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WEB STRUCTURE MEMBRANE SPACER

FIELD OF INVENTION

- 5 The invention relates to spacers for use between membranes in electrodialysis devices and in particular to circular membrane spacers that provide at least partially helical flow paths to fluid flowing between adjacent membranes.

BACKGROUND

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Electrodialysis devices are used to exchange ions between two or more fluids, for example, a concentrate and a dilute fluid. The devices include a stack of membranes and spacers packed between two electrodes. The membrane and spacer stack is made liquid-tight by mechanical means so that holes within the spacers become conduits and passages between adjacent membranes through which the fluids in the device flow. The membranes are cation and/or anion permeable. The concentrate and dilute fluids flow through spacers between adjacent membranes and the membranes allow ions to pass from the concentrate fluid to the dilute fluid. An electric current applied to the device provides electrically charged membranes that separate ions from the concentrate fluid flowing through the spacers between the membranes.

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Ideally the membranes are flexible and spaced close together with typical spacing between membranes of between 0.5 and 2mm. This means that membrane spacers must be thin. However, the spacers must still offer support to the membranes. Two types of spacers are commonly used, tortuous path spacers and sheet flow path spacers.

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Tortuous path spacers are typically rectangular with a series of holes at the top and bottom ends. The spacer between a pair of membranes is typically formed from two spacers sections each the same size. In one prior art tortuous path spacer a channel is provided that starts at a hole at the top of the spacer and ends a hole at the bottom of the spacer. The path moves from side to side down the spacer, at each side turning a corner so that fluid in the channel flowing say from left to right between the sides flows around

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the corner then right to left towards the other side and the next corner. In this way a large portion of the area between the top holes and the bottom holes forms a channel for fluid in the spacer. Each of the spacer sections also includes a plurality of rectangular segments that run perpendicular to the flow path. These segments are staggered so that where one segment is positioned on one spacer section there is no segment on the other spacer section. The provision of the rectangular segments forces fluid flowing in the channel to not only move from side to side down the spacer but also up and down around the rectangular segments. This produces turbulence within the fluid flow that increases the effectiveness of the electrodialysis device. Disadvantages of the tortuous path membrane spacer include the increase of flow resistance at each corner where fluid flowing in the channel must turn 180 degrees and the membrane wastage that occurs at the channel forming segments and sides of the spacer where not all the membrane can be used to exchange ions.

A typical sheet flow spacer is rectangular with three spacer sections. The upper and lower spacer sections are rectangular with a central rectangular aperture. Both the upper and lower sections include a plurality of holes at the top and bottom ends where one hole at each of the upper and lower sections is connected to the central aperture. The central section is a mesh that is sandwiched between the other two sections. The mesh fills the rectangular aperture of the upper and lower spacer sections. Fluid flowing in this spacer enters at one of the holes connected to the central aperture and flows through the mesh to the hole connected to the aperture at the other end of the spacer. Flow in mesh spacers is generally not uniform since the inlet and outlet are usually small circular holes and therefore the fluid needs to fan out from the inlet and fan in to the outlet. The mesh acts to maintain the gap between the spacers. While the mesh spacer has higher usable area than the tortuous flow spacer, the mesh spacer has the disadvantages of lower flow distance between the inlet and outlet and lower flow turbulence.

SUMMARY OF INVENTION

It is the object of the invention to provide a membrane spacer that has overcomes the disadvantages of the spacers described above or to at least provide the public with a useful choice.

In broad terms in one aspect the invention comprises a membrane spacer comprising, two or more sub-spacers, at least one sub-spacer including, at least one inlet aperture, at least one outlet aperture, said at least one inlet aperture connected to said at least one outlet aperture by a substantially curved flow path, said substantially curved flow path including a plurality of grid sectors running perpendicular to the curved flow path, wherein the two or more sub-spacers are aligned to provide a tortuous path between the inlet aperture and the outlet aperture.

Preferably a plurality of inlet and outlet apertures is provided on each sub-spacer.

Preferably the inlet and outlet apertures are uniformly spaced about the sub-spacer.

In one embodiment each sub-spacer in a membrane stack is identical to the other sub-spacers. In this embodiment one sub-spacer in a membrane spacer is rotated and/or reversed relative to another sub-spacer in the membrane spacer to provide the tortuous path through which fluid flows.

In a second embodiment at least one sub-spacer in a membrane spacer is different from at least one other sub-spacer in the membrane spacer. In this embodiment the two sub-spacers are aligned to provide a tortuous path through which fluid flows.

Ideally membrane spacers are rotated by 90, 180 or 270 degrees between membranes so that the same membrane spacer can be provided between each pair of membranes. This allows alternation between different fluids within the electrolysis device without altering membrane design.

In broad terms in a further aspect the invention comprises a membrane sub-spacer including at least one inlet aperture, at least one outlet aperture, said at least one inlet aperture connected to said at least one outlet aperture by a substantially curved flow path, said substantially curved flow path including a plurality of grid sector running
5 perpendicular to the curved flow path.

BRIEF DESCRIPTION OF DRAWINGS

The invention including preferred form sub-spacers will be further described by way of
10 example only and without intending to be limiting with reference to the following drawings, wherein:

Figure 1 shows an electrodialysis module;

15 Figure 2 shows a first embodiment of sub-spacer of the invention;

Figure 3 shows a membrane spacer formed from two sub-spacers of Figure 2;

Figure 4 shows a second embodiment of sub-spacer of the invention;

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Figure 5 shows a third embodiment of sub-spacer of the invention; and

Figure 6 shows a fourth embodiment of sub-spacer of the invention.

25 DETAILED DESCRIPTION

Figure 1 shows an electrodialysis module 10. The module includes cathode chamber 11 and anode chamber 12. Between the cathode and anode chambers are a plurality of membranes and membrane spacers 13.

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In one embodiment of electrodialysis device the membranes are divided into cation exchange membranes, anion exchange membranes and bipolar membranes. Bipolar

membranes have anion exchange functionality and cation exchange functionality on each side of the membrane. The membranes alternate down the module for example, cation exchange membrane, anion exchange membrane, bipolar membrane, cation exchange membrane, etc. Between each pair of membranes is a membrane spacer. The membranes and membrane spacers are arranged to provide channels for a process fluid, product fluids and an electrorinse fluid. Other electrodialysis devices may use different arrangements of membranes.

The membrane stack of Figure 1 contains cation exchange membranes, anion exchange membranes and bipolar membranes in the order given above. In an example system the bipolar membranes in the membrane stack may be used to split water into hydroxide ions and protons, where the protons move through the cation exchange part of the bipolar membrane and the hydroxide ions move through the anion exchange part of the bipolar membrane. The process stream flows between the cation and anion exchange membranes. Product streams flow between the anion and bipolar membranes and the cation and bipolar membranes. One product stream (the acid product stream) flows between the bipolar membrane and the anion exchange membrane. This stream consists of protons generated from the bipolar membrane and the anions from the process stream. The other product stream (the base product stream) flows between the bipolar membrane and the cation exchange membrane. This stream consists of the hydroxide ions generated from the bipolar membrane and the cations from the process stream. In this way the cations and anions of the process stream are separated into two product streams.

The electrorinse stream contains a chemical that limits undesirable reactions at the electrodes. For example the electrorinse stream may consist of sodium sulphate. In a membrane stack of for example 500 or more cell pairs only one is for the electrorinse system. Only a small portion of the cations and anions are transferred to the electrorinse stream.

The electrodialysis module is arranged to remove cations and anions from the process fluid. These cations or anions are exchanged through the membranes into the product fluids when an electric signal is applied to the electrodialysis module.

- 5 The membrane spacers provide channels between membranes through which the process and product fluids flow. Ideally the membrane spacers provide channels between the membranes that provide a high level of contact between the membranes and the process and product fluids. Membrane spacers must also be strong to provide support to the membranes and thin, typically between 0.5 and 2mm thick. Membrane
10 spacers ideally utilise as much membrane area as possible and have low flow resistance and a low pressure drop.

Figure 2 shows one embodiment of membrane sub-spacer of the invention. The sub-spacer includes inlet and outlet apertures 20 that lead to fluid channel 26. Channel 26
15 runs between the inlet and outlet apertures and follows a substantially curved path. Arrows 27 show a fluid path between the inlet and outlet apertures. Alternatively the fluid path may be in the direction opposite to that shown by arrows 27. Grid sectors 23 and 24 run perpendicular to channel 26 across the flow of fluid in the channel. The membrane sub-spacer also includes a plurality of apertures 21 spaced about the
20 periphery of the sub-spacer and a central aperture 25. Central aperture 25 may be used as a fluid channel or may be used to connect the membranes and membrane spacers together.

In use a membrane spacer comprising two or more sub-spacers is sandwiched between a
25 pair of membranes. The membranes include apertures that align with inlet and outlet apertures 20 to allow fluid to enter and exit the membrane spacer. If the membrane sub-spacer shown in Figure 2 is used to form a membrane spacer between one pair of membranes, the membrane spacers between the membrane pairs on either side of the sub-spacer will be rotated by either 90, 180, or 270 degrees. This means that the
30 apertures 20 in the membrane sub-spacer will be aligned with a pair of apertures 21 in the upper and lower membrane spacers providing a channel that allows either the process or a product fluid into the middle membrane spacer and the other fluid(s) into

the membrane spacers on either side of the middle membrane spacer. In this way the same sub-spacers can be used to form all the membrane spacers in a stack while ensuring that the process and product fluids do not mix.

- 5 In use either grid sectors 23 or grid sectors 24 are removed from each sub-spacer in the membrane spacer. Two sub-spacers are then aligned so that one sub-spacer is the mirror image of the other sub-spacer. This is shown in Figure 3. The two sub-spacers together form a membrane spacer. Alternatively more than two sub-spacers may be aligned to form the membrane spacer.

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Figure 3 shows membrane spacer 30. This spacer is formed from two sub-spacers 32 (shaded) and 39 with the design shown in Figure 2. Inlet and outlet apertures 38 are provided in both sub-spacers. Apertures 31 are spaced uniformly from the centre of the sub-spacer so that the apertures remain aligned when the sub-spacers are arranged to form a membrane spacer.

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Both sub-spacers 32 and 39 that form membrane spacer 30 have had either grid sectors 33 or grid sectors 34 removed. In Figure 3 both sub-spacers 32 and 39 have had grid sectors 33 removed. These grid sectors are the same as grid sectors 23 shown in Figure 2. When the two sub-spacers are arranged together the grid sectors alternate from one sub-spacer to the other. This provides a tortuous path for fluid flowing in channel 36 as shown by arrows 37. Fluid in the channel flows under grid sectors 34 of sub-spacer 32 and over grid sectors 34 of sub-spacer 39. The advantage of a tortuous path is that it promotes turbulence in the fluid and increases contact between the fluid and the membrane. The increase of contact between the fluid and membrane increases the efficiency of the ion exchange by the electrodialysis device.

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Figure 4 shows a second embodiment of membrane sub-spacer of the invention. The sub-spacer includes inlet and outlet apertures 48 that lead to fluid channel 46. Channel 46 runs between the inlet and outlet apertures and follows a substantially curved path. Arrows 47 show a fluid path between the inlet and outlet apertures. Alternatively the fluid path may be in the direction opposite to that shown by arrows 47. Grid sectors 43

and 44 run perpendicular to channel 46 across the flow of fluid in the channel. The membrane sub-spacer also includes a plurality of apertures 41 spaced about the periphery of the sub-spacer, and a central aperture 45. Central aperture 45 may be used as a fluid channel or may be used to connect the membranes and membrane spacers together. Membrane sub-spacer 40 is designed to fit into a square stack of membranes and spacers. Membrane sub-spacer 40 also includes a plurality of apertures 49 that may be used to connect a stack of membranes and spacers in a fluid-tight arrangement so that no fluid leaks from the electrodialysis device.

- 10 In use a membrane spacer comprising two or more sub-spacers is sandwiched between a pair of membranes. The membranes include apertures that align with inlet and outlet apertures 48 to allow fluid to enter and exit the membrane spacer. If the membrane sub-spacer shown in Figure 4 is used to form a membrane spacer between one pair of membranes, the membrane spacers between the membrane pairs on either side of the sub-spacer will be rotated by either 90, 180, or 270 degrees. This means that the apertures 48 in the membrane sub-spacer will be aligned with a pair of apertures 41 in the upper and lower membrane spacers providing a channel that allows either the process or a product fluid into the middle membrane spacer and the other fluid(s) into the membrane spacers on either side of the middle membrane spacer. In this way the same sub-spacers can be used to form all the membrane spacers in a stack while ensuring that the process and product fluids do not mix.

- In use either grid sectors 43 or grid sectors 44 are removed from each sub-spacer in the membrane spacer. Two sub-spacers are then aligned so that one sub-spacer is the mirror image of the other sub-spacer. The two sub-spacers together form a membrane spacer. Alternatively more than two sub-spacers are aligned to form the membrane spacer. The removal of grid sectors 43 or 44 provides a tortuous path between the two sub-spacers in the membrane through which fluid flows.

- 30 One difference between the sub-spacer of Figure 4 and the sub-spacer of Figure 2 is that in the centre of the sub-spacer of Figure 4 fluid flows in almost a complete circle. This

reduces the number of 180 degree turns through which the fluid flows and lowers the fluid pressure required for fluid to flow through the spacer.

Figure 5 shows a third embodiment of sub-spacer of the invention. The sub-spacer includes inlet and outlet apertures 58 that lead to fluid channel 56. Channel 56 runs between the inlet and outlet apertures and follows a substantially curved path. Arrows 57 show a fluid path between the inlet and outlet apertures. Alternatively the fluid path may be in the direction opposite to that shown by arrows 57. Grid sectors 53 and 54 run perpendicular to channel 56 across the flow of fluid in the channel. Membrane sub-spacer 50 is designed to fit into a square stack of membranes and spacers. The membrane sub-spacer also includes a plurality of apertures 51 spaced about the periphery of the sub-spacer. At least two of apertures 51 are used by a second fluid in other membrane spacers in the electrodialysis device. Further apertures may be provided for connections means used to connect the membranes and membrane spacers in fluid tight connection.

In use a membrane spacer comprising two or more sub-spacers is sandwiched between a pair of membranes. The membranes include apertures that align with inlet and outlet apertures 58 to allow fluid to enter and exit the membrane spacer. If the membrane sub-spacer shown in Figure 5 is used to form a membrane spacer between one pair of membranes, the membrane spacers between the membrane pairs on either side of the sub-spacer will be rotated by either 90, 180, or 270 degrees. This means that the apertures 58 in the membrane sub-spacer will be aligned with a pair of apertures 51 in the upper and lower membrane spacers providing a channel that allows either the process or a product fluid into the middle membrane spacer and the other fluid(s) into the membrane spacers on either side of the middle membrane spacer. In this way the same sub-spacers can be used to form all the membrane spacers in a stack while ensuring that the process and product fluids do not mix.

In use either grid sectors 53 or grid sectors 54 are removed from each sub-spacer in the membrane spacer. Two sub-spacers are then aligned so that one sub-spacer is the mirror image of the other sub-spacer. The two sub-spacers together form a membrane

spacer. Alternatively more than two sub-spacers may be aligned to form the membrane spacer. The removal of grid sectors 53 or 54 provides a tortuous path between the two sub-spacers in the membrane through which fluid flows.

5 One advantage of the membrane sub-spacer of Figure 5 over those of Figures 2 and 4 is that fluid flowing in the channel 56 of the sub-spacer of Figure 5 has fewer 180 degree turns than those of Figures 2 and 4. This reduces the pressure drop experienced by the fluid flow in channel 56 of the membrane sub-spacer of Figure 5.

10 Figure 6 shows a fourth embodiment of sub-spacer of the invention. The sub-spacer includes inlet and outlet apertures 68 that lead to fluid channel 66. Channel 66 runs between the inlet and outlet apertures and follows a substantially curved path. Arrows 67 show a fluid path between the inlet and outlet apertures. Alternatively the fluid path may be in the direction opposite to that shown by arrows 67. Grid sectors 63 and 64 run
15 perpendicular to channel 66 across the flow of fluid in the channel. Membrane sub-spacer 60 is designed to fit into a square stack of membranes and spacers. The membrane sub-spacer also includes a plurality of apertures 61 spaced about the periphery of the sub-spacer. At least two of apertures 61 are used by a second fluid in other membrane spacers in the electrodialysis device. Further apertures may be
20 provided for connections means used to connect the membranes and membrane spacers in fluid tight connection.

In use a membrane spacer comprising two or more sub-spacers is sandwiched between a pair of membranes. The membranes include apertures that align with inlet and outlet
25 apertures 68 to allow fluid to enter and exit the membrane spacer. If the membrane sub-spacer shown in Figure 6 is used to form a membrane spacer between one pair of membranes, the membrane spacers between the membrane pairs on either side of the sub-spacer will be rotated by either 90, 180, or 270 degrees. This means that the apertures 68 in the membrane sub-spacer will be aligned with a pair of apertures 61 in
30 the upper and lower membrane spacers providing a channel that allows either the process or a product fluid into the middle membrane spacer and the other fluid(s) into the membrane spacers on either side of the middle membrane spacer. In this way the

same sub-spacers can be used to form all the membrane spacers in a stack while ensuring that the process and product fluids do not mix.

In use grid sectors 63 are removed from one sub-spacer and grid sectors 64 are removed from the other sub-spacer in the membrane spacer. Two sub-spacers are then aligned one on top of the other. The two sub-spacers together form a membrane spacer. Alternatively more than two sub-spacers may be aligned to form the membrane spacer. The removal of grid sectors 63 or 64 provides a tortuous path between the two sub-spacers in the membrane through which fluid flows. In an alternative embodiment grid sectors 63 or 64 are removed from one sub-spacer and a second sub-spacer is provided with inlet and outlet apertures 61 and 68 and with the same channel shape but without aperture 62 leading to the inlet and outlet aperture 68 and with aperture 69 replaced with an circular aperture. In this alternative embodiment two different sub-spacers form each membrane spacer.

The membrane spacer of Figure 6 provides a tortuous flow path with no 180 degree turns through which the fluid must flow. This has the advantage of reducing the pressure drop over the membrane and reducing flow resistance. The membrane sub-spacer of Figure 6 provides a regular channel for fluid flow.

The foregoing describes the invention including preferred forms thereof. Alterations and modifications as will be obvious to those skilled in the art are intended to be incorporated in the scope hereof as defined by the accompanying claims.

CLAIMS

1. A membrane spacer including,
two or more sub-spacers,
5 at least one sub-spacer including,
at least one inlet aperture,
at least one outlet aperture,
said at least one inlet aperture connected to said at least one outlet
aperture by a substantially curved flow path,
10 said substantially curved flow path including a plurality of grid sectors
running perpendicular to the curved flow path,
wherein the two or more sub-spacers are aligned to provide a tortuous path
between the inlet aperture and the outlet aperture.
- 15 2. A membrane spacer as claimed in claim 1 wherein at last one sub-spacer
includes a plurality of inlet and outlet apertures.
3. A membrane spacer as claimed in claim 1 or claim 2 wherein each sub-spacer
includes a plurality of inlet and outlet apertures.
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4. A membrane spacer as claimed in claim 2 or claim 3 wherein the inlet and outlet
apertures are uniformly spaced about the sub-spacer.
5. A membrane spacer as claimed in any one of claims 1 to 4 wherein each sub-
25 spacer in a membrane stack is identical to the other sub-spacers.
6. A membrane spacer as claimed in claim 5 wherein one sub-spacer in a
membrane spacer is rotated and/or reversed relative to another sub-spacer in the
membrane spacer to form a tortuous path through which fluid in the membrane spacer
30 flows.

7. A membrane spacer as claimed in any one of claims 1 to 4 wherein at least one sub-spacer in a membrane spacer is different from at least one other sub-spacer in the membrane spacer.
- 5 8. A membrane spacer as claimed in claim 7 wherein the two sub-spacers are aligned to provide a tortuous path through which fluid in the membrane spacer flows.
9. A membrane spacer as claimed in any one of claims 1 to 8 wherein membrane spacers are rotated by 90 degrees between membranes so that the same membrane
10 spacer can be provided between each pair of membranes.
10. A membrane spacer as claimed in any one of claims 1 to 8 wherein membrane spacers are rotated by 180 degrees between membranes so that the same membrane spacer can be provided between each pair of membranes.
- 15 11. A membrane spacer as claimed in any one of claims 1 to 8 wherein membrane spacers are rotated by 270 degrees between membranes so that the same membrane spacer can be provided between each pair of membranes.
- 20 12. A membrane spacer as claimed in any one of claims 1 to 11 wherein the tortuous path is smooth with no curves of 180 degrees.
13. A membrane sub-spacer including:
at least one inlet aperture,
25 at least one outlet aperture,
said at least one inlet aperture connected to said at least one outlet aperture by a substantially curved flow path,
said substantially curved flow path including a plurality of grid sector running perpendicular to the curved flow path.
- 30 14. A membrane sub-spacer as claimed in claim 13 wherein the sub-spacer includes a plurality of inlet and outlet apertures.

15. A membrane sub-spacer as claimed in claim 14 wherein the inlet and outlet apertures are uniformly spaced about the sub-spacer.
- 5 16. A membrane sub-spacer as claimed in any one of claims 13 to 15 wherein the curved path is a smooth curve with no curves of 180 degrees.