WHAT IS CLAIMED IS:

1. A membrane distillation system comprising:

a flat-sheet composite mixed matrix hydrophilic/hydrophobic membrane having at least a a hydrophilic layer and a hydrophobic layer;

the hydrophilic layer further comprising a hydrophilic polymer and inorganic nano-particles of high thermal conductivity, and

the hydrophobic layer further comprising fluorinated surface-modifying macromolecule (SMM).

2. The membrane distillation system as claimed in claim 1, wherein said hydrophilic polymer is a thermoplasitc polymer.

3. The membrane distillation system as claimed in claim 2, wherein the thermoplastic polymer is selected from the group consisting of polysulfone, polyethersulfone, polyetherimide and cellulose acetate.

4. The membrane distillation system as claimed in claim 1, wherein said nano-particle is an inorganic nano-particle of high thermal conductivity.

5. The membrane distillation system as claimed in claim 1, wherein said inorganic nano-particles is selected from the group consisting of cupper oxide, boron nitride, aluminum nitride, aluminum, iron and silicone carbide.

6. The membrane distillation system as claimed in claim 1, wherein said fluorinated surface-modifying macromolecules (SMM) are oligomeric fluoropolymers synthesized using polyurethane chemistry, the surface-modifying macromolecules comprise fluorinated end-groups.

7. The membrane distillation system as claimed in claim 1, wherein said fluorinated SMM is blended within said hydrophilic layer.

8. The membrane distillation system as claimed in claim 7, wherein said SMM is selected from the group consisting of poly(urethane propylene glycol) and poly(urea dimethylsiloxane urethane).

9. The membrane distillation system as claimed in claim 1, wherein said mixed matrix membrane has a morphological structure conceived to maximize permeate flux and permeability.

10. The composite mixed matrix membrane as claimed in claim 9, wherein said morphological structure comprise parameters representing a thickness and a porosity of said hydrophobic layer, and a thickness, a porosity and a thermal conductivity of said hydrophilic layer, and internal structure of flat-sheet membranes.

11. The membrane distillation system as claimed in claim 1, wherein said composite mixed matrix membrane has higher vapor permeate flux than composite polymeric membranes.

12. The membrane distillation system as claimed in claim 1, wherein said composite mixed matrix membrane has a higher mechanical strength than composite polymeric membranes.

13. The membrane distillation system as claimed in claim 1, where the composited mixed matrix membrane has lower wetting tendency than commercial membranes of single hydrophobic layer.

14. A phase inversion method for manufacturing a membrane distillation composite mixed matrix hydrophilic/hydrophobic membrane, said method comprising:

(a) dispersing a host hydrophilic polymer with a predetermined amount of insoluble inorganic nano-particles and a non-solvent additive in a solvent to form a polymer-inorganic solution;

(b) adding a fluorinated surface modifying macromolecule (SMM) to the polymer-inorganic solution to form a polymer-inorganic nano-particles SMM blend;

(c) casting said polymer-inorganic nano-particles blend and allowing said solvent to evaporate at room temperature for a predetermined time to form a cast film;

(d) varying a time of evaporation systematically to study and modify an effect of the evaporation time on settling of the inorganic nano-particles in a bottom layer as well as the hydrophobic SMM migration to the top layer;

(e) covering the cast film by a cover having a certain displacement to control evaporation of the solvent allowing more time for settling of the inorganic nano-particle in the bottom layer and migration of a hydrophobic SMM to the air/polymer interface; and

(f) immersing said cast film produced in step (c) in water to allow gelation.

15. The method of manufacturing a composite mixed matrix membrane as claimed in claim 14, further comprising maximizing porosity and minimizing thickness of said hydrophobic polymer layer of said composite membrane in order to increase permeate flux of said composite membrane.

16. The method of manufacturing a composite mixed matrix membrane as claimed in claim 14, further comprising maximizing thickness and thermal conductivity of said hydrophilic layer.

17. The method of manufacturing a composite mixed matrix membrane as claimed in claim 14, further comprising maximizing the temperature polarization coefficient in the hydrophilic sublayer, according to the following equations:

$$U = \left(\frac{1}{h_f} + \frac{1}{h_s} + \frac{1}{h_p} \right)^{-1} (1 - \theta)$$

and

$$\theta = \theta_f + \theta_p + \theta_s - 2$$

where θ_f, θ_s and θ_p are the temperature polarization coefficients corresponding to the feed, hydrophilic sublayer and permeate phases, respectively; and are defined as follows.

$$\theta_f = 1 - \frac{U}{h_f} = \frac{T_{m,f} - T_{b,p}}{T_{b,f} - T_{b,p}}$$

$$\theta_s = 1 - \frac{U}{h_s} = \frac{(T_{b,f} - T_{b,p}) - (T_{m,p} - T_{s,p})}{T_{b,f} - T_{b,p}}$$

$$\theta_p = 1 - \frac{U}{h_p} = \frac{T_{b,f} - T_{s,p}}{T_{b,f} - T_{b,p}}$$

18. The method of manufacturing a composite mixed matrix membrane as claimed in claim 14, wherein said host hydrophilic layer comprises at least one of polysulfone, polyethersulfone, polytherimide, cellulose acetate and other polymers known as thermoplastics as a hydrophilic polymer and at least one of cupper oxide, boron nitride, aluminum nitride, aluminum, iron, silicone carbide and other inorganic or organic nano-particles of high thermal conductivity.

19. The method of manufacturing a composite mixed matrix membrane as claimed in claim 14, wherein said hydrophobic top-layer is from either polymeric nature such as SMM or inorganic nature such as zeolites.

20. The method of manufacturing a composite mixed matrix membrane as claimed in claim 14, wherein said non-solvent additive is selected from the group consisting of γ-butyrolactone, ethanol, lithium chloride and others known in the membrane literature as non solvent additive.

21. The method of manufacturing a composite mixed matrix membrane as claimed in claim 14, wherein said solvent is selected from the group consisting of N,N-dimethylacetamide, 1-methyl-2-pyrrolidone and others known as solvents or mixtures of solvents for the polymers defined in 19 as hydrophilic polymers.

22. The method of manufacturing a composite mixed matrix membrane as claimed in claim 14, exhibited higher permeate flux because of the higher thermal conductivity of the sublayer and the decrease in the resistance of the water vapor migration in the hydrophobic layer.

CLAIMS

1. A membrane distillation system comprising:

a flat-sheet composite mixed matrix hydrophilic/hydrophobic membrane having at least a hydrophilic layer and a hydrophobic layer;

the hydrophilic layer further comprising a hydrophilic polymer and inorganic nano-particles of high thermal conductivity selected from the group consisting of copper (II) oxide, boron nitride, aluminium nitride, aluminium, iron and silicon carbide; and

the hydrophobic layer further comprising a fluorinated surface-modifying macro-molecule (SMM).

2. The system as claimed in claim 1, wherein said hydrophilic polymer is a thermoplastic polymer.

3. The system as claimed in claim 2, wherein the thermoplastic polymer is selected from the group consisting of polysulfone, polyethersulfone, polyether-imide and cellulose acetate.

4. The system as claimed in claim 1, wherein said fluorinated surface-modifying macro-molecules (SMM) are oligomeric fluoropolymers synthesized using polyurethane chemistry, the surface-modifying macromolecules comprise fluorinated end groups.

5. The system as claimed in claim 1, wherein said fluorinated SMM is blended with the hydrophilic polymer-inorganic nano-particles dispersion.

6. The system as claimed in claim 5, wherein said SMM is selected from the group consisting of poly(urethane propylene glycol) and poly(urea dimethylsiloxane urethane).

7. The system as claimed in claim 1, where the composited mixed matrix membrane is adapted to possess a lower wetting tendency than commercial membranes of single hydro-phobic layer.

8. A phase inversion method for manufacturing a membrane distillation composite mixed matrix hydrophilic/hydrophobic membrane, said method comprising:

(a) dispersing a host hydrophilic polymer with a predetermined amount of insoluble

inorganic nano-particles and a non-solvent additive in a solvent to form a polymer-inorganic solution;

(b) adding a fluorinated surface modifying macromolecule (SMM) to the polymer inorganic solution to form a polymer-inorganic nano-particles SMM blend;

(c) casting said polymer-inorganic nano-particles SMM blend and allowing said solvent to evaporate at room temperature for a predetermined time to form a cast film;

(d) varying a time of evaporation systematically to study and modify the evaporation time on the settling of the inorganic nano-particles in a bottom (or host hydrophilic) layer as well as the hydrophobic SMM migration to form a hydrophobic top layer;

(e) covering the cast film by a cover in such a manner as to control further evaporation of the solvent allowing more time for settling of the inorganic nano-particle in the bottom layer and migration of a hydrophobic SMM to an air/polymer interface; and

(f) immersing said cast film produced in step (c) in water to allow gelation,

wherein said host hydrophilic layer comprises at least one of polysulfone, polyethersulfone, polyetherimide, cellulose acetate and other polymers known as thermoplastics as a hydrophilic polymer and at least one of copper oxide, boron nitride, aluminium nitride, aluminium, iron, silicon carbide and other inorganic nano-particles of high thermal conductivity.

9. The method as claimed in claim 8, further comprising maximizing the temperature polarization coefficient in the hydrophilic sublayer, according to the following equations:

$$U = \left(\frac{1}{h_f} + \frac{1}{h_s} + \frac{1}{h_p} \right)^{-1} (1 - \theta)$$

and

$$\theta = \theta_f + \theta_p + \theta_s - 2$$

where θ_f, θ_S and θ_P are the temperature polarization coefficients corresponding to the feed, hydrophilic sub-layer and permeate phases, respectively; and are defined as follows:

$$\theta_f = 1 - \frac{U}{h_f} = \frac{T_{m,f} - T_{b,p}}{T_{b,f} - T_{b,p}}$$

$$\theta_s = 1 - \frac{U}{h_s} = \frac{(T_{b,f} - T_{b,p}) - (T_{m,p} - T_{s,p})}{T_{b,f} - T_{b,p}}$$

$$\theta_p = 1 - \frac{U}{h_p} = \frac{T_{b,f} - T_{s,p}}{T_{b,f} - T_{b,p}}$$

10. The method as claimed in claim 8, wherein said hydrophobic top-layer is of a polymeric nature such as an SMM.

11. The method as claimed in claim 8, wherein said non-solvent additive is selected from the group consisting of *y*-butyrolactone, ethanol and lithium chloride.

12. The method as claimed in claim 8, wherein said solvent is N,N-dimethylacetamide or 1-methyl-2-pyrrolidone.

13. The method as claimed in claim 8, exhibited higher permeate flux because of the higher thermal conductivity of the sub-layer and the decrease in the resistance of the water vapour migration in the hydrophobic layer.