The ceramic support has a thickness of 1 to 10000 μm (preferably, 50-1000 μm, and, more preferably, 100-300 μm) and a pore size of 1 to 200 nm (preferably, 5-100 nm, and, more preferably, 10-40 nm). Examples of the ceramic support include, but are not limited to, α-alumina, titania, zirconia, and a combination thereof.

The polymeric gutter layer has a thickness of 1 to 10000 nm (preferably, 20-1000 nm, and, more preferably, 50-500 nm) and can be made of polydopamine (PDA) or a polyelectrolyte having an amine functional group, e.g., polyethyleneimine (PEI). Examples of a polyelectrolyte can be found in Krasemann et al., Self-assembled polyelectrolyte multilayer membranes with highly improved pervaporation separation of ethanol/water mixtures, J. Membr. Sci. 181 (2001) 221–228.

The thin film layer, having a thickness of 10 to 1000 nm (preferably, 20-500 nm, and, more preferably, 50-100 nm), can be made of a polyamide covalently bonding to the polymeric gutter layer via an ester bond or an amide bond.

In one embodiment, the TFC membrane includes a ceramic support made of α-alumina, a polymeric gutter layer made of PEI, and a thin film layer made of poly(m-phenylenediamine trimesoyl amide) covalently bonding to the polymeric gutter layer via an amide bond.

In another embodiment of the TFC membrane, the ceramic support is a tube that has an outer diameter of 0.1 to 100 mm and an inner diameter of 0.05 to 95 mm, the polymeric gutter layer bonding onto the inner surface of the tube.

Optionally, the TFC membrane of this invention further includes a sealing layer that bonds to the thin film layer. The sealing layer, which can be made of polydimethylsiloxane (PDMS), has a thickness of 1 to 250 nm (preferably, 5-100 nm, and, more preferably, 10-40 nm).

Another aspect of this invention relates to a method of preparing the above-described TFC membrane. The method includes the following steps: (i) providing a ceramic support having a thickness of 1 to 10000 μm and a pore size of 1 to 200 nm, (ii) coating a polymer on a surface of the ceramic support to form a polymeric gutter layer having a thickness of 1 to 10000 nm, and (iii) forming by interfacial

polymerization a thin film layer having a thickness of 10 to 1000 nm and bonding covalently onto the polymeric gutter layer. The TFC membrane thus formed has a ceramic support, a polymeric gutter layer, and a thin film layer.

As disclosed above, the ceramic support can be made of α-alumina, titania, zirconia, or a combination thereof; the polymeric gutter layer can be made of PDA or a polyelectrolyte having an amine functional group; and the thin film layer can be made of a polyamide. Poly(m-phenylenediamine trimesoyl amide), an example of a polyamide, is typically formed via interfacial polymerization between phenylenediamine (MPD) and trimesoyl chloride (TMC).

The above-described method can include a step of coating a sealing layer onto the thin film layer. Examples of the polymer used for the sealing layer are enumerated above.

The details of the invention are set forth in the description below. Other features, objects, and advantages of the invention will be apparent from the description and from the claims.

DETAILED DESCRIPTION

The TFC membrane of this invention includes a ceramic support, which swells minimally and maintains the stability of the membrane in a pervaporation process. It has a flux rate of 6.0 $kgm^{-2}h^{-1}$ and a separation factor of greater than 1000 at 80 °C for pervaporation dehydration of isopropyl alcohol (IPA).

Both the flux rate and the separation factor of a TFC membrane can be measured in a laboratory scale pervaporation study described in Shi *et al*., Dual-layer PBI/P84 hollow fibers for pervaporation dehydration of acetone, AIChE J., 58 (2012) 1133-1145.

The flux rate J is determined by the following equation:

$$J = \frac{Q}{AT} \quad ,$$

wherein Q is the total mass transferred over time t and A is the membrane area. The mass of permeate is weighed by using a Mettler Toledo balance.

What is claimed is:

1. A thin film composite (TFC) membrane comprising

a ceramic support having a thickness of 1 to 10000 μm and a pore size of 1 to 200 nm,

a polymeric gutter layer having a thickness of 1 to 10000 nm, and

a thin film layer having a thickness of 10 to 1000 nm,

wherein the polymeric gutter layer bonds covalently or non-covalently onto the ceramic support and the thin film layer bonds covalently onto the polymeric gutter layer.

2. The TFC membrane of claim 1, wherein the ceramic support is made of α-alumina, titania, zirconia, or a combination thereof.

3. The TFC membrane of claim 2, wherein the ceramic support is made of α-alumina.

4. The TFC membrane of claim 1, wherein the polymeric gutter layer is made of polydopamine or a polyelectrolyte having an amine functional group.

5. The TFC membrane of claim 4, wherein the polymeric gutter layer is made of polyethyleneimine.

6. The TFC membrane of claim 1, wherein the thin film layer is made of a polyamide covalently bonding to the polymeric gutter layer via an ester bond or an amide bond.

7. The TFC membrane of claim 6, wherein the thin film layer is made of poly(m-phenylenediamine trimesoyl amide) covalently bonding to the polymeric gutter layer via an amide bond.

8. The TFC membrane of claim 7, wherein the ceramic support is made of α-alumina, the polymeric gutter layer is made of polyethyleneimine.

9. The TFC membrane of claims 1, wherein the ceramic support is a tube that has an outer diameter of 0.1 to 100 mm, an inner diameter of 0.05 to 95 mm, and an inner surface, the polymeric gutter layer bonding onto the inner surface.

10. The TFC membrane of claim 9, wherein the ceramic support is made of α-alumina, titania, zirconia, or a combination thereof, the polymeric gutter layer is made of polydopamine or a polyelectrolyte having an amine functional group, and the thin film layer is made of a polyamide covalently bonding to the polymeric gutter layer via an ester bond or an amide bond.

11. The TFC membrane of claim 10, wherein the ceramic support is made of α-alumina, the polymeric gutter layer is made of polyethyleneimine, and the thin film layer is made of poly(m-phenylenediamine trimesoyl amide) covalently bonding to the polymeric gutter layer via an amide bond.

12. The TFC membrane of claim 1, further comprising a sealing layer that bonds to the thin film layer, the sealing layer having a thickness of 1 nm to 250 nm.

13. The TFC membrane of claim 12, wherein the ceramic support is made of α-alumina, titania, zirconia, or a combination thereof, the polymeric gutter layer is made of polydopamine or a polyelectrolyte having an amine functional group, and the thin film layer is made of a polyamide covalently bonding to the polymeric gutter layer via an ester bond or an amide bond.

14. The TFC membrane of claim 12, wherein the sealing layer is made of polydimethylsiloxane.

15. The TFC membrane of claim 14, wherein the ceramic support is made of α-alumina, the polymeric gutter layer is made of polyethyleneimine, and the thin film layer is made of poly(m-phenylenediamine trimesoyl amide) covalently bonding to the polymeric gutter layer via an amide bond.

16. A method of preparing a TFC membrane of claim 1, the method comprising:

providing a ceramic support having a thickness of 1 to 10000 μm and a pore size of 1 to 200 nm,

coating a polymer on a surface of the ceramic support to form a polymeric gutter layer having a thickness of 1 to 10000 nm, and

forming by interfacial polymerization a thin film layer bonding covalently onto the polymeric gutter layer, the thin film layer having a thickness of 10 to 1000 nm.

17. The method of claim 16, further comprising coating a sealing layer onto the thin film layer.

18. The method of claim 17, wherein the ceramic support is a tube that has an outer diameter of 0.1 to 100 mm, an inner diameter of 0.05 to 95 mm, an outer surface, and an inner surface, the polymeric gutter layer bonding onto the inner surface.

19. The method of claim 18, further comprising coating a sealing layer onto the thin film layer, wherein the ceramic support is made of α-alumina, titania, zirconia, or a combination thereof, the polymeric gutter layer is made of polydopamine or a polyelectrolyte having an amine functional group, and the thin film layer is made of a polyamide covalently bonding to the polymeric gutter layer via an ester bond or an amide bond.

20. The method of claim 19, wherein the ceramic support is made of α-alumina, the polymeric gutter layer is made of polyethyleneimine, the thin film layer is made of poly(m-phenylenediamine trimesoyl amide) covalently bonding to the polymeric gutter layer via an amide bond, and the sealing layer is made of polydimethylsiloxane.