Claims

1. A wound-pleated filter useful to reduce an amount of a trace impurity in a fluid, the wound-pleated filter comprising:

a multi-layer filter membrane assembly comprising a first porous filter membrane layer and a second porous filter membrane layer, each of the first porous filter membrane layer and the second porous filter membrane layer comprising an inlet surface, an outlet surface, a length, an inlet end that extends along the length, an outlet end that extends along the length, and a width between the inlet end and the outlet end, with:

the porous filter membrane layer assembly wound along the length, about a central axis, to form the wound-pleated filter, with:

the inlet surface of the first porous filter membrane layer facing an inlet surface of the second porous filter membrane layer,

a wound inlet pleat that comprises inlet ends of adjacent filter membrane layers at an inlet end of the wound-pleated filter, and

a wound outlet pleat that comprises outlet ends of adjacent filter membrane layers at an outlet end of the wound-pleated filter.

2. The wound-pleated filter of claim 1 comprising multiple porous filter membrane layer windings.

3. The wound-pleated filter of claim 1 comprising an outlet surface of the first porous filter membrane layer facing an outlet surface of an adjacent porous filter membrane layer.

4. The wound-pleated filter of claim 1, the wound inlet pleat comprising:

a fold between the inlet ends of adjacent porous filter membrane layers,

inlet ends of two adjacent porous filter membrane layers bonded together by bonding agent, or

inlet ends of two adjacent porous filter membrane layers bonded together by a weld.

5. The wound-pleated filter of claim 1, the wound outlet pleat comprising:

a fold between the outlet ends of adjacent porous filter membrane layers,

outlet ends of two adjacent porous filter membrane layers bonded together by bonding agent, or

outlet ends of two adjacent porous filter membrane layers bonded together by a weld.

6. The wound-pleated filter of claim 4, the bonding agent comprising thermoplastic polymer selected from: a polyolefin, a fluoropolymer, and a perfluoropolymer.

7. The wound-pleated filter of claim 4, the bonding agent selected from: polypropylene, polyethylene, poly tetrafluoroethylene (PTFE), and a polyfluoroalkylenes (PFA).

8. The wound-pleated filter of claim 1, wherein each of the first membrane layer and the second membrane layer comprises polymeric membrane capable of reducing an amount of a trace impurity from a fluid as the fluid passes through the polymeric membrane.

9. The wound-pleated filter of claim 1, wherein each of the first porous filter membrane layer and the second porous filter membrane layer comprises polymer selected from: a polyamide, a polyimide, a polyamide-polyimide, a polysulfone, a fluoropolymer, and a nylon.

10. The wound-pleated filter of claim 1, wherein each of the first porous filter membrane layer and the second porous filter membrane has a thickness in a range from 2 to 200 microns.

11. The wound-pleated filter of claim 1, wherein each of the first porous filter membrane layer and the second porous filter membrane comprises a polymeric membrane having a symmetrical morphology.

12. The wound-pleated filter of claim 1, wherein each of the first porous filter membrane layer and the second porous filter membrane comprises a polymeric membrane having an asymmetrical morphology.

13. The wound-pleated filter of claim 1, having a total inlet surface area in a range of 0.1 to 100 square meters.

14. The wound-pleated filter of claim 1 comprising:

an inlet-side spacer between the inlet surface of the first porous filter membrane layer and the inlet surface of the second porous filter membrane layer, and

an outlet-side spacer located between an outlet surface of the porous filter membrane layer and an outlet surface of an adjacent porous filter layer membrane.

15. The wound-pleated filter of claim 14, wherein each of the inlet-side spacer and the outlet-side spacer has a thickness in a range from 10 to 2000 microns.

16. A wound-pleated filter comprising:

a multi-layer filter membrane assembly comprising a first porous filter membrane layer and a second porous filter membrane layer, each of the first porous filter membrane layer and the second porous filter membrane layer comprising an inlet surface, an outlet surface, a length, an inlet end that extends along the length, an outlet end that extends along the length, and a width between the inlet end and the outlet end, with:

the porous filter membrane layer assembly wound along the length and about a central axis to form the wound-pleated filter comprising multiple porous filter membrane layer assembly windings, with:

the inlet surface of the first porous filter membrane layer facing an inlet surface of the second porous filter membrane layer,

a pleat comprising an outlet end of the first porous filter membrane layer and an outlet end of an adjacent porous filter membrane layer, the pleat comprising a fold, a weld, or a thermoplastic bonding agent, and

wound inlet ends of the membrane layers at an inlet end of the wound-pleated filter,

wound outlet ends of the membrane layers at an outlet end of the wound-pleated filter.

17. The wound-pleated filter of claim 16, comprising:

an outlet surface of a first porous filter membrane layer facing an outlet surface a second porous filter membrane layer of an adjacent filter membrane layer,

a pleat comprising an inlet end of the first porous filter membrane layer and an inlet end of an adjacent filter membrane layer, the pleat comprising a fold, a weld, or a thermoplastic bonding agent.

18. The wound-pleated filter of claim 16, wherein each of the first porous filter membrane layer and the second porous filter membrane layer has a thickness in a range from 2 to 200 microns.

19. The wound-pleated filter of claim 16, wherein each of the first porous filter membrane layer and the second porous filter membrane layer comprises polymer selected from: a polyamide, a polyimide, a polyamide-polyimide, a polysulfone, a fluoropolymer, and a nylon.

20. A method of removing an impurity from a fluid, the method comprising:

causing fluid to pass through a filter of any of claims 1 through 19, the fluid comprising a trace impurity, such that the filter membrane retains a portion of the trace impurity.

21. The method of claim 20, wherein the impurity is present in the liquid in an amount of below 100 parts per million.