with the adsorbents, separating the adsorbents bound to the one or more biomolecules from other components of a bioprocessing procedure.