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ABSTRACT

Semipermeable capillary comprising a tubular semipermeable wall composed of membrane-forming material, the capillary furthermore comprising a tubular strengthening layer composed of at least one elongated tape 5 which is converted into a tubular shape and of which at least the longitudinal edges mutually overlap, and the strengthening layer being joined to the wall and the mutually overlapping tape sections being joined together by the membrane-forming material.





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INVENTION TITLE:

Semipermeable capillary and also a method and device for manufacturing it



The following statement is a full description of this invention, including the best method of performing it known to me/us:-



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The invention relates to a semipermeable capillary comprising a tubular semipermeable wall made of membrane-forming material.

Such a semipermeable capillary is disclosed in DE-
5 A-22 36 226. In the latter, a capillary is described which is composed in its entirety of spun polymer solution. Said spun polymer solution is brought into contact with a coagulation liquid. Depending on the direction of flow of the coagulation liquid through the wall, a very dense skin
10 is produced on the inside or outside, while a porous structure is produced on the other side. The dense skin serves as semipermeable membrane layer and the porous structure as supporting material.

A disadvantage of this known capillary is that it
15 is weak as a result of the lack of a reinforcement. As a result, the semipermeable wall can rapidly become damaged. In order to make such a capillary stronger, the wall thickness can be increased, but this increases the flow resistance appreciably, as a result of which the filtration
20 characteristics decrease considerably.

Advantageously the present invention provides reinforced tubular semipermeable capillary in which these disadvantages are alleviated.

According to one aspect of the invention there is
25 provided semipermeable capillary, comprising:

- a tubular strengthening layer composed of at least one elongated tape having longitudinal edge sections, which tape has been converted into a tubular shape with at least the longitudinal edge sections mutually overlapping; and
- a tubular semipermeable wall composed of membrane-forming material supported by the strengthening layer; in which the capillary has a fine bore permitting



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addition to forming the reinforced semipermeable wall, the membrane-forming material has yet another function, viz. the mutual joining of the mutually overlapping tape sections. The capillary according to the invention is
5 cheap, rapid and simple to manufacture.

It is pointed out that GB-A-2 289 634 discloses a supported tubular semipermeable membrane. In this case, the membrane comprises a tubular supporting layer made of a nonwoven polyester material and a thin membrane layer
10 applied thereto. In this structure, the tubular supporting layer is formed from an elongated tape, the longitudinal edges being welded to one another by means of ultrasonic welding. In this case, no capillary is involved and the technique described in this document cannot easily be
15 applied to capillaries.

In particular, the tape of the semipermeable capillary according to the invention has an open cohesive structure which is embedded, preferably completely, in the membrane-forming material. The open cohesive structure of
20 the strengthening layer serves as reinforcement of the membrane-forming material. The strengthening layer is completely anchored in the membrane-forming material and, consequently, the joint between the strengthening layer and the wall is very strong. The wall will not quickly become
25 detached from the strengthening layer and will not quickly become damaged in the event of any deformation of the capillary. The strong bond is advantageous, in particular, in backflushing in countercurrent in order to clean the capillary because the flow direction of the semipermeable
30 wall and the strengthening layer is then reversed with respect to that during use. The tape material may be composed, for example, of a strip of nonwoven, woven, knitted or braided material.

Since, according to the invention, at least the
35 longitudinal edges of the tape or tapes converted to a tubular shape mutually overlap, the joint between the mutually overlapping tape sections is advantageously formed by the membrane-forming material itself. Gluing or welding

the mutually overlapping tape sections is virtually impossible in the case of capillaries because the anvil which is needed for this purpose and which has to be accommodated in the tubular strengthening layer would have too little mass in the case of such small tube diameters. Furthermore, gluing or welding would appreciably slow down the production rate. In addition, in the case of the joint according to the invention, the joining seam is itself also semipermeable, which keeps the effective semipermeable membrane surface optimum and offers the possibility of making the joining seam in wide form in order to obtain a strong joint. This is in contrast to gluing and welding seams, which are usually impenetrable and are therefore kept as narrow as possible. Advantageously, the internal diameter of the capillary is smaller than, or equal to, 5 mm. A very large reinforced semipermeable wall surface can therefore be obtained for each m³ of volume.

In particular, the overlap is greater than, or equal to, 90°. A very strong joint is therefore obtained between the mutually overlapping tape sections. By making the overlap still greater, in particular greater than, or equal to, 360°, not only is a very strong joint obtained, but also a very stiff tubular strengthening layer made up of a plurality of layers.

It is also possible to provide the semipermeable wall with a top layer having nanofiltration and/or reverse osmosis characteristics. A possible method for doing this is to wet the semipermeable capillary as described above with an aqueous solution of a suitably chosen amine, after which the capillary is brought into contact with a suitably chosen acid chloride dissolved in an organic solvent not miscible with water, for example hexane, to thus form a polyamide top layer having reverse osmosis and/or nanofiltration characteristics by means of boundary surface polymerisation. In this way an advantageous embodiment of the strengthened semipermeable capillary is obtained, which has the capacity to withstand the pressures prevailing during nanofiltration or reverse osmosis.

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According to another aspect of the invention there is provided a method for manufacturing a semipermeable capillary, wherein at least one elongated, initially flat tape having an open cohesive structure is converted into a tubular shape in such a way that at least the longitudinal edges mutually overlap, the open cohesive structure being impregnated with membrane-forming material, after which the membrane-forming material in the tape or tapes converted into the tubular shape is coagulated with a coagulation liquid or in another way with the result that there is simultaneous formation both of a joint between the mutually overlapping tape sections and of a semipermeable membrane layer on the internal wall and/or external wall of the tape converted into a tubular shape.

According to a further aspect of the invention there is provided a device for carrying out the above method, the device comprising a device for carrying out the method according to claim 4 or 5, comprising shaping means for converting the initially flat tape into the tubular shape and feed means for moving the tape through the shaping means, wherein the shaping means comprise a shaping chamber having a conical part and a tubular part, which conical part comprises filling means for filling the conical part with membrane-forming material and which device comprises feed means for supplying coagulation liquid.

The invention will be explained in greater detail by reference to the accompanying drawing, in which:

Figure 1 is a view in cross-section of a first embodiment of a semipermeable capillary according to the invention;

Figure 2 is a view corresponding to Figure 1 of a second embodiment;



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Figure 3 is a view corresponding to Figure 1 of a third embodiment;

Figure 4 is a view corresponding to Figure 1 of a fourth embodiment;

Figure 5 diagrammatically shows a device for carrying out a method according to the invention; and

Figure 6 shows a detail on an enlarged scale of a variant of the device shown in Figure 5.

Figure 1 shows a semipermeable capillary according to the invention which has a tubular strengthening layer which has on the inside a semipermeable wall 2 composed of membrane-forming material. The strengthening layer has an open cohesive structure and is formed by a tape 1 converted into a tubular shape. The tape 1 converted into a tubular shape overlaps itself over an angle of approximately 90°. According to the invention, the open cohesive structure of the strengthening layer is completely embedded in the membrane-forming material from which the semipermeable wall 2 is also formed. As a result of the embedding, not only is the capillary strengthened and a strong joint formed between the strengthening layer and the semipermeable wall 2, but a joint is advantageously obtained at the same time between the mutually overlapping tape sections. The semipermeable wall thus forms a continuous phase with the strengthening layer, with the result that a reinforced capillary is obtained.

Figure 2 shows a similar capillary to that in



Figure 1. The strengthening layer is again formed by a tape 3 converted into a tubular shape. However, the overlap is now approximately 360° and the semipermeable wall 4 is provided on the outside. As a result of the large overlap, the strengthening layer is made up over the entire section of two layers. The open cohesive structure of the strengthening layer is again embedded in the membrane-forming material. A very stiff capillary and a very strong joint between the mutually overlapping tape sections are thus obtained.

In the variant shown in Figure 3, the strengthening layer is formed by two tapes 5, 6 which have been converted together into a tubular shape. This time the semipermeable wall 7 is provided on the outside. The overlaps between the two tapes 5, 6 is again approximately 90° for the two longitudinal edges.

Figure 4 shows a similar capillary to that in Figure 3. The strengthening layer is again formed by two tapes 8, 9 converted to a tubular shape. However, the overlap is now complete and the semipermeable wall 10 is provided on the inside and outside. Just as in Figure 2, the strengthening layer is made up of two layers over the entire section.

The invention is not limited to the embodiments of the capillary shown in Figures 1 - 4. The overlap may, for example, be smaller or greater. The strengthening layer may also be formed from more than two tapes.

The membrane-forming material is composed, in particular, of a polymer solution which coagulates in a coagulating liquid such as water, but may also be composed, for example, of a polymer containing oil which coagulates as a result of a temperature reduction. The polymer solution may be formed from polysulphone, polyvinylidene fluoride, polyether sulphone or polyacrylonitrile or any other polymer suitable for forming the semipermeable wall. The strengthening layer is formed by at least one tape which is converted to a tubular shape and may be made up of a nonwoven fibrous fleece material, a knitted material, a

woven material or a braided material, or any other suitable material for forming the strengthening layer which has an open cohesive structure. The internal diameter of the capillaries according to the invention is preferably in the
5 range between 1 and 5 mm.

Figure 5 shows a device which is suitable for manufacturing in a continuous process an embodiment of a reinforced semipermeable capillary according to the invention in which the strengthening layer is formed from
10 one tape which is converted to a tubular shape and has an open cohesive structure. In the device tape 11 is passed through a shaping chamber 12. The elongated tape 11 is fed from a roll and is shown in side view at the top of Figure 5, that is to say viewed along the longitudinal edge. The
15 shaping chamber 12 comprises a conical part 13 and a tubular part 14. Since the tape is moved downwards in the conical part 13, which becomes increasingly narrower, the initially flat tape 11 is rolled up in tubular shape. The tape 11 is rolled up in tubular shape in such a way that at
20 least its longitudinal edges mutually overlap. During the rolling-up, the tape 11 is impregnated with a membrane-forming material 20. Since this impregnation takes place at the same time as the rolling-up, in particular the membrane-forming material situated between the mutually
25 overlapping tape sections is forced through the open cohesive structure with the result that the latter is well and completely impregnated with it. The conical part 13 is filled for this purpose with the membrane-forming material 20, which is supplied via a line 21. Advantageously, the
30 membrane-forming material 20 functions as a lubricant during the rolling-up of the tape 11. The tubular strengthening layer thus formed and impregnated with membrane-forming material is then passed through the tubular part 14 and brought into contact therein with a
35 coagulation liquid 25. As a result, the membrane-forming material 20 coagulates and, depending on the dimensions of the conical part 13 and the tubular part 14, a semipermeable wall is produced on the inside and/or outside

of the tubular strengthening layer. In addition, a very strong joint is produced between the mutually overlapping tape sections of the tape 11 because the membrane-forming material 20 which is situated in the open cohesive

5 structure of the tape 11 and, in particular, at the position of the mutually overlapping tape sections cures.

In the device shown in Figure 5, the semipermeable wall is provided substantially on the inside of the tubular strengthening layer. This is brought about because the
10 inside diameter d_{tube} of the tubular part 14 is of equally large construction as the smallest internal diameter $d_{c,\text{min}}$ of the conical part 13. The tape 11 rolled up in tubular form in the conical part 13 to form said smallest internal diameter is situated, as a result, with its outside
15 substantially against the internal wall of the tubular part 14. Consequently, little or no space is left free at the outside of the tubular strengthening layer, as a result of which the formation of an unbroken semipermeable layer is prevented at that point. In addition, the coagulation
20 liquid 25 is first supplied on the inside of the tubular strengthening layer impregnated with membrane-forming material. This takes place via a line 26 which extends from the conical part 13 into the top of the tubular part 14 and, specifically, as far as into the shaped tubular
25 strengthening layer. The thickness of the semipermeable wall to be formed is determined by the difference in diameter of the external diameter of the line 26 and the internal diameter of the tubular strengthening layer formed in the conical part 13. As a result, a semipermeable wall
30 composed of the membrane-forming material 20 is formed on the inside of the tubular strengthening layer impregnated with membrane-forming material. Only after the tubular strengthening layer has emerged from the tubular part 14 does its outside come into contact with coagulation liquid
35 25. For this purpose, a vessel 28 which is filled with coagulation liquid 25 via a line 27 is situated underneath the shaping chamber 12.

In the device shown in Figure 6, the semipermeable

wall is substantially provided on the outside of the tubular strengthening layer. This is brought about because the internal diameter d_{tube} of the tubular part 14 is of larger construction than the smallest internal diameter $d_{c,\min}$ of the conical part 13. Consequently, space is left free at the outside of the tubular strengthening layer, with the result that a continuous semipermeable wall is able to form at that point. In particular, additional membrane-forming material 20 is provided on the outside of the tubular strengthening layer via a supply line 29. The line 26 has in this case an external diameter which is virtually equal to the internal diameter of the tubular strengthening layer formed in the conical part 13. Consequently, little or no space is left free on the inside of the tubular strengthening layer, as a result of which the formation of a continuous semipermeable wall is prevented at that point. The line 26 is provided in such a way that it debouches downstream of the supply line 29 and also serves to ensure that the tubular strengthening layer cannot be pressed together as a consequence of the supply of additional membrane-forming material 20 via the supply line 29.

If the semipermeable wall is to be provided both on the inside and the outside, a device can be used which is a combination of the devices shown in Figures 5 and 6.

As can be seen in Figure 5, the tape 11 is moved downwards in the shaping chamber 12 by driving guide rollers 30 situated at the top in the shaping chamber 12 and/or a guide roller 31 situated underneath the shaping chamber 12. The guide rollers 30 are provided in the shaping chamber 12 in such a way that they close off the latter at the top. It is consequently advantageously possible to bring the membrane-forming material 20 to a certain pressure above atmospheric pressure, as a result of which the membrane-forming material 20 can impregnate the open cohesive tape 10 well. With a sufficiently high pressure, even the line 29 can be omitted in the embodiment of Figure 6; the membrane-forming material then in fact

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Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a
5 stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

The reference to any prior art in this specification is not, and should not be taken as, an
10 acknowledgment or any form of suggestion that that prior art forms part of the common general knowledge in Australia.



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The claims defining the invention are as follows:

1. Semipermeable capillary, comprising:
 - a tubular strengthening layer composed of at least one
 - 5 elongated tape having longitudinal edge sections, which tape has been converted into a tubular shape with at least the longitudinal edge sections mutually overlapping; and
 - a tubular semipermeable wall composed of membrane-forming material supported by the strengthening layer;
 - 10 in which the capillary has a fine bore permitting capillarity, with an internal diameter smaller than, or equal to, 5 mm, and in which the mutually overlapping edge sections have an overlap greater than, or equal to, 90°; the mutually overlapping edge sections having been joined
 - 15 together by membrane-forming material in a simultaneous formation process as the formation of and joining with the strengthening layer of the semipermeable wall by the same membrane-forming material, wherein the tape has an open cohesive structure which is embedded in the membrane-forming
 - 20 material.
2. Semipermeable capillary according to claim 1 wherein the overlap is greater than, or equal to, 360°.
- 25 3. Semipermeable capillary according to claim 1 or 2, wherein on top of the semipermeable wall a layer having nanofiltration and/or reverse osmosis characteristics have been applied.
4. Method for manufacturing a semipermeable capillary, wherein at least one elongated, initially flat tape having



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an open cohesive structure is converted into a tubular shape in such a way that at least the longitudinal edges mutually overlap, the open cohesive structure being impregnated with membrane-forming material, after which the membrane-forming material in the tape or tapes converted into the tubular shape is coagulated with a coagulation liquid or in another way with the result that there is simultaneous formation both of a joint between the mutually overlapping tape sections and of a semipermeable membrane layer on the internal wall and/or external wall of the tape converted into a tubular shape.

5. Method according to claim 4, wherein the tape is impregnated with the membrane-forming material during the conversion to a tubular shape.

6. Device for carrying out the method according to claim 4 or 5, comprising shaping means for converting the initially flat tape into the tubular shape and feed means for moving the tape through the shaping means, wherein the shaping means comprise a shaping chamber having a conical part and a tubular part, which conical part comprises filling means for filling the conical part with membrane-forming material and which device comprises feed means for supplying coagulation liquid.

7. Device according to claim 6, wherein the internal diameter of the tubular part is substantially as large as the smallest diameter of the conical part.

8. Device according to claim 6, wherein the internal diameter of the tubular part is greater than the smallest



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diameter of the conical part.

9. Semipermeable capillary substantially as hereinbefore described with reference to the drawings.

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10. Method substantially as hereinbefore described with reference to the drawings.

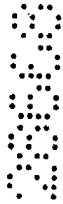
11. Device substantially as hereinbefore described with
10 reference to the drawings.

DATED this 5th day of March, 2001

STORK FRIESLAND B.V.

by its Patent Attorneys

15 DAVIES COLLISON CAVE



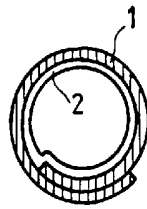


FIG. 1

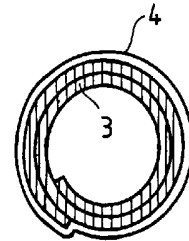


FIG. 2

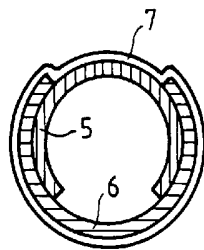


FIG. 3

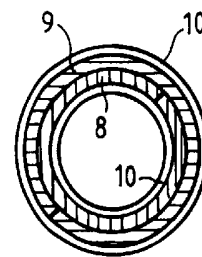


FIG. 4

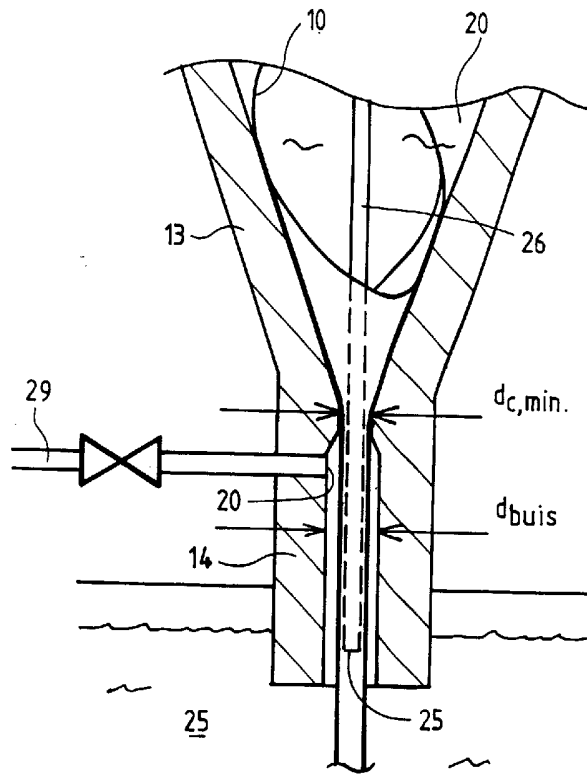


FIG. 6