

CLAIMS

1. Adsorbents for use as a bioprocessing clarification agent, said adsorbents comprising:
 - metal oxide particles having a wide pore size distribution as measured by a pore size distribution span 90 value of greater than 2.5; 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 .
3. The adsorbents of claim 2, wherein said metal oxide particles have a median pore size of less than about 2000 Å.
4. The adsorbents of claim 3, wherein said metal oxide particles have a pore size distribution of from about 30 to about 5000 Å.
5. The adsorbents of claim 1, wherein said metal oxide particles have a BET particle surface area of at least about 100 m^2/g up to about 1000 m^2/g .
6. The adsorbents of claim 1, wherein said metal oxide particles have a pore volume, as measured by mercury intrusion, of from about 1.0 ml/g up to about 2.0 ml/g .
7. The adsorbents of claim 1, wherein said metal oxide particles have a pore size distribution span 90 value of about 2.8 to about 7.8.
8. The adsorbents of claim 1, 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 claim 9, wherein said at least one bifunctional moiety comprises (3-glycidoxypentyl)-trimethoxysilane.

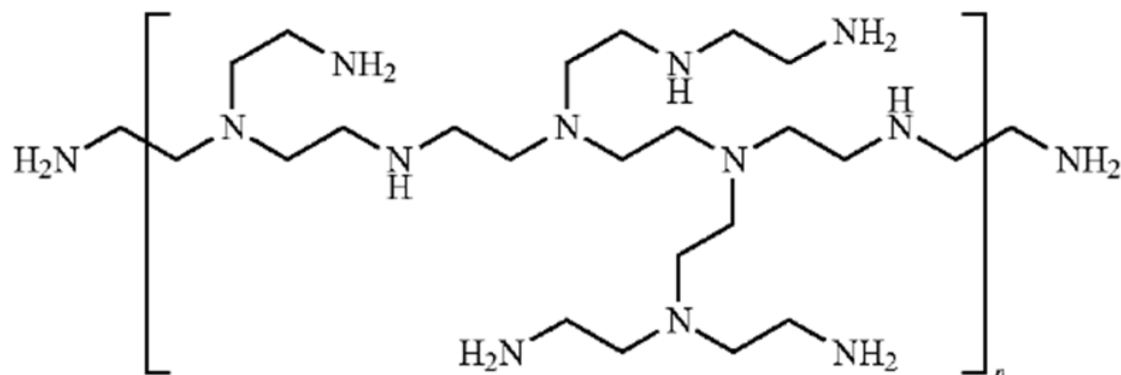
11. The adsorbents of claim 1, wherein said polymeric material is covalently bonded to said surfaces via a covalent bond linkage consisting of one or more atoms selected from the group consisting of C, O, Si and N.

12. The adsorbents of claim 1, wherein said polymeric material comprises a cationic polyelectrolyte.

13. The adsorbents of claim 12, wherein said cationic polyelectrolyte comprises polyethyleneimine, polyallylamine, polyvinyl pyridine, polydiallyldimethylammonium chloride (pDADMAC), or a copolymer containing one or more cationic or cationic-forming functional groups or the reaction product of said metal oxide particles and an aqueous trimethoxysilyl-polyethyleneimine solution.

14. The adsorbents of claim 13, wherein said cationic polyelectrolyte comprises polyethyleneimine having (i) a weight average molecular weight, Mw, and (ii) a number average molecular weight, Mn, each of which is less than about 5000.

15. The adsorbents of claim 13, wherein said cationic polyelectrolyte comprises polyethyleneimine having 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 claim 1, wherein said polymeric material comprises an anionic polyelectrolyte.

17. The adsorbents of claim 16, wherein the anionic polyelectrolyte comprises polyacrylic acid, polymethacrylic acid, polystyrene sulfonic acid, nucleic acid, or a copolymer containing one or more anionic or anionic-forming functional groups.

18. The adsorbents of claim 1, 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.

19. The adsorbents of claim 1, wherein less than 100% of said surfaces are bonded to said polymeric material.

20. The adsorbents of claim 1, wherein said metal oxide particles comprise silica particles.

21. The adsorbents of claim 1, wherein the adsorbents are bound to one or more particular biological compounds, wherein the one or more particular biological compounds 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 claim 1, said method comprising:

contacting the metal oxide particles having a wide pore size distribution as measured by a pore size distribution span 90 value of greater than 2.5 with one or more reactants under reaction conditions that result in the polymeric material covalently bonded to the surfaces of the metal oxide particles, wherein said contacting step utilizes a reaction mixture free of organic solvent.

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. A method of using adsorbents as defined in claim **1** as a bioprocessing clarification agent, wherein the adsorbents are added to a bioprocessing vessel containing one or more biomolecules, the one or more biomolecules 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.

25. Adsorbents for use as a bioprocessing clarification agent, said adsorbents comprising:

metal oxide particles having a wide pore size distribution as measured by a pore size distribution span 90 value of greater than 2.0; and

a cationic polyelectrolyte covalently bonded to surfaces of said metal oxide particles, wherein said cationic polyelectrolyte comprises polyethyleneimine, polyallylamine, polyvinyl pyridine, polydiallyldimethylammonium chloride (pDADMAC), or a copolymer containing one or more cationic or cationic-forming functional groups or the reaction product of said metal oxide particles and an aqueous trimethoxysilyl-polyethyleneimine solution.

26. The adsorbents of claim **25**, wherein said metal oxide particles comprise silica particles having (i) a wide pore size distribution as measured by a pore size distribution span 90 value of from about 2.8 to about 7.8, (ii) a BET particle surface area of at least about 100 m²/g up to about 1000 m²/g, and (iii) a pore volume, as measured by mercury intrusion, of from about 1.0 ml/g to about 2.0 ml/g.

27. The adsorbents of claim **26**, wherein said cationic polyelectrolyte comprises polyethyleneimine.

28. Adsorbents for use as a bioprocessing clarification agent, said adsorbents comprising:

metal oxide particles having a wide pore size distribution as measured by a pore size distribution span 90 value of from about 2.8 to about 7.8; and

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

29. The adsorbents of claim **28**, wherein said metal oxide particles comprise silica particles having (i) a BET particle surface area of at least about 100 m²/g up to about 1000 m²/g, and (ii) a pore volume, as measured by mercury intrusion, of from about 1.0 ml/g to about 2.0 ml/g.