CLAIMS

We claim:

1. A method for coupling a ligand to a functionalized composite material, comprising the steps of:

    a. providing a functionalized composite material, wherein the functionalized composite material is arranged in a coplanar stack of coextensive sheets, a tubular configuration, or a spiral wound configuration, comprising:

        i. a support member, comprising a plurality of pores extending through the support member; and

        ii. a macroporous cross-linked gel, wherein the macroporous cross-linked gel comprises a polymer formed from a reaction of one or more polymerizable monomers with one or more cross-linkers; the macroporous cross-linked gel comprises a plurality of pendant reactive functional groups; the macroporous cross-linked gel is located in the pores of the support member; and said macropores of the macroporous cross-linked gel are smaller than the pores of the support member; and

    b. flowing at a first flow rate a first solution substantially through or substantially across the functionalized composite material, wherein the first solution comprises a plurality of first ligands, such that a plurality of covalent bonds forms between the reactive functional groups and the first ligands.

2. The method of claim 1, wherein the pendant reactive functional groups are selected from the group consisting of aldehydes, amines, carbon-carbon double bonds, carbon-carbon triple bonds, epoxides, hydroxyls, thiols, anhydrides, azides, reactive halogens, acid chlorides, and a mixture thereof.

3. The method of claim 1, wherein the pendant reactive functional groups are selected from the group consisting of carbon-carbon double bonds, carbon-carbon triple bonds, and thiols.

4. The method of claim 1, wherein the pendant reactive functional groups are derived from a molecule comprising a thiol functional group or a molecule comprising an unsaturated carbon-carbon bond.

5. The method of claim 4, wherein the pendant reactive functional groups are derived from a molecule comprising a thiol functional group; and the molecule comprising a thiol

functional group is selected from the group consisting of 3-mercaptopropionic acid, 1-mercaptosuccinic acid, a polypeptide comprising a cysteine residue, a protein comprising a cysteine residue, a recombinant protein comprising a cysteine residue, a bacterial immunoglobulin-binding protein comprising a cysteine residue, a recombinant fusion protein comprising a cysteine residue, cysteamine, 1-thiohexitol, poly(ethylene glycol) 2-mercaptoethyl ether acetic acid, poly(ethylene glycol) methyl ether thiol, 1-thioglycerol, 2-naphthalenethiol, biphenyl-4-thiol, 3-amino-1,2,4-triazole-5-thiol, 5-(trifluoromethyl)pyridine-2-thiol, 1-[2-(dimethylamino)ethyl]-1H-tetrazole-5-thiol, 1-propanethiol, 1-butanethiol, 1-pentanethiol, 1-hexanethiol, 1-octanethiol, 8-amino-1-octanethiol hydrochloride, 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluoro-1-octanethiol, 8-mercapto-1-octanol, and γ-Glu-Cys.

6. The method of claim 5, wherein the molecule comprising a thiol functional group is a polypeptide comprising a cysteine residue, a protein comprising a cysteine residue, a recombinant protein comprising a cysteine residue, a bacterial immunoglobulin-binding protein comprising a cysteine residue, and a recombinant fusion protein comprising a cysteine residue.

7. The method of claim 6, wherein the molecule comprising a thiol functional group is a protein comprising a cysteine residue.

8. The method of claim 4, wherein the pendant reactive functional groups are derived from a molecule comprising an unsaturated carbon-carbon bond; and the molecule comprising an unsaturated carbon-carbon bond is selected from the group consisting of 1-octene, 1-hexyne, 4-bromo-1-butene, allyldiphenylphosphine, allylamine, allyl alcohol, 3,4-dihydroxy-1-butene, 7-octene-1,2-diol, 3-allyloxy-1,2-propanediol, 3-butenoic acid, 3,4-dehydro-L-proline, vinyl laurate, 1-vinyl-2-pyrrolidinone, vinyl cinnamate, an acylamide, or an acrylate.

9. The method of claim 1, wherein the pendant reactive functional groups are selected from the group consisting of aldehydes, amines, epoxides, hydroxyls, anhydrides, azides, reactive halogens, and acid chlorides.

10. The method of claim 9, wherein the one or more monomers comprising a pendant reactive functional group are selected from the group consisting of glycidyl methacrylate, acrylamidoxime, acrylic anhydride, azelaic anhydride, maleic anhydride, hydrazide, acryloyl chloride, 2-bromoethyl methacrylate, and vinyl methyl ketone.

11. The method of claim 9, wherein the pendant reactive functional groups are amines.

12. The method of claim 9, wherein the pendant reactive functional groups are epoxides.

13. The method of claim 9, wherein the pendant reactive functional groups are hydroxyls.

14. The method of any one of the preceding claims, wherein the first ligand comprises a first functionality.

15. The method of claim 14, wherein the first ligand further comprises at least one grafting end-group; and the first functionality is selected from the group consisting of cationic, anionic, hydrophobic, hydrophilic, thiophilic, hydrogen bond donating, hydrogen bond accepting, pi-pi bond donating, pi-pi bond accepting, metal chelating, a biological molecule, and a biological ion.

16. The method of claim 15, wherein the first functionality is selected from the group consisting of cationic, anionic, hydrophobic, hydrophilic, thiophilic, hydrogen bond donating, hydrogen bond accepting, pi-pi bond donating, and pi-pi bond accepting.

17. The method of claim 15, wherein a molecule comprises a first functionality, and the molecule is selected from the group consisting of 2-(diethylamino)ethyl methacrylate, 2-aminoethyl methacrylate, 2-carboxyethyl acrylate, 2-(methylthio)ethyl methacrylate, acrylamide, N-acryloxysuccinimide, butyl acrylate or methacrylate, N,N-diethylacrylamide, N,N-dimethylacrylamide, 2-(N,N-dimethylamino)ethyl acrylate or methacrylate, N-[3-(N,N-dimethylamino)propyl]methacryl-amide, N,N-dimethylacrylamide, ethyl acrylate or methacrylate, 2-ethylhexyl methacrylate, hydroxypropyl methacrylate, glycidyl acrylate or methacrylate, ethylene glycol phenyl ether methacrylate, methacrylamide, methacrylic anhydride, propyl acrylate or methacrylate, N-isopropylacrylamide, styrene, 4-vinylpyridine, vinylsulfonic acid, N-vinyl-2-pyrrolidinone (VP), acrylamido-2-methyl-1-propanesulfonic acid, styrenesulfonic acid, alginic acid, (3-acrylamidopropyl)trimethylammonium halide, diallyldimethylammonium halide, 4-vinyl-N-methylpyridinium halide, vinylbenzyl-N-trimethylammonium halide, methacryloxyethyltrimethylammonium halide, 3-sulfopropyl methacrylate, 2-(2-methoxy)ethyl acrylate or methacrylate, hydroxyethyl acrylamide, N-(3-methoxypropyl acrylamide), N-[tris(hydroxymethyl)methyl]acrylamide, N-phenyl acrylamide, N-tert-butyl acrylamide, or diacetone acrylamide.

18. The method of claim 15, wherein the first functionality is a metal chelating functionality.

19. The method of claim 15, wherein the first functionality comprises a metal chelating functionality selected from the group consisting of octadentate, hexadentate, tetradentate, tridentate, bidentate, iminodicarboxylic acid, and iminodiacetic acid.

20. The method of claim 15, wherein the first functionality comprises a biological molecule or a biological ion functionality selected from the group consisting of albumins, lysozyme, viruses, cells, γ-globulins of human and animal origins, immunoglobulins of both human and animal origins, proteins of recombinant or natural origin including, polypeptides of synthetic or natural origin, interleukin-2 and its receptor, enzymes, monoclonal antibodies, antigens, lectins, bacterial immunoglobulin-binding proteins, trypsin and its inhibitor, cytochrome C, myoglobulin, recombinant human interleukin, recombinant fusion protein, Protein A, Protein G, Protein L, Peptide H, nucleic acid derived products, DNA of either synthetic or natural origin, and RNA of either synthetic or natural origin.