Title of the Invention

Low-Cost Homogeneous Ion Exchange Membrane Formed from Off-the-Shelf Precursors and Manufacturing Process Thereof

Cross-Reference to Related Applications

Not Applicable.

Statement Regarding Federally Sponsored Research or Development

Not Applicable.

Background of the Invention

[0001] The present invention relates to ion exchange membranes, particularly homogeneous cation and anion exchange membranes for electrochemical applications, including but not limited to electrolysis cells, redox flow batteries, mining processes (e.g., acid regeneration and metal leaching), water treatment, and chemical production.
[0002] Ion exchange membranes enable selective transport of cations or anions under an applied electric field, facilitating direct electrochemical control of reactions with minimal waste. Applications span energy storage (e.g., redox flow batteries), resource recovery (e.g., precious metal extraction), agriculture (e.g., pH control in hydroponics), waste management, and general chemical synthesis.
[0003] Conventional ion exchange membranes are typically produced using specialized precursors and multi-step functionalization processes, such as sulfonation or amination of polymer backbones, often requiring hazardous chemicals (e.g., chlorosulfonic acid) or complex post-treatments. These methods result in high manufacturing costs (often hundreds of dollars per square foot), limited accessibility, and challenges in scalability or integration into electrolysis cells. Commercial membranes are expensive and not readily available to researchers or hobbyists, while makeshift alternatives (e.g., clay pots) exhibit poor selectivity, high resistivity, and mechanical/chemical limitations.
[0004] Prior art, such as US2948637A, relies on sulfonating agents to functionalize polymers, while US4851100A describes coating existing membranes to form bipolar structures rather than standalone homogeneous membranes. Other approaches involve melt-processing, additives, or post-functionalization, which add complexity and cost.
[0005] There remains a need for low-cost, homogeneous ion exchange membranes using readily available, off-the-shelf ingredients, with simple manufacturing that avoids post-functionalization and enables easy integration into cells

Brief Summary of the Invention

[0006] The present invention provides a homogeneous ion exchange membrane comprising pulverized commercial ion exchange resin particles dispersed in a polyvinyl chloride (PVC) or

chlorinated polyvinyl chloride (CPVC) matrix, formed from a solvent-based mixture and dried into a film. The membrane utilizes pre-functionalized resins (e.g., strong/weak cation or anion exchange resins from water softeners), achieving high ion selectivity, low resistivity, and chemical durability at a cost less than $1 per square foot (or yard in thin applications).
[0007] The manufacturing process involves: (1) pulverizing commercial resin beads into fine powder; (2) mixing the powder with dissolved PVC/CPVC in a compatible solvent to form a homogeneous glue; and (3) applying the mixture to a surface, drying, and peeling to form the membrane. No post-functionalization, heating, or cross-linking is required.
[0008] Advantages include accessibility using household equipment (e.g., blender), compatibility with PVC/CPVC cements for cell sealing, tunable properties (e.g., resin type/ratio for selectivity), and applications in harsh environments (e.g., pH 0, high oxidizing potential).

Brief Description of the Drawings

FIG. 1 is a flowchart illustrating the manufacturing process for the homogeneous ion exchange membrane according to embodiments of the present invention, including optional dry and wet pulverizing paths, water removal options, and the mixing, application, and formation steps.

Detailed Description of the Invention

[0009] The invention provides a homogeneous ion exchange membrane and method of manufacture using off-the-shelf precursors. The membrane is homogeneous, meaning uniform distribution of ion exchange functionality throughout the structure without distinct layers or heterogeneous particles.
[0010] The membrane comprises: (a) pulverized particles of commercial ion exchange resin (pre-functionalized, e.g., strong acid cation, weak acid cation, strong base anion, weak base anion, or mixtures thereof); and (b) a binder matrix of PVC or CPVC with a solvent.
[0011] As illustrated in FIG. 1, the overall manufacturing process begins with commercial ion exchange resins, which are typically spherical beads (small, insoluble, porous micro-beads used, for example, in water softening). These beads are pulverized into fine powder using mechanical shearing methods such as grinding (step 2, dry or wet), ball milling (step 3, dry or wet), or other grinding techniques. Wet processes may include water to assist lubrication. If water is introduced, it is removed to obtain dry powder or a controlled slurry before further processing.
[0012] Water removal from slurries can be accomplished by spray drying (step 4), settling/decanting followed by air drying and blending (step 5), or sieving collected slurries. These options are shown in the branched paths of FIG. 1. The resulting dry powder or suitably prepared material is then mixed with a solution of PVC or CPVC dissolved in a compatible solvent (e.g., tetrahydrofuran (THF), cyclohexanone, methyl ethyl ketone) (step 6). Preferred ratio: 10-70% resin powder by volume (typically ~50% for balanced conductivity and mechanical strength); polymer-to-solvent ratio ~3:7 (adjustable for desired viscosity). Optional additives (e.g., fiberglass, fumed silica, sand) may be included for structural enhancement. Additional solvent can be added to reduce viscosity for spraying or other application methods.
[0013] The homogeneous glue-like mixture (referred to as the "Ion Exchange Membrane Mix" in FIG. 1) is applied (step 7) to a non-adhesive, solvent-resistant surface (e.g., polypropylene sheet) or directly onto a substrate (e.g., polypropylene felt for reinforcement), cell frame, or electrode by spreading, extruding, spraying, pouring, or other suitable means. The applied mixture dries to

form a peelable film or permanent coating, with thickness tunable by the application technique. Uneven drying is prevented (e.g., using an enclosed environment). The membrane may be partially dried to avoid cracking or warping before peeling or further handling.
[0014] Embodiments include: cation-selective membranes (using cation resins); anion-selective (using anion resins); specialized ion resins for selectivity (e.g., rare earths, platinum group metals); thin spray films (<$1/sq yard); coatings on electrodes or microporous ion selective separator (e.g., for lithium separation to block out larger sodium ions).
[0015] Best mode: Use water softener cation exchange resin beads, pulverize in a high-speed blender (<120 seconds), mix 50% powder with PVC in THF (3:7 polymer:solvent), spread on polypropylene sheet, dry partially to avoid cracking, peel. Result: flexible/rigid, watertight membrane with commercial-level conductivity/selectivity.
[0016] Testing in harsh conditions (acidic/alkaline mining solutions, high ORP) shows durability over months, low energy loss, and electro-osmosis. Cost: fraction of commercial membranes.

Claims

1. A homogeneous ion exchange membrane comprising: pulverized particles of a commercial pre-functionalized ion exchange resin dispersed in a matrix of polyvinyl chloride (PVC) or chlorinated polyvinyl chloride (CPVC).
2. The membrane of claim 1, wherein the ion exchange resin is selected from strong acid cation exchange resin, weak acid cation exchange resin, strong base anion exchange resin, weak base anion exchange resin, or mixtures thereof.
3. The membrane of claim 1, wherein the resin particles are pulverized to a particle size less than 200 microns.
4. The membrane of claim 1, wherein the resin particles comprise 10-70% by volume of the membrane.
5. A method of manufacturing a homogeneous ion exchange membrane, comprising:
   a) pulverizing beads of a commercial pre-functionalized ion exchange resin into a fine powder;
   b) mixing the powder with a solution of polyvinyl chloride (PVC) or chlorinated polyvinyl chloride (CPVC) in a solvent to form a homogeneous mixture; and
   c) applying the mixture to a surface and drying to form a membrane composite.
6. The method of claim 5, wherein pulverizing is performed using a mechanical shearing device selected from a blender, grinder, or ball mill.
7. The method of claim 5, wherein the solvent is selected from tetrahydrofuran, cyclohexanone, or methyl ethyl ketone.
8. The method of claim 5, further comprising removing water from the powder prior to mixing if introduced during pulverizing.
9. The method of claim 5, wherein applying comprises spreading, spraying, extruding, or pouring.
10. The method of claim 5, wherein the membrane is peeled from the surface after partial drying or left as a permanent coating.

Abstract

A low-cost homogeneous ion exchange membrane is formed from pulverized commercial pre-functionalized ion exchange resin particles dispersed in a PVC or CPVC matrix. The membrane is manufactured by pulverizing resin beads into powder, mixing with dissolved PVC/CPVC in solvent to create a glue-like mixture, applying to a surface, and drying to form a peelable film. The process avoids post-functionalization, enabling costs less than $1 per square foot, high selectivity, durability in harsh conditions, and easy integration into electrochemical cells for applications including mining, energy storage, and chemical processing.

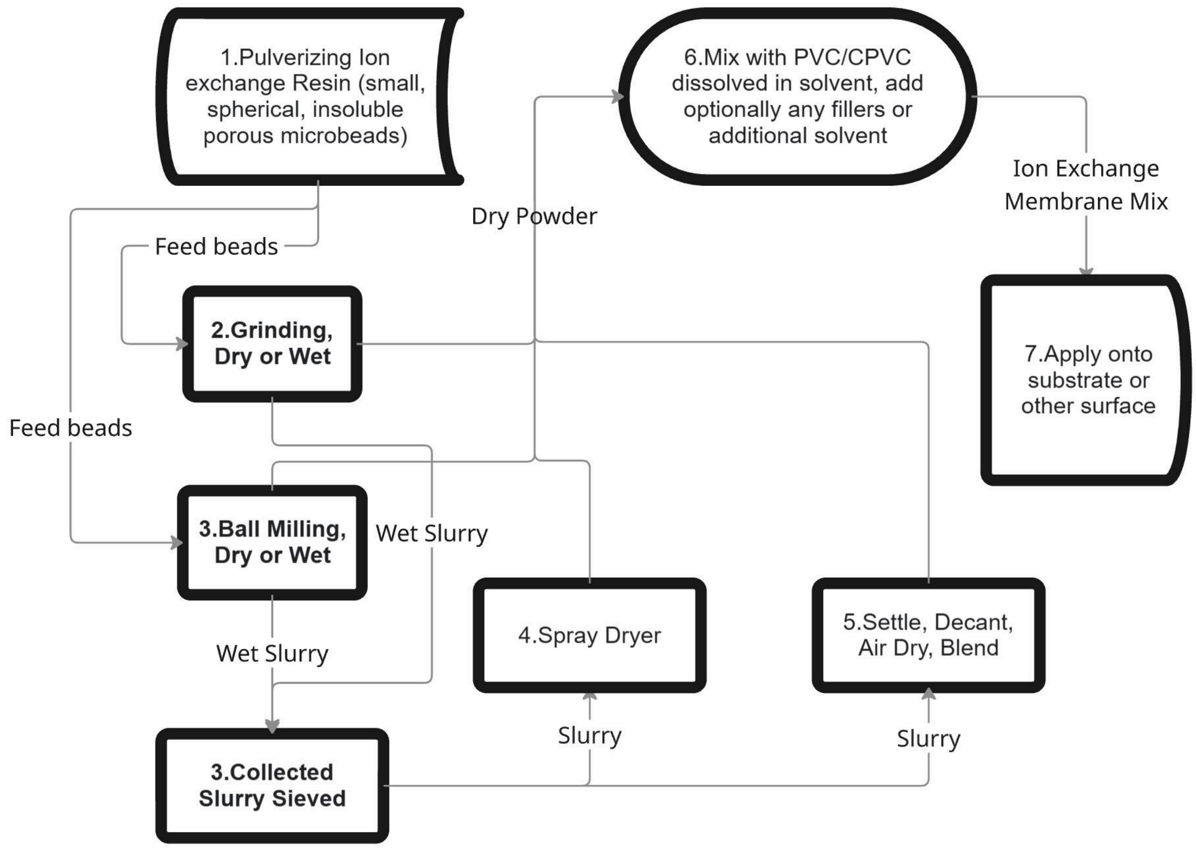
1.Pulverizing Ion exchange Resin (small, spherical, insoluble porous microbeads)
6.Mix with PVC/CPVC dissolved in solvent, add optionally any fillers or additional solvent
Ion Exchange Membrane Mix
Dry Powder
Feed beads
2.Grinding, Dry or Wet
7.Apply onto substrate or other surface
Feed beads
3.Ball Milling, Dry or Wet
Wet Slurry
4.Spray Dryer
5.Settle, Decant, Air Dry, Blend
Wet Slurry
Slurry
Slurry
3.Collected Slurry Sieved

FIG. 1