

CLAIMS

What is claimed is:

1. A membrane assembly comprising:

- a. a porous membrane comprising poly(tetrafluoroethylene), wherein the membrane has a coating thereon, wherein the coating is prepared from the polymerization of at least one monomer and at least one cross-linker, wherein the monomer has a positive charge in an organic liquid; and
- b. a porous membrane comprising poly(tetrafluoroethylene), wherein the membrane has a coating thereon, wherein the coating is prepared from the polymerization of at least one monomer and at least one cross-linker, wherein the monomer has a negative charge in an organic liquid; and

wherein the assembly exhibits a total removal efficiency of greater than 90% of one or more metal ions chosen from ions of lithium, boron, sodium, magnesium, aluminum, potassium, calcium, titanium, vanadium, chromium, manganese, iron, nickel, copper, zinc, molybdenum, silver, tin, barium, and lead, from a feed stream containing 1ppb of metal ions chosen from ions of lithium, boron, sodium, magnesium, aluminum, potassium, calcium, titanium, vanadium, chromium, manganese, iron, nickel, copper, zinc, molybdenum, silver, tin, barium, and lead.

2. The membrane assembly of claim 1, wherein the assembly exhibits a total removal efficiency of greater than 90% for all of the metal ions chosen from ions of lithium, boron, sodium, magnesium, aluminum, potassium, calcium, titanium, vanadium, chromium, manganese, iron, nickel, copper, zinc, molybdenum, silver, tin, barium, and lead.

3. The membrane assembly of claim 1, wherein the metal ions are chosen from iron, nickel, chromium, copper, and aluminum Al ions.

4. The membrane assembly of claim 1, wherein the metal ions are chosen from manganese, magnesium, and zinc ions.

5. The membrane assembly of claim 1, wherein the metal ions are chosen from iron, nickel, and chromium ions.
6. The membrane assembly of claim 1, wherein the monomer having a positive charge in an organic liquid is a quaternary ammonium compound having at least one carbon-carbon double bond.
7. The membrane assembly of claim 6, wherein the quaternary ammonium compound is chosen from diallyldimethyl ammonium chloride, diallyldimethyl ammonium bromide, vinyl benzyl trimethyl ammonium chloride, and vinyl benzyl trimethyl ammonium bromide.
8. The membrane assembly of claim 1, wherein the cross-linker is chosen from methylene bis(acrylamide), tetraethylene glycol diacrylate, tetraethylene glycol diamethacrylate, divinyl sulfone, divinyl benzene, 1,3,5-Triallyl-1,3,5-triazine-2,4,6(1H,3H,5H)-trione 98%, ethylene glycol divinyl ether, divinyl polyethylene glycols, and triallylamine.
9. The membrane assembly of claim 1, wherein the feed stream comprises a PGME/PGMEA solution (70:30, by volume), PGMEA, n-butyl acetate, or cyclohexanone.
10. A filter device comprising the assembly of claim 1.
11. A filter device comprising a plurality of membranes, comprising:
- a. a porous membrane comprising poly(tetrafluoroethylene), wherein the membrane has a coating thereon, wherein the coating is prepared from the polymerization of at least one monomer and at least one cross-linker, wherein the monomer has a positive charge in an organic liquid; and
 - b. a porous membrane comprising poly(tetrafluoroethylene), wherein the membrane has a coating thereon, wherein the coating is prepared from the polymerization of at least one monomer and at least one cross-linker, wherein the monomer has a negative charge in an organic liquid; and
- wherein the filter device, when soaked in a PGME/PGMEA solution (70:30, by volume), for 8 hours generates less than 0.080 ppb of at least one metal ion chosen from ions of sodium, magnesium, aluminum, potassium, calcium, iron, and zinc.

12. The filter device of claim 11, wherein the monomer having a positive charge is a quaternary ammonium compound having at least one carbon-carbon double bond.

13. The filter device of claim 12, wherein the quaternary ammonium compound is chosen from diallyldimethyl ammonium chloride, diallyldimethyl ammonium bromide, vinyl benzyl trimethyl ammonium chloride, and vinyl benzyl trimethyl ammonium bromide.

14. The filter device of claim 11, wherein the cross-linker is chosen from methylene bis(acrylamide), tetraethylene glycol diacrylate, tetraethylene glycol diamethacrylate, divinyl sulfone, divinyl benzene, 1,3,5-Triallyl-1,3,5-triazine-2,4,6(1H,3H,5H)-trione 98%, ethylene glycol divinyl ether, divinyl polyethylene glycols, and triallylamine.

15. The filter device of claim 11, wherein the device generates less than 0.080 ppb of metal ions from each of the ions of sodium, magnesium, aluminum, potassium, calcium, iron, and zinc.

16. A porous membrane comprising poly(tetrafluoroethylene), wherein:

the membrane has a coating thereon,

the coating is prepared from the polymerization of at least one monomer and at least one cross-linker,

the monomer has a positive charge in an organic liquid, and

the monomer is a quaternary ammonium compound having at least one carbon-carbon double bond.

17. The porous membrane of claim 16, wherein the quaternary ammonium compound is chosen from diallyldimethyl ammonium chloride, diallyldimethyl ammonium bromide, vinyl benzyl trimethyl ammonium chloride, and vinyl benzyl trimethyl ammonium chloride, and vinyl benzyl trimethyl ammonium bromide.

18. The porous membrane of claim 17, wherein the at least one monomer further comprises a monomer having a negative charge in an organic liquid.

19. The porous membrane of claim 16, wherein the monomer having a negative charge in an organic liquid is chosen from 2-ethylacrylic acid, acrylic acid, 2-carboxyethyl acrylate, 3-sulfopropyl acrylate potassium salt, 2-propyl acrylic acid, 2-(trifluoromethyl)acrylic acid, methacrylic acid, 2-methyl-2-propene-1-sulfonic acid sodium salt, mono-2-(methacryloyloxy)ethyl maleate, 3-sulfopropyl methacrylate potassium salt, 2-acrylamido-2-methyl-1-propanesulfonic acid, 3-methacrylamido phenyl boronic acid, vinyl sulfonic acid, acrylamidomethyl propane sulfonic acid, and vinyl phosphonic acid.

20. The porous membrane of claim 19, wherein the monomer having a negative charge in an organic liquid is acrylamidomethyl propane sulfonic acid.

21. A filter device comprising the porous membrane of claim 16.

22. A method of removing metal contaminants from an organic liquid, the method comprising: passing a liquid through (i) the membrane assembly of claim 1; (ii) the filter device of claim 10, claim 11, or claim 21; or (iii) the porous membrane of claim 16.