Ji et al., Recent developments in nanofiltration membranes based on nanomaterials, *Chinese Journal of Chemical Engineering* 2017, 25: 1639-1652 is a review of studies on nanofiltration membranes including metal and metal oxide nanoparticles, carbon-based nanomaterials, metal-organic frameworks (MOFS), water channel proteins, and organic micro-nanoparticles.

US 2011/0284456 discloses stabilized surfactant-based membranes and methods of manufacture thereof. Membranes comprising a stabilized surfactant mesostructure on a porous support are used for various separations. The membranes are stabilized after evaporation of solvents; in some embodiments no removal of the surfactant is required. The surfactant solution may or may not comprise a hydrophilic compound such as an acid or base. The surface of the porous support is preferably modified prior to formation of the stabilized surfactant mesostructure.

Lou et al., Photo-induced proton gradients and ATP biosynthesis produced by vesicles encapsulated in a silica matrix, *Nature Materials* 2005, 4(3): 220-224 describes a liposome/sol-gel architexture in which the liposome provides membrane structure an protein orientation to two transmembrane proteins, bacteriorhodopsin and F_0F_1-ATP synthase.

Besanger and Brennan, Ion sensing and inhibition studies using the transmembrane ion channel peptide gramicidin A entrapped in sol-gel-derived silica, *Analytical Chemistry* 2003, 75(5): 1094-1101 describes the immobilization of liposomes containing the transmembrane peptide ion-channel gramicidin A into sol-gel-derived silicate materials.

Despite the above mentioned approaches, the commercial potential of nanoscale biomimetic water filtration is still little explored. The main reasons for the limited commercial implementation are manufacturing difficulties, in particular related to formation of macroscopic defects in the selective layer and the lack of stability needed for practical use with membrane designs incorporating aquaporins. Despite the efforts invested in the development of biomimetic water filters through a variety of creative approaches, this area of research has therefore not yet been able to deliver real-world performance that is on par with its predicted potential.

SUMMARY

It is a general objective to provide a macromolecule membrane structure with improved mechanical properties.

It is a particular objective to provide such a macromolecule membrane structure having sufficient stability to be used in filtration devices.

These and other objectives are met by embodiments as disclosed herein.

The present invention is defined in the independent claims. Further embodiments of the invention are defined in the dependent claims.

An aspect of the embodiments relates to a macromolecule membrane structure comprising a membrane comprising water-channeling integral membrane proteins and coated, on a first surface of the membrane, with a silica layer.

Another aspect of the embodiments relates to a filtration device comprising a porous support comprising a plurality of pores and macromolecule membrane structures according to above.

A further aspect of the embodiments relates to a method of preparing a water filtrate. The method comprises filtering an aqueous solution through a macromolecule membrane structure according to above or a filtration device according to above to obtain the water filtrate.

Yet another aspect of the embodiments relates to a method for concentrating a compound dissolved or dispersed in an aqueous solution. The method comprises filtering the aqueous solution through a macromolecule membrane structure according to above or a filtration device according to above to obtain a water filtrate lacking the compound and a retentate comprising the compound at a higher concentration than the aqueous solution.

An aspect of the embodiments relates to a process for preparation of a macromolecule membrane structure. The process comprises contacting a membrane comprising water-channeling integral membrane proteins with a silica precursor to form a silica layer coated on a first surface of the membrane.

Another aspect of the embodiments relates to a process for preparation of a filtration device. The process comprises depositing a membrane comprising water-channeling integral membrane proteins onto and/or into a porous support. The process also comprises contacting the membrane comprising