CLAIMS

1. A macromolecule membrane structure (2) comprising a membrane (3), **characterized in** that the membrane (3) comprises water-channeling integral membrane proteins (1) and is coated, on a first surface of the membrane (3), with a silica layer (4) having an average thickness selected within a range of from 1 to 100nm.

2. The macromolecule membrane structure according to claim 1, wherein the membrane (3) is a bilayer membrane (3) comprising amphiphilic molecules.

3. The macromolecule membrane structure according to claim 2, wherein the membrane (3) is a lipid bilayer membrane (3), amphiphilic lipids of the lipid bilayer (3) are preferably selected from the group consisting of phosphatidylcholine, phosphatidylserine, phosphatidylethanolamine, phosphatidylglycerol, phosphatidylinositol, cardiolipin, cholesterol, sphingomyelin, asolectin, diphytanoylphosphatidylcholine (DPhPC), 1,2-dipalmitoyl-*sn*-glycero-3-phosphocholine (DPPC), 1,2-diheptanoyl-*sn*-glycero-3-phosphocholine (DHPC), 1,2-dihexanoyl-*sn*-glycero-3-phosphoethanolamine (DHPE), 1,2-dimyristoyl-*sn*-glycero-3-phosphocholine (DMPC), dimyristoyl phosphatidylserine (DMPS), dimyristoyl phosphatidylglycerol, dilauroyl phosphatidycholine (DLPC), 1,2-dimyristoyl-*sn*-glycero-3-phosphoethanolamine (DMPE), 1,2-dimyristoyl-*sn*-glycero-3-[phospho-rac-(1-glycerol)] (DMPG), lyso PC, such as 1-myristoyl-2-hydroxy-*sn*-glycero-3-phosphocholine (14:0 lyso PC) or 1-palmitoyl-2-hydroxy-*sn*-glycero-3-phosphocholine (16:0 lyso PC), lyso PE, such as 1-palmitoyl-2-hydroxy-*sn*-glycero-3-phosphoethanolamine (16:0 lyso PE) or 1-oleoyl-2-hydroxy-*sn*-glycero-3-phosphoethanolamine (18:1 lyso PE), 1,2-didecanoyl-*sn*-glycero-3-phosphocholine (DDPC), 1,2-dierucoyl-*sn*-glycero-3-phosphate (DEPA), 1,2-erucoyl-*sn*-glycero-3-phosphocholine (DEPC), 1,2-dierucoyi-*sn*-alycero-3-phosphoethanolamine (DEPE), 1,2-linoleoyl-*sn*-glycero-3-phosphocholine (DLOPC), 1,2-dilauroyl-*sn*-glycero-3-phosphate (DLPA), 1,2-dilauroyl-*sn*-glycerco-3-phosphoethanolamine (DLPE), 1,2-dilauroyl-*sn*-glycero-3-phosphoserine (DLPS), 1,2-dimyristoyl-*sn*-glycero-3-phosphate (DMPA), 1,2-dimyristoyl-*sn*-glycero-3-phosphoserine (DMPS), 1,2-dioleoyl-*sn*-glycero-3-phosphate (DOPA), 1,2-oleoyl-*sn*-glycero-3-phosphocholine (DOPC), 1,2-dioleoyl-*sn*-glycero-3-phosphoethanolamine (DOPE), 1,2-dioleoyl-*sn*-glycero-3-phosphoserine (DOPS), 1,2-dipalmitoyl-*sn*-glycero-3-phosphate (DPPA), 1,2-dipalmitoyl-*sn*-glycero-3-phosphoethanolamine (DPPE), 1,2-dipalmitoyl-*sn*-glycerco-3-phosphoserine (DPPS), 1,2-distearoyl-*sn*-glycero-3-phosphate (DSPA), 1,2-distearoyl-*sn*-glycero-3-phosphocholine (DSPC), 1,2-diostearpyl-*sn*-glycero-3-phosphoethanolamine (DSPE), 1-myristoyl-2-stearoyl-*sn*-glycero-3-phosphocholine (MSPC), 1-palmitoyl-2-myristoyl-*sn*-glycero-3-phosphocholine (PMPC), 1-palmitoyl-2-oleoyl-*sn*-glycero-3-phosphocholine (POPC), 1-

palmitoyl-2-oleoyl-*sn*-glycero-3-phosphoethanolamine (POPE), 1-palmitoyl-2-stearoyl-*sn*-glycero-3-phosphocholine (PSPC), 1-stearoyl-2-myristoyl-*sn*-glycero-3-phosphocholine (SMPC), 1-stearoyl-2-oleoyl-*sn*-glycero-3-phosphocholine (SOPC), 1-stearoyl-2-palmitoyl-*sn*-glycero-3-phosphocholine (SPPC), a lipid from a cell membrane, a lipid from an organelle, a cross-linkable lipid, and a mixture thereof, preferably POPC.

4. The macromolecule membrane structure according to claim 2, wherein the amphiphilic molecules are selected from amphiphilic AB, ABA and ABC copolymers, and mixtures thereof, such as poly(methyloxazoline)-poly(dimethylsiloxane)-poly(methyloxazoline) (PMOXA-PDMS-PMOXA), poly(2-ethyl-2-oxazoline)-*b*-poly(dimethylsiloxane)-*b*-poly(2-ethyl-2-oxazoline) (PEtOz-PDMS-PEtOz), and a mixture thereof.

5. The macromolecule membrane structure according to any of the claims 1 to 4, wherein the membrane (3) is a proteoliposome or a proteopolymersome and the outer surface of the proteoliposome or proteopolymersome is coated with the silica layer (4).

6. The macromolecule membrane structure according to any of the claims 1 to 5, wherein the water-channel integral membrane proteins (1) are aquaporins, preferably selected from the group consisting of a human aquaporin (hAQP), such as hAQP0, hAQP1, hAQP2, hAQP3, hAQP4, hAQP5, hAQP6, hAQP7, hAQP8, hAQP9, hAQP10, hAQP11, hAQP12, preferably hAQP0, hAQP1, hAQP2, hAQP4, hAQP5, hAQP6, or hAQP8, and more preferably hAPQ4; a bovine aquaporin, such as bAQP1; a fish aquaporin, such as cpAQP1aa; a yeast aquaporin, such as Aqy1; a plant aquaporin, such as SoPIP2; 1, AtTIP2; 1 or AtPIP2; 4; a bacterial aquaporin, such as AqpZ; and a mixture thereof.

7. The macromolecule membrane structure according to any of the claims 1 to 6, wherein the silica layer (4) has an average thickness selected within a range of from 1 to 10 nm.

8. The macromolecule membrane structure according to any of the claims 1 to 7, wherein the silica layer (4) is a functionalized silica layer (4), preferably comprising a silane, such as fluoroalkylsilane (FAS), an alkoxysilane, hexamethyldisilazane (HMDZ), or a combination thereof.

9. A filtration device (5) comprising:
a porous support (6) comprising a plurality of pores (7); and
macromolecule membrane structures (2) according to any of the claims 1 to 8.

10. The filtration device according to claim 9, wherein the macromolecule membrane structures (2) are provided on a surface of the porous support (6) and/or are provided in the pores (7) of the porous support (6).

11. The filtration device according to claim 9 or 10, wherein the porous support (6) is made of a material selected from the group consisting of a polymer, such as polysulfone, polyethersulfone, polyphenylsulfone, polyetherethersulfone, polyetherketone, polyetheretherketone, polyphenylene ether, polydiphenylphenylene ether, cellulose, polyvinylene cellulose acetate, cellulose diacetate, cellulose triacetate, cellulose nitrate, polyphenylene sulfide, nitrocellulose, acetylated methylcellulose, polyacrylonitrile, polyvinylalcohol, polycarbonate, organic siloxane carbonate, polyestercarbonate, organic polysiloxane, polyethylene oxide, polyamide, polyimide, polyamidoimide, polybenzimidazole, polyolefin, polyacrylonitrile, nylon and a mixture thereof; a metal, or an oxide of the metal, such as aluminum, titanium, zirconium, iron, or an oxide thereof; silicon dioxide; glass fiber; and a mixture thereof.

12. The filtration device according to any of the claims 9 to 11, wherein

the filtration device (5) comprises macromolecule membrane structures (2) according to claim 8; and

functionalized groups of the functionalized silica layer (4) link the macromolecule membrane structures (2) to the porous support (6).

13. A method of preparing a water filtrate, the method comprising filtering an aqueous solution through a macromolecule membrane structure (2) according to any of the claims 1 to 8 or a filtration device (5) according to any of the claims 9 to 12 to obtain the water filtrate.

14. A method for concentrating a compound dissolved or dispersed in an aqueous solution, the method comprising filtering the aqueous solution through a macromolecule membrane structure (2) according to any of the claims 1 to 8 or a filtration device (5) according to any of the claims 9 to 12 to obtain a water filtrate lacking the compound and a retentate comprising the compound at a higher concentration than the aqueous solution.

15. A process for preparation of a macromolecule membrane structure (2), **characterized** by contacting a membrane (3) comprising water-channeling integral membrane proteins (1) with a silica precursor to form a silica layer (4) coated on a first surface of the membrane (3), wherein the silica

layer (4) has an average thickness selected within a range of from 1 to 100 nm and wherein the silica precursor is optionally selected from the group consisting of a silicon alkoxide such as tetramethyl orthosilicate (TMOS), tetraethyl orthosilicate (TEOS), tetrapropyl orthosilicate, tetrabutylorthosilicate, methyltriethoxysiloxane (MTES), dimethyldiethoxysiloxane (DMDES), tetrakis(glycerol)orthosilicate (TGS) or tetrakis-(2-hydroxyethyl)-orthosilicate (THEOS); a silane, such as allyltrimethoxysilane, (3-aminopropyl)triethoxysilane, bytyltrichlorosilane, chloropentamethyldisilane, 1,2-dichlorotetramethylsilane, diethoxydiphenylsilane, [3-(diethylamino)propyl]trimethoxysilane, dimethoxydimethylsilane, dimethoxy(methyl)octylsilane, (3-glycidyloxypropyl)trimethoxysilane, hexamethyldisilane, isobutyl(trimethoxy)silane, methyltrichlorosilane, pentamethyldisilane, n-propyltriethoxysilane, tetraethylsilane, 1,1,2,2-tetramethyldisilane, tetramethylsilane, triethoxymethylsilane, triethoxyoctylsilane, trimethoxyphenylsilane, triethoxyphenylsilane, triethoxyvinylsilane, trimethoxymethylsilane, γ-aminopropyltriethoxysilane, silicon tetrachloride (tetrachlorosilane), silicon tetrabromide (tetrabromidesilane) or γ-aminopropylsilanetriol (APSTOL); a silicate, such as sodium silicate; a silanol, such as tris(*tert*-pentoxy)silanol or tris(*tert*-butoxy)silanol; a silazane, *N*-*sec*-butyl(trimethylsilylamine, and a combination thereof, preferably TEOS.

16. A process for preparation of a filtration device (5), **characterized** by:

depositing a membrane (3) comprising water-channeling integral membrane proteins (1) onto and/or into a porous support (6); and

contacting the membrane (3) comprising water-channeling integral membrane proteins (1) deposited onto and/or into the porous support (6) with a silica precursor to form a silica layer (4) coated on a first surface of the membrane (3), wherein the silica layer (4) has an average thickness selected within a range of from 1 to 100nm and wherein the silica precursor is optionally selected from the group consisting of a silicon alkoxide, such as tetramethyl orthosilicate (TMOS), tetraethyl orthosilicate (TEOS), tetrapropyl orthosilicate, tetrabutylorthosilicate, methyltriethoxysiloxane (MTES), dimethyldiethoxysiloxane (DMDES), tetrakis(glycerol)orthosilicate (TGS) or tetrakis-(2-hydroxyethyl)-orthosilicate (THEOS); a silane, such as allyltrimethoxysilane, (3-aminopropyl)triethoxysilane, bytyltrichlorosilane, chloropentamethyldisilane, 1,2-dichlorotetramethyldisilane, diethoxydiphenylsilane, [3-(diethylamino)propyl]trimethoxysilane, dimethoxydimethylsilane, dimethoxy(methyl)octylsilane, (3-glycidyloxypropyl)trimethoxysilane, hexamethyldisilane, isobutyl(trimethoxy)silane, methyltrichlorosilane, pentamethyldisilane, n-propyltriethoxysilane, tetraethylsilane, 1,1,2,2-tetramethyldisilane, tetramethylsilane, triethoxymethylsilane, triethoxyoctylsilane, trimethoxyphenylsilane, triethoxyphenylsilane, triethoxyvinylsilane, trimethoxymethylsilane, γ-aminopropyltriethoxysilane, silicon tetrachloride (tetrachlorosilane), silicon tetrabromide

(tetrabromidesilane) or γ-aminopropylsilanetriol (APSTOL); a silicate, such as sodium silicate; a silanol, such as tris(*tert*-pentoxy)silanol or tris(*tert*-butoxy)silanol; a silazane, *N*-*sec*-butyl(trimethylsilyl)amine, and a combination thereof, preferably TEOS.
