[0005]

[Patent Literature 1]

WO 2011/111679

[Patent Literature 2]

WO 2013/012024

[Patent Literature 3]

WO 2016/113964

[Summary of Invention]

[Technical Problem]

[0006]

However, the hollow fiber membrane mentioned in Patent Literature 1 has a substantially homogeneous structure and tends to have low pure water permeability.

[0007]

The hollow fiber membranes mentioned in Patent Literatures 2 and 3 contain a copolymer of vinylpyrrolidone and vinyl acetate to suppress clogging due to protein adhesion. However, since both hollow fiber membranes have low permeability, there is a need to treat under high pressure.

[0008]

Embodiments of the present invention provide a hollow fiber membrane which has excellent removing performance of substances to be separated such as viruses, and can be used as a separation membrane having high permeability even in a treatment under low pressure.

[Solution to Problem]

[0009]

According to a first aspect of the present invention, there is provided a porous hollow fiber membrane containing a polysulfone-based polymer as a main component, which has an asymmetric structure in which the inner surface side is dense

and the outer surface side is coarse, wherein an average of a minor axis diameter of pores of an inner surface is 20 nm or more and 40 nm or less, an open porosity of the inner surface is 5% or more and 30% or less, and a polymer including a monocarboxylic acid vinyl ester unit is supported on at least one of the outer surface and the inner surface, wherein the monocarboxylic acid vinyl ester unit is a unit represented by "-CH(OCO-R)-CH_2-" (R is an aliphatic hydrocarbon group or an aromatic hydrocarbon group having 2 to 5 carbon atoms).

According to a second aspect of the present invention, there is provided a purification system for obtaining desired cells or proteins from a solution containing cells and proteins, comprising the above porous hollow fiber membrane and a separation membrane having pores each having a diameter smaller than that in the hollow fiber membrane, wherein the porous hollow fiber membrane and the separation membrane are arranged such that the solution is sequentially treated by the porous hollow fiber membrane and the separation membrane.

[Advantageous Effects of Invention]

[0010]

According to embodiments of the porous hollow fiber membrane of the present invention, it is possible to perform separation of biological components, particularly separation of proteins such as antibodies, from viruses under low pressure in a short time.

[Brief Description of the Drawings]

[0011]

Fig. 1 is a SEM image of a cross-section of a porous hollow fiber membrane fabricated in Example 1 taken at 10,000 times.

CLAIMS

1. A porous hollow fiber membrane containing a polysulfone-based polymer as a main component, which has an asymmetric structure in which the inner surface side is dense and the outer surface side is coarse, wherein an average of a minor axis diameter of pores of an inner surface is 20 nm or more and 40 nm or less, an open porosity of the inner surface is 5% or more and 30% or less, and a polymer including a monocarboxylic acid vinyl ester unit is supported on at least one of the outer surface and the inner surface, wherein the monocarboxylic acid vinyl ester unit is a unit represented by "-CH(OCO-R)-CH_2-" (R is an aliphatic hydrocarbon group or an aromatic hydrocarbon group having 2 to 5 carbon atoms).

2. The porous hollow fiber membrane according to claim 1, wherein the thickness of a dense layer with no pores having a pore diameter of 130 nm or more on the inner surface side is 1 μm or less.

3. The porous hollow fiber membrane according to claim 1 or 2, wherein a ratio of a major axis diameter to a minor axis diameter of pores of the inner surface is 2 or more and 6 or less.

4. The porous hollow fiber membrane according to any one of claims 1 to 3, which has a thickness of 20 μm or more and 100 μm or less.

5. The porous hollow fiber membrane according to claim 1, wherein the monocarboxylic acid vinyl ester unit is selected from the group consisting of ~~a vinyl acetate unit,~~ a vinyl propanoate unit, a vinyl butyrate unit, a vinyl pentanoate unit, a vinyl pivalate unit and a vinyl hexanoate unit.

6. The porous hollow fiber membrane according to any one of claims 1 to 5, wherein the polymer including a monocarboxylic acid vinyl ester unit is a copolymer composed of a

hydrophobic unit including a monocarboxylic acid vinyl ester unit, and a hydrophilic unit.

7. The porous hollow fiber membrane according to claim 6, wherein the hydrophilic unit is a vinylpyrrolidone unit.

8. The porous hollow fiber membrane according to claim 7, wherein the polymer including a monocarboxylic acid vinyl ester unit is a copolymer composed of a monocarboxylic acid vinyl ester unit and a vinylpyrrolidone unit.

9. The porous hollow fiber membrane according to any one of claims 1 to 8, wherein an area percentage of a carbon peak derived from an ester group is 0.1 (atomic %) or more and 25 (atomic %) or less, when the measurement is performed on at least one surface of the outer surface or the inner surface of the porous hollow fiber membrane by X-ray photoelectron spectroscopy, on the assumption that the total peak area derived from carbon is 100 (atomic %).

10. The porous hollow fiber membrane according to any one of claims 1 to 9, wherein an average of a ratio $(A_{COO})/(A_{CC})$ of a peak area (A_{COO}) of an infrared absorption spectrum derived from an ester group to a peak area (A_{CC}) of an infrared absorption spectrum derived from a benzene ring of a polysulfone-based polymer is 0.01 or more and 1 or less, when the measurement is performed on at least one surface of the outer surface or the inner surface of the porous hollow fiber membrane by infrared microspectroscopy.

11. The porous hollow fiber membrane according to any one of claims 1 to10, wherein the polymer including a monocarboxylic acid vinyl ester unit has a number-average molecular weight of 1,000 or more and 1,000,000 or less.

12. A porous hollow fiber membrane module comprising the porous hollow fiber membrane according to any one of claims 1 to 11 housed in a housing.

13. The porous hollow fiber membrane according to any one of claims 1 to 11 or the porous hollow fiber membrane module according to claim12, which is used for a virus removal step.

14. The porous hollow fiber membrane according to any one of claims 1 to 11 or the porous hollow fiber membrane module according to claim12, which is used in a step of separating an antibody-producing cell from an antibody.

15. The porous hollow fiber membrane according to any one of claims 1 to 11 or the porous hollow fiber membrane module according to claim 12, which is used in a step of separating an antibody from an aggregate of the antibody.

16. A purification system for obtaining desired cells or proteins from a solution containing cells and proteins, comprising the porous hollow fiber membrane according to any one of claims 1 to 11 and a separation membrane having pores each having a diameter smaller than that in the hollow fiber membrane, wherein the porous hollow fiber membrane and the separation membrane are arranged such that the solution is sequentially treated by the porous hollow fiber membrane and the separation membrane.