

Claims

1. An ion exchange membrane for electrodialysis comprising a microporous membrane support having a porous first side and a porous second side and a continuous porous structure extending from said first side to said second side, and a crosslinked ion transferring polymer substantially completely filling said porous structure, said polymer formed in the porous structure and comprising the polymerization product of
 - a. a monofunctional ionogenic monomer and a multifunctional monomer, or,
 - b. the polymerization product of one or more ionogenic monomers, a neutral monomer, and a multifunctional crosslinking monomer.
2. The ion exchange membrane of Claim 1 wherein the thickness of the porous support is greater than about approximately 55 microns and less than about approximately 155 microns.
3. The ion exchange membrane of Claim 1 wherein the thickness of the porous support is greater than about approximately 20 microns and less than about approximately 55 microns.
4. The ion exchange membrane of Claim 1 wherein the microporous support comprises polypropylene, high molecular weight polyethylene, ultrahigh molecular weight polyethylene or polyvinylidene fluoride .
5. The ion exchange membrane of Claim 1 wherein the ion transfer polymer is a cation transfer polymer.
6. The ion exchange membrane of Claim 5 wherein the crosslinked ion transferring polymer is formed by polymerization of 2-sulfoethylmethacrylate (2-SEM or 2-acrylamide-2-methyl propane sulfonic acid (AMPS) and a suitable crosslinking monomer to form a cation exchange membrane.
7. The ion exchange membrane of Claim 6 wherein the crosslinker is ethyleneglycoldimethacrylate.
8. The ion exchange membrane of Claim 5 wherein the crosslinked ion transferring polymer is formed by polymerization of 2-sulfoethylmethacrylate (2-

SEM, 2-acrylamide-2-methyl propane sulfonic acid (AMPS), a neutral monomer, and a suitable crosslinking monomer to form a cation exchange membrane.

9. The membrane of Claim 8 wherein the neutral monomer is hydroxyethylacrylate or hydroxymethacrylate.
10. The cation exchange membrane of Claim 5 wherein the membrane has a resistivity not greater than about approximately 0.5 Ohm-cm².
11. The cation exchange membrane of Claim 5 wherein the membrane has a resistivity not greater than about approximately 0.5 Ohm-cm² and a permselectivity of greater than about approximately 95%.
12. The cation exchange membrane of Claim 5 wherein the membrane has a resistivity not greater than about approximately 0.5 Ohm-cm² and a permselectivity of greater than about approximately 99%.
13. The cation exchange membrane of Claim 5 wherein the membrane has a resistivity not greater than about approximately 1.0 Ohm-cm².
14. The cation exchange membrane of Claim 5 wherein the membrane has a resistivity not greater than about approximately 1.0 Ohm-cm² and a permselectivity of greater than about approximately 95%.
15. The cation exchange membrane of Claim 5 wherein the membrane has a resistivity not greater than about approximately 0.5 Ohm-cm² and a permselectivity of greater than about approximately 99%.
16. The ion exchange membrane of Claim 1 wherein the ion transfer polymer is a anion transfer polymer.
17. The anion exchange membrane of Claim 16 wherein the crosslinked ion transferring polymer is formed by polymerization of Trimethylammoniummethacrylic chloride crosslinked with ethyleneglycoldimethacrylate.
18. The anion exchange membrane of Claim 16 wherein the crosslinked ion transferring polymer is formed by polymerization of Trimethylammoniummethacrylic chloride, vinylbenzyl trimethylammonium chloride and a neutral monomer crosslinked with divinylbenzene.

19. The anion exchange membrane of Claim 18 wherein the neutral monomer is hydroxyethylacrylate or hydroxymethacrylate.
20. The anion exchange membrane of Claim 15 wherein the membrane has a resistivity not greater than about approximately 1.0 Ohm-cm².
21. The anion exchange membrane of Claim 15 wherein the membrane has a resistivity not greater than about approximately 1.0 Ohm-cm² and a permselectivity of greater than about approximately 94%.
22. The anion exchange membrane of Claim 16 wherein the membrane has a resistivity not greater than about approximately 0.5 Ohm-cm².
23. The anion exchange membrane of Claim 16 wherein the membrane has a resistivity not greater than about approximately 0.5 Ohm-cm² and a permselectivity of greater than about approximately 94%.
24. A process for producing an ion exchange membrane capable of use for electro dialysis comprising;
- choosing a suitable porous substrate,
 - saturating the porous regions of the substrate with a solution comprising a monofunctional ionogenic monomer, a multifunctional monomer, and a polymerization initiator, or with a solution of
 - one or more ionogenic monomers, a neutral monomer, and a multifunctional crosslinking monomer
 - removing excess solution from the surfaces of the substrate while leaving the porous volume saturated with solution,
 - initiating polymerization by the application of heat, ultraviolet light, or ionizing radiation, optionally in the absence of substantially all oxygen, to form a crosslinked ion transferring polymer substantially completely filling the pores of the substrate.
25. The process of Claim 24 wherein the porous support comprises polypropylene, high molecular weight polyethylene, ultrahigh molecular weight polyethylene or polyvinylidene fluoride.
26. The process of Claim 24 wherein the thickness of the porous support is greater than about approximately 55 microns and less than about approximately 155 microns.

27. The process of Claim 24 wherein the thickness of the porous support is greater than about approximately 20 microns and less than about approximately 55 microns.
28. The process of Claim 24 wherein the ion exchange membrane is a cation exchange membrane.
29. The process of Claim 28 wherein the crosslinked ion transferring polymer is formed by polymerization of 2-sulfoethylmethacrylate (2-SEM or 2-acrylamide-2-methyl propane sulfonic acid (AMPS) and a suitable crosslinking monomer.
30. The process of Claim 29 wherein the crosslinker is ethyleneglycoldimethacrylate.
31. The process of Claim 28 wherein the crosslinked ion transferring polymer is formed by polymerization of 2-sulfoethylmethacrylate (2-SEM, 2-acrylamide-2-methyl propane sulfonic acid (AMPS), a neutral monomer, and a suitable crosslinking monomer to form a cation exchange membrane.
32. The process of Claim 31 wherein the neutral monomer is hydroxyethylacrylate or hydroxymethacrylate.
33. The process of Claim 24 wherein the ion exchange membrane is an anion exchange membrane.
34. The process of Claim 33 wherein the crosslinked ion transferring polymer is formed by polymerization of Trimethylammoniummethacrylic chloride crosslinked with ethyleneglycoldimethacrylate to form an anion exchange membrane.
35. The process of Claim 33 wherein the crosslinked ion transferring polymer is formed by polymerization of Trimethylammoniummethacrylic chloride, vinylbenzyl trimethylammonium chloride and a neutral monomer crosslinked with divinylbenzene.
36. The process of Claim 35 wherein the neutral monomer is hydroxyethylacrylate or hydroxymethacrylate.
37. An ion exchange membrane for electrodialysis comprising a microporous membrane support having a porous first side and a porous second side and a

continuous porous structure extending from said first side to said second side, and a crosslinked ion transferring polymer substantially completely filling said porous structure, said polymer formed in the porous structure and comprising the polymerization product of,

- a. the polymerization product of a quaternary salt formed from a polyamine and a vinyl aromatic halide, or,
- b. the reaction product of a cyclic ether and a polyamine, crosslinked with a suitable monomer.

38. The ion exchange membrane of Claim 37 wherein the thickness of the porous support is greater than about approximately 55 microns and less than about approximately 155 microns

39. The ion exchange membrane of Claim 37 wherein the thickness of the porous support is greater than about approximately 20 microns and less than about approximately 55 microns.

40. The ion exchange membrane of Claim 37 wherein the microporous support comprises polypropylene, high molecular weight polyethylene, ultrahigh molecular weight polyethylene or polyvinylidene fluoride .

41. The ion exchange membrane of Claim 37 wherein the crosslinked ion transferring polymer is formed by polymerization of N,N,N',N',N"-pentamethyldiethylenetriamine di(vinylbenzyl chloride) (a quaternary salt of N,N,N',N',N"-pentamethyldiethylenetriamine and vinylbenzyl chloride) or 1,4-diazabicyclo[2,2,2]octane di(vinylbenzyl chloride) (a quaternary salt of 1,4-diazabicyclo[2,2,2]octane (DABCO) and vinylbenzyl chloride), or glycidyl methacrylate/ N, N-dimethylethylenediamine reaction product crosslinked with a suitable crosslinker monomer to form an anion exchange membrane.

42. The ion exchange membrane of Claim 41 wherein the crosslinker is ethyleneglycoldimethacrylate.

43. The anion exchange membrane of Claim 37 wherein the membrane has a resistivity not greater than about approximately 1.0 Ohm-cm² .

44. The anion exchange membrane of Claim 37 wherein the membrane has a resistivity not greater than about approximately 1.0 Ohm-cm² and a permselectivity of greater than about approximately 90%.
45. The anion exchange membrane of Claim 37 wherein the membrane has a resistivity not greater than about approximately 0.5 Ohm-cm².
46. The anion exchange membrane of Claim 37 wherein the membrane has a resistivity not greater than about approximately 0.5 Ohm-cm² and a permselectivity of greater than about approximately 90%.

CLAIMS

1. An ion exchange membrane for electrodialysis comprising a microporous membrane support having a porous first side, a porous second side and a continuous porous structure extending from said first side to said second side, and a crosslinked ion transferring polymer filling said continuous porous structure, said polymer formed in the continuous porous structure and comprising the polymerization product of one or more ionogenic monomers, a neutral monomer, and a multifunctional crosslinking monomer, wherein the membrane has a permselectivity of at least 90%.
2. The ion exchange membrane of Claim 1 wherein the thickness of the porous support is greater than 55 microns and less than 155 microns.
3. The ion exchange membrane of Claim 1 wherein the thickness of the porous support is greater than 20 microns and less than 55 microns.
4. The ion exchange membrane of any one of Claims 1 to 3 wherein the microporous support comprises polypropylene, high molecular weight polyethylene, ultrahigh molecular weight polyethylene or polyvinylidene fluoride.
5. The ion exchange membrane of any one of Claims 1 to 4 wherein the ion transfer polymer is a cation transfer polymer.
6. The ion exchange membrane of Claim 5 wherein the crosslinked ion transferring polymer is formed by polymerization of 2- sulfoethylmethacrylate (2-SEM) or 2-acrylamide-2-methyl propane sulfonic acid (AMPS) and a crosslinking monomer to form a cation exchange membrane.
7. The ion exchange membrane of Claim 6 wherein the crosslinker is ethyleneglycoldimethacrylate.
8. The ion exchange membrane of Claim 5 wherein the crosslinked ion transferring polymer is formed by polymerization of 2- sulfoethylmethacrylate (2-SEM), 2-acrylamide-2-methyl propane sulfonic acid (AMPS), a neutral monomer, and a suitable crosslinking monomer to form a cation exchange membrane.
9. The membrane of Claim 8 wherein the neutral monomer is hydroxyethylacrylate or hydroxymethacrylate or vinyl benzyl chloride.

10. The cation exchange membrane of any one of Claims 5 to 9 wherein the membrane has a resistivity not greater than 0.5 Ohm-cm^2 .
11. The cation exchange membrane of any one of Claims 5 to 9 wherein the membrane has a resistivity not greater than 1.0 Ohm-cm^2 .
12. The cation exchange membrane of any one of Claims 5 to 11 wherein the membrane has a permselectivity of greater than 95%.
13. The cation exchange membrane of any one of Claims 5 to 12 wherein the membrane has a permselectivity of greater than 99%.
14. The ion exchange membrane of any one of Claims 1 to 4 wherein the ion transfer polymer is an anion transfer polymer.
15. The anion exchange membrane of Claim 14 wherein the crosslinked ion transferring polymer is formed by polymerization of trimethylammoniummethacrylic chloride crosslinked with ethyleneglycoldimethacrylate.
16. The anion exchange membrane of Claim 14 wherein the crosslinked ion transferring polymer is formed by polymerization of trimethylammoniummethacrylic chloride, vinylbenzyl trimethylammonium chloride and a neutral monomer crosslinked with divinylbenzene.
17. The anion exchange membrane of Claim 16 wherein the neutral monomer is hydroxyethylacrylate or hydroxymethacrylate or vinyl benzyl chloride.
18. The anion exchange membrane of any one of Claims 14 to 17 wherein the membrane has a resistivity not greater than 1.0 Ohm-cm^2 .
19. The anion exchange membrane of any one of Claims 14 to 18 wherein the membrane has a resistivity not greater than 0.5 Ohm-cm^2 .
20. The anion exchange membrane of any one of Claims 14 to 19 wherein the membrane has a permselectivity of greater than 94%.

21. A process for producing an ion exchange membrane capable of use for electrodialysis, wherein it comprises: choosing a suitable porous substrate having a porous first side and a porous second side and a continuous porous structure extending from said first side to said second side, saturating the porous regions of the substrate with a solution of one or more ionogenic monomers, a neutral monomer, and a multifunctional crosslinking monomer, removing excess solution from the surfaces of the substrate while leaving the porous volume saturated with solution, initiating polymerization by the application of heat, ultraviolet light, or ionizing radiation, optionally in the absence of substantially all oxygen, to form a crosslinked ion transferring polymer substantially completely filling the continuous pores of the substrate, wherein the membrane has a permselectivity of at least 90%.

22. The process of Claim 21 wherein the porous support comprises polypropylene, high molecular weight polyethylene, ultrahigh molecular weight polyethylene or polyvinylidene fluoride.

23. The process of Claim 21 or Claim 22 wherein the thickness of the porous support is greater than 55 microns and less than 155 microns.

24. The process of Claim 21 or Claim 22 wherein the thickness of the porous support is greater than 20 microns and less than 55 microns.

25. The process of any one of Claims 21 to 24 wherein the ion exchange membrane is a cation exchange membrane.

26. The process of Claim 25 wherein the crosslinked ion transferring polymer is formed by polymerization of 2-sulfoethylmethacrylate (2-SEM) or 2-acrylamide-2-methyl propane sulfonic acid (AMPS) and a suitable crosslinking monomer.

27. The process of Claim 26 wherein the crosslinker is ethyleneglycoldimethacrylate.

28. The process of Claim 25 wherein the crosslinked ion transferring polymer is formed by polymerization of 2-sulfoethylmethacrylate (2-SEM), 2-acrylamide-2-methyl propane sulfonic acid (AMPS), a neutral monomer, and a suitable crosslinking monomer to form a cation exchange membrane.

29. The process of Claim 28 wherein the neutral monomer is hydroxyethylacrylate or hydroxymethacrylate or vinyl benzyl chloride.

30. The process of any one of Claims 21 to 24 wherein the ion exchange membrane is an anion exchange membrane.

31. The process of Claim 30 wherein the crosslinked ion transferring polymer is formed by polymerization of trimethylammoniummethacrylic chloride crosslinked with ethyleneglycoldimethacrylate to form an anion exchange membrane.

32. The process of Claim 30 wherein the crosslinked ion transferring polymer is formed by polymerization of trimethylammoniummethacrylic chloride, vinylbenzyl trimethylammonium chloride and a neutral monomer crosslinked with divinylbenzene.

33. The process of Claim 32 wherein the neutral monomer is hydroxyethylacrylate or hydroxymethacrylate or vinyl benzyl chloride.

34. An ion exchange membrane capable of use for electrodialysis produced by the process of any one of claims 21 to 33.