United States Patent [19]

Baucke

[11] **3,879,279**

[45] **Apr. 22, 1975**

[54] **ELECTRODE WITH EXCHANGEABLE MEMBRANE**

[75] Inventor: **Friedrich Gustav Karl Baucke,** Mainz, Germany

[73] Assignee: **Jenaer Glaswerk, Schott & Gen.,** Mainz, Germany

[22] Filed: **Nov. 26, 1971**

[21] Appl. No.: **202,416**

[30] **Foreign Application Priority Data**

Dec. 3, 1970 Germany 2059559

[52] **U.S. Cl.** .... **204/195 M;** 204/195 G

[51] **Int. Cl.** **G01n 27/46**

[58] **Field of Search** .... 204/1 T, 195 M, 195 G

[56] **References Cited**

UNITED STATES PATENTS

3,216,915	11/1965	Arthur et al.	204/195 G
3,591,464	7/1971	Frant et al.	204/195 M

FOREIGN PATENTS OR APPLICATIONS

1,237,808	3/1967	Germany	
495,303	11/1938	United Kingdom	204/195 G

OTHER PUBLICATIONS

NBS Special Publication 314, Nov. 1969, pp. 91–92.

Primary Examiner—T. Tung
Attorney, Agent, or Firm—David R. Murphy

[57] **ABSTRACT**

An electrode for measuring ion activities having an electrode shaft divided into an upper portion and a lower portion. An ion-sensitive membrane is held between the upper and the lower portions of the shaft. The outer surface of the membrane contacts the material whose ion activity is to be measured.

6 Claims, 13 Drawing Figures

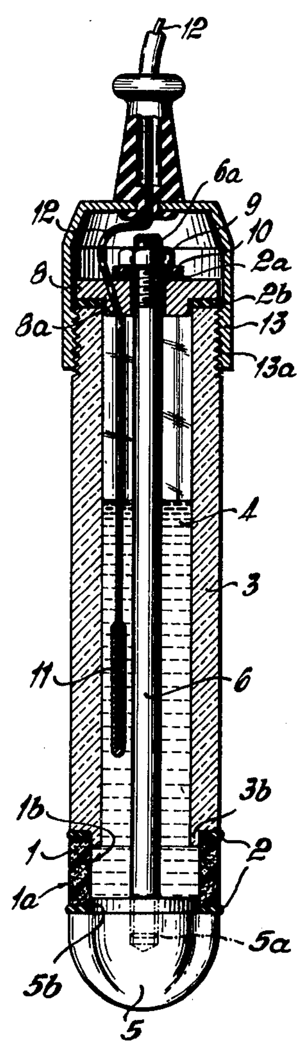


FIG. 1a

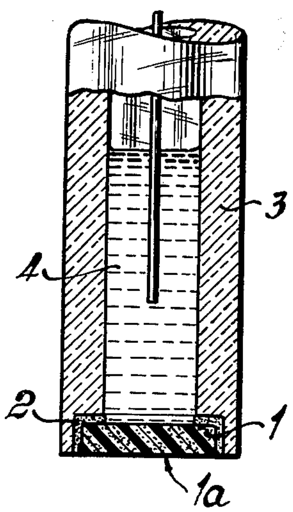


FIG. 1b

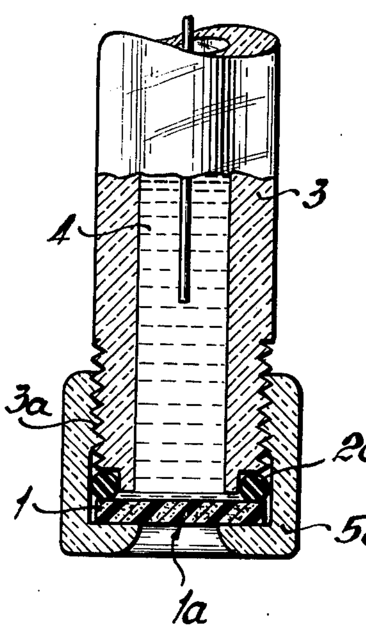
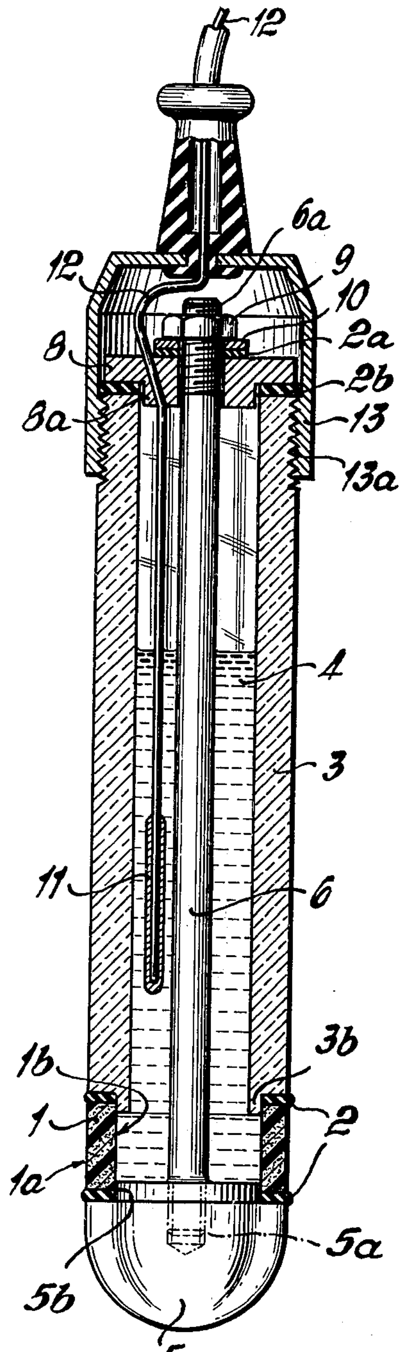


FIG. 2



INVENTOR

FIG. 2a

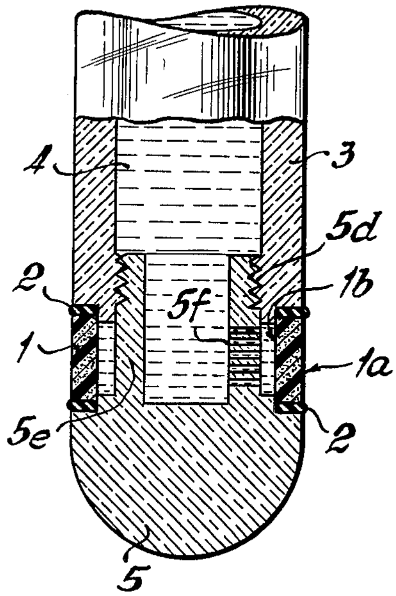


FIG. 3

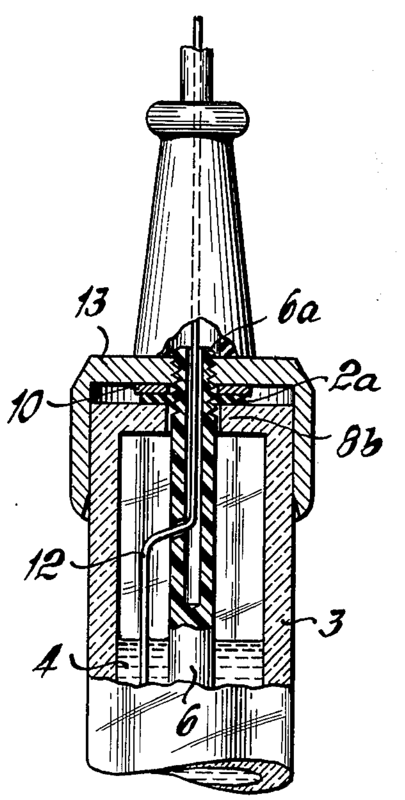
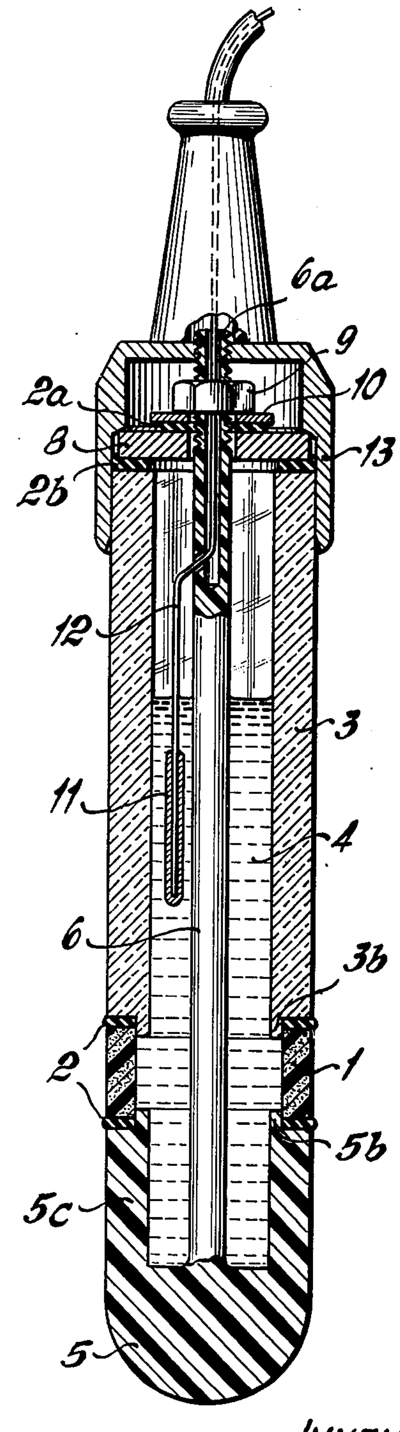


FIG. 4



INVENTOR

FIG. 5

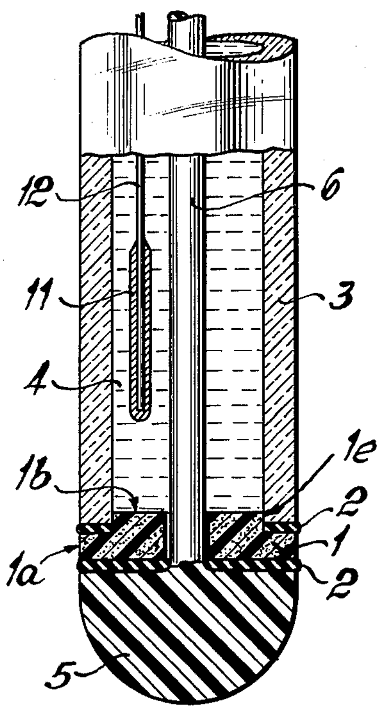


FIG. 6

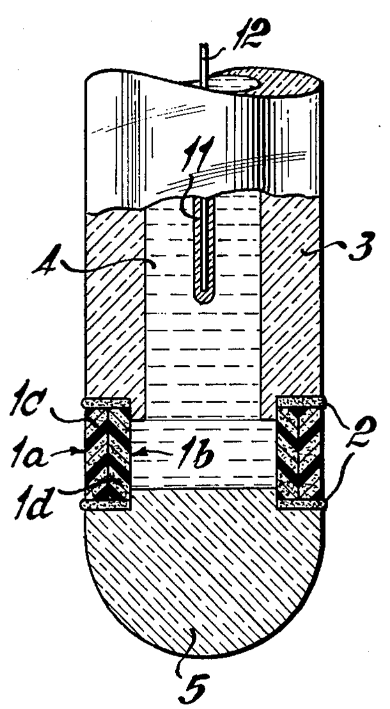
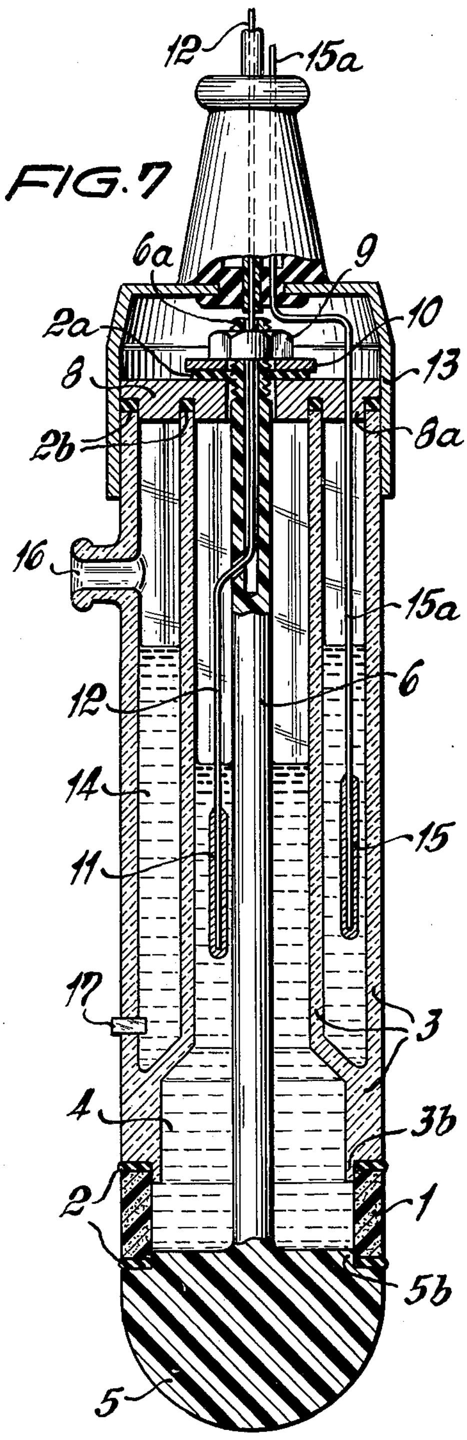


FIG. 7



INVENTOR

FIG. 8

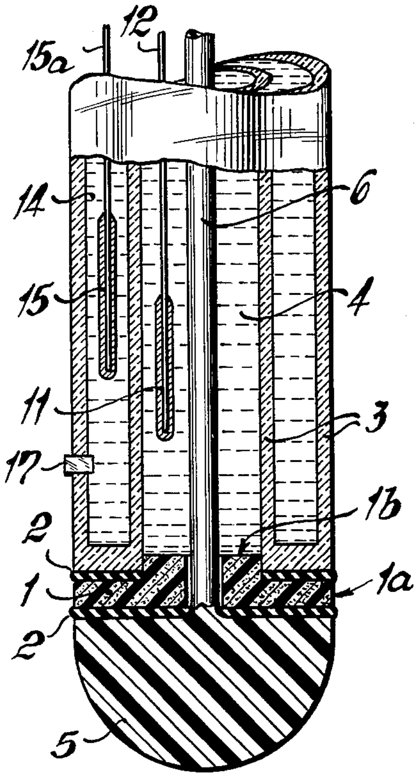


FIG. 10

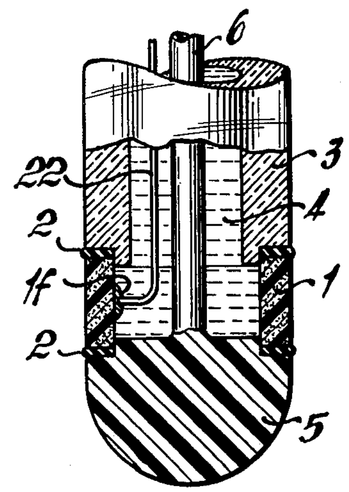
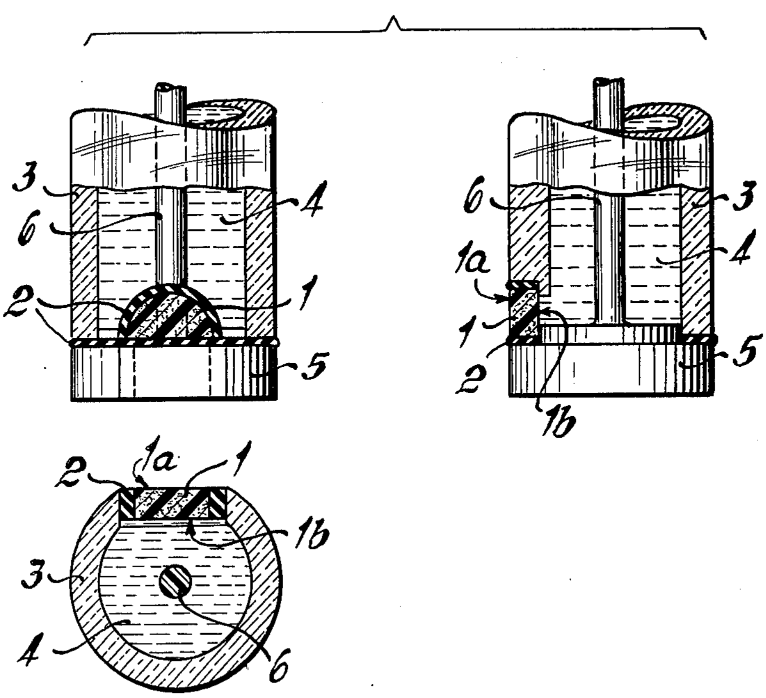
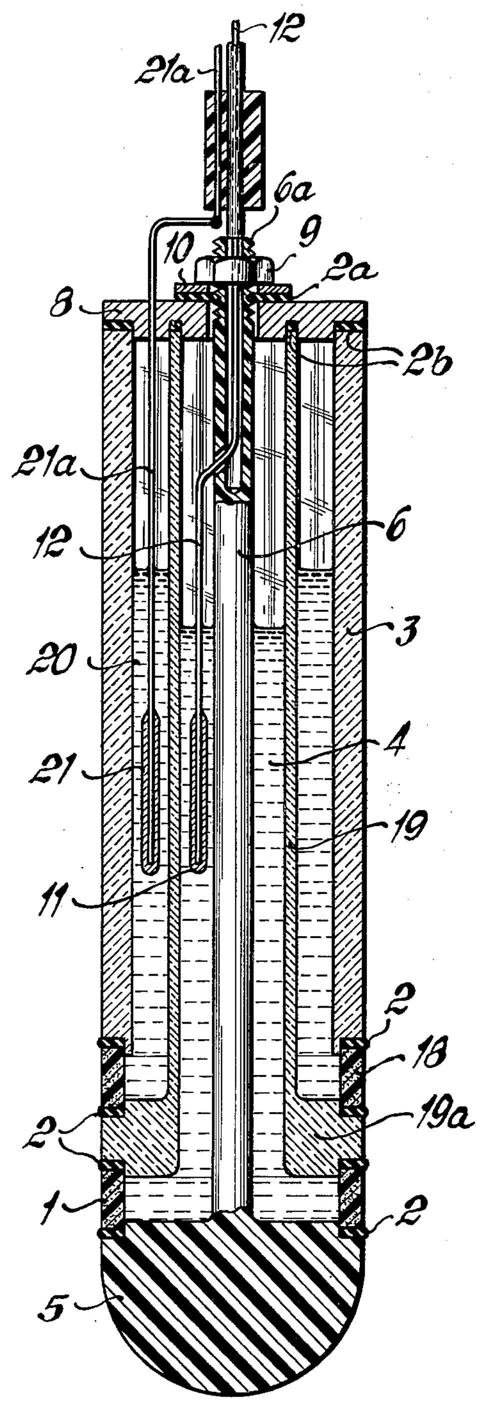


FIG. 11



INVENTOR

FIG. 9



INVENTOR

ELECTRODE WITH EXCHANGEABLE MEMBRANE

The invention relates to an electrode with an exchangeable ion-sensitive membrane for measuring ion activities in solutions, suspensions, pastes, or the like, which electrode may be constructed as measuring electrode or single-bar measuring chain. The invention is characterized in that the membrane is incorporated in the electrode shaft and the surface of the ion-sensitive membrane which is in contact with the solution to be measured forms a portion of the outer wall of the electrode shaft. In a particular embodiment of the electrode there is provided, in the electrode shaft, two or more exchangeable membranes for the simultaneous measurement of the activities of two or more different ions.

Ion membranes can be employed in a great variety of types, e.g. they may consist of:

1. compressed bodies formed by inorganic salts;
2. monocrystals of such salts;
3. fine powders of such salts embedded, e.g. by polymerization, in a plastic, e.g. silicone rubber;
4. porous bodies imbued with a usually organic solution of an ion exchanger.

Electrodes for measuring ion activities are known (British Pat. No. 1,198,589) wherein a membrane **1** (FIG. **1***a*) which separates a solution **4** in the inner space of the electrode from the solution to be measured and on the outer surface **1***a* of which electrode the potential determined by the activity of the ions concerned of the solution to be measured is generated, is fastened by means of an adhesive or cement **2** at the base of the electrode shaft **3.** In this structure the adhesive or cement **2** must furthermore seal the gap between shaft and membrane to such an extent that the liquid to be measured cannot enter the electrode and thus mix with the inside solutuion thereof. Conversely the inside solution must of course not leak from the electrode into the solution to be measured. The demands relating to the pasting or cementing which must be observed in this case are extremely high since for a fully satisfactory functioning of the electrode even a creeping of traces of the inside solution or the solution to be measured along the membrane and thus an electric shunt must be strictly avoided. This fully satisfactory insulating separation of the two solutions is a great problem since besides the high impermeability of the adhesive to the solutions the adhesive must also adhere to the membrane (e.g. ion crystal) as well as to the shaft material (e.g. glass, plastic). Such an adhesive strength can be achieved, if at all, only with great difficulties. The British patent indicates that the materials used for the shaft, the adhesive and the membrane must have the same or at least a very similar coefficient of expansion (Brit. Pat. No. 1,198,589, Page 2, Lines 20–32), in order to retain even at temperature variations prevailing for instance in the case of measurements at high or low temperatures, a perfect firm adhesion of the adhesive on shaft and membrane. However, suitable materials with similar coefficients of expansion cannot always be found. Moreover, many adhesives, such as the one mentioned in the British patent, require for hardening very high temperatures which adversely effect the membranes to be pasted. Furthermore the membrane is not exchangeable when it is fixed by pasting. A further disadvantage of such an arrangement is that the membrane which forms a portion of the shaft base may easily be slightly damaged when the electrode is being mounted.

It is also known (U.S. Pat. No. 3,431,182) to fix membrane **1** (FIG. **1***b*) by a screwed joint **3***a* with use of gasket rings, e.g., an O-ring **2***c*, to the shaft end and thus to seal the electrode. Thereby the membrane becomes exchangeable. However, this structure involves the disadvantage that, when the electrode is immersed in the liquid to be measured, air bubbles, hard to remove even by shaking of the electrode, are enclosed or retained between the necessarily projecting edges of the screw cap **5***d*, i.e., in the space below the membrane which is mounted perpendicularly to the electrode shaft. Such air bubbles caues great disturbances and prevent even a satisfactory potential adjustment. This has also been pointed out in the Brit. Pat. No. 1,198,598 (p. 3, lines 17–20) referred to.

The present invention overcomes all these disadvantages in the simplest manner by the device that the membrane does not, as was hitherto the case, form the base end, namely a portion of the base of the electrode shaft but is inserted as intermediate ring or as "window" in the round or angular shaft of the electrode, in which structure the cohesion of the electrode parts, namely electrode base, intermediate ring or window (membrane) and electrode top is assured by a screwed joint within the electrode. The seal between the individual parts may consist of elastic gasket rings or an elastic cement. By this arrangement the following disadvantages are avoided and the following advantages with respect to known constructions result:

1. The membrane is not rigidly connected with the shaft but is exchangeable;
2. Shaft, membrane and sealing materials need not have the same or a similar coefficient of expansion;
3. By the screwed joint a pressure of any value is exerted upon the gasket rings or the elastic cement. The sealing is therefore accomplished not only by a not always safe adhesion of different materials to each other or by the elastic properties of cement or shaft materials which, when used over a longer period of time, may exhibit symptoms of fatigue.
4. Any capturing of air bubbles being in contact with the membrane surface and therefore disturbing the potential adjustment is completely impossible since for the insertion of the membrane in the shaft no screw cap is used and therefore no space at all where air bubbles might be retained exists in front of or underneath the membrane.
5. In spite of these advantages the electrode is shaped as a straight shaft without any projections and can be inserted in appliances or equipment through normal openings provided therefor, such as cuts or inserted tubes.
6. A damage to the membrane when the electrode is being mounted is impossible.
7. The ratio between the size of the surface and the distance between inner and outer surface can be selected at will within a wide range. This can be of great importance since the ratio between the size of the surface and the distance between inner and outer surface must be adapted to the conductivity of the membrane material used.
8. The construction of the invention can very well be employed in singe-bar measuring chains.

9. Membranes with inside contacts by liquids, e.g. electrolyte solutions, as well as by solid state bodies, e.g. metals, can be produced.

10. Electrodes with two or more different membranes for simultaneous measurement of activities of different ions can be produced, one of which membranes, insofar as the constancy, in the solution to be measured, of the ion activity which determines its potential is assured, can be used as reference electrode membrane.

11. Multiple-layer membranes can be employed.

12. It is feasible to incorporate in the electrode shaft instead of solid state membrane ring-shaped bodies of porous material, e.g. of ceramic material, porous glass, porous plastic, or the like, which are imbued with a solution of a soluble ion exchanger known per se in an organic solvent and thus constitute an electrode with a potential adjustment between organic and aqueous liquid phases.

Thus according to the present invention, there is provided an electrode for measuring ion activities. The electrode comprises an electrode shaft and an ion sensitive membrane. The electrode shaft is divided into an upper portion and a lower portion. The ion sensitive membrane is located between the upper and lower portions of the shaft. The outer surface of the membrane is adapted to contact the material whose ion activity is to be measured. In one embodiment of the present invention, the ion sensitive membrane is in the form of an annular ring, whereas in another embodiment of the present invention, it is in the form of a window which can have a curved or planar outer surface. According to yet another embodiment of the present invention, the electrode further comprises a second membrane for measuring the activity of a second ion. In a preferred embodiment of the present invention, the outer wall of the electrode shaft is substantially co-extensive with the outer wall of the membrane. This permits the electrodes of the present invention to be inserted into chemical process equipment through the holes characteristically provided for prior art electrodes.

When the electrode contains a single ion sensitive membrane in the form of an annular ring, the top of the ring forms a fluid tight seal with the upper portion of the electrode shaft, whereas the bottom of the ring forms a fluid tight seal with the lower portion of the electrode shaft. The electrode is provided with means for pressing the upper and lower portions of the electrode shaft against the ring in order to maintain fluid seals. This can be accomplished according to one embodiment by a tension shaft and according to another embodiment by providing threads on a portion of the electrode shaft.

The tension shaft is preferably fixed to the lower portion of the electrode shaft and extends through the annulus of the ring and through and beyond the hollow upper portion of the electrode shaft. The tension shaft further extends beyond the upper extremity of the upper portion of the electrode shaft. The end of the tension shaft is provided with threads having a nut thereon. A force transmitting member is slidably mounted on the tension shaft between the nut and the upper extremity of the upper portion of the electrode shaft. This force transmitting member extends laterally to contact the upper extremity of the upper portion of the electrode shaft. The force transmitting member exerts a force on this portion of the electrode shaft. By virtue of this structural relationship turning of the nut creates tension in the tension shaft and compresses the ring between the upper and lower portions of the electrode shaft, thereby maintaining the above described fluid tight seals.

According to another embodiment of the present invention the means for pressing the upper and lower portions of the electrode shaft against the ring is accomplished by providing the hollow upper portion of the shaft with internal threads adjacent to the lower extremity of the upper portion. The lower portion of the electrode shaft is provided with an externally threaded member which engages the internal threads of the upper portion. In this embodiment the ion-sensitive membrane in the form of an annular ring surround the externally threaded member.

According to yet another embodiment of the present invention, the electrode is provided with a second chamber within the upper portion of the electrode shaft. The first chamber is, or course, formed by the upper and lower portions of the electrode shaft and the membrane. A sensing electrode is located in the first chamber, and a reference electrode is located in the second chamber. This embodiment of the present invention is exemplified by the structure of FIG. 7.

According to that embodiment of the present invention, wherein the electrode is provided with means for measuring the activities of two ions the electrode shaft has an intermediate portion in addition to the upper and lower portions. A first ion sensitive membrane is located between the upper and the intermediate portions whereas a second ion-sensitive membrane is located between the lower and the intermediate portions. In this embodiment the sealing is preferably accomplished by providing the upper and lower portions of the electrode shaft each with a planar surface at right angles to the center line of the electrode shaft. The intermediate portion of the electrode shaft is also provided with two such planar surfaces, one designated an upper planar surface, the other designated a lower planar surface. The first ion sensitive membrane is located between the upper and the intermediate portions of the shaft. This ion-sensitive membrane is in the form of an annular ring. The ring has an upper planar surface adapted to form a fluid tight seal with the planar surface of the upper portion of the shaft. The ring also has a lower planar surface adapted to form a fluid tight seal with the planar surface of the intermediate portion of the shaft. The second ion-sensitive membrane is similarly situtated between the intermediate portion of the shaft and the lower portion of the shaft. In this embodiment a first fluid tight chamber is defined by the upper portion of the shaft, the intermediate portion of the shaft, and the first membrane. Also a second fluid tight chamber is defined by the lower portion of the shaft, the intermediate portion of the shaft, and the second membrane. Electrodes may be located within each of these fluid tight chambers together with appropriate ionic solutions. The electrodes of the present invention are characteristically sold and shipped without the ionic solution in place.

The invention is explained in greater detail below, with the aid of figures. All figures show different embodiments in sectional view.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1*a* is a partial cross-sectional diagram of a prior art electrode.

FIG. 1*b* is a partial cross-sectional diagram of a second prior art electrode.

FIG. 2 illustrates one electrode according to the present invention.

FIG. 2*a* illustrates an alternate embodiment for a base for the device of FIG. 2.

FIG. 3 illustrates an alternate electrical connection for the device of FIG. 2.

FIG. 4 illustrates another embodiment of the electrode according to the invention using a different membrane level.

FIG. 5 illustrates another electrode construction.

FIG. 6 illustrates the base of an electrode as in FIG. 2, but using a two-layer membrane.

FIG. 7 illustrates a single-bar measuring circuit with a ring-shaped electrode.

FIG. 8 illustrates a single-bar measuring circuit with a plate-shaped electrode.

FIG. 9 illustrates a double electrode with two ring-shaped membranes.

FIG. 10 illustrates an electrode on whose membrane the electric connection is fastened by means of a solid state element.

FIG. 11 illustrates an electrode with a semiconductor membrane.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 2 shows an electrode of the invention with a ring-shaped membrane **1** whose surface **1***b* is in contact with the inner solution **4** of the electrode and whose surface **1**a is in contact with the solution to be measured.

The electrode contains the following parts: a base **5**, a membrane **1**, gasket rings or elastic cement **2**, an electrode shaft **3**, electrode head sealings **2***a* and **2***b*, an electrode cover **8** and one or more supporting discs **10**. A nut **9** supported by that portion of shaft **6** which is provided with threads **6***a* compresses under a pressure of optional value these individual parts of the electrode. The electrode is held together and sealed by a tension and compression arrangement. The tension occurs when nut **9** is tightened along tension shaft **6**, upon which nut **9** sits. As the nut is turned, tension is exerted on tension shaft **6** which is fixed to base **5** of the lower portion of the electrode shaft. The tension is therein converted, via the force-transmitting cover **8**, into compression conveyed along shaft **3** to rings **2**. The compression exerted on rings **2** forms a fluid tight seal. Thus the electrode is held together and sealed by the pressure of base **5** relative to cover **8** produced by nut **9** at the electrode head and transferred by a traction force on shaft **6**. Shaft **6**, which may consist e.g. of plastic, may be a portion of base **5** or may be screwed at **5***a* into the latter. The construction is centered by a guide **5***b* in base **5**, and a guide **3***b* in shaft **3**. Besides, cover **8** of the electrode should contain a guide **8***a*. The electric connection **12** of an inside shunt electrode **11** projecting into the inner solution **4** of the electrode may either, as shown in FIG. **2**, be tightly cemented into cover **8** or, as indicated e.g. in FIGS. 3 and **4**, pass through a bore in shaft **6**. The top end of the electrode consists suitably of cap **13** which is screwed by means of a thread **13***a* onto shaft **3** or, if the electric connection **12** passes through shaft **6**, onto the spiral section **6***a* of shaft **6**, as shown in FIGS. **3** and **4**. Other shapes of the electrode top end are of course also possible. Thus FIG. 3 shows that, e.g., electrode shaft **3** may be provided with a stationary perforated end **8***b* against which electrode cap **13**, which at **6***a* is provided with a thread, is screwed from the top. The sealing consists in this case also of a gasket ring **2***a* which is pressed, together with a supporting disc **10**, between end **8***b* and cap **13**.

The inner screwed joint of the electrode which presses membrane **1** with elastic gasket rings or cement **2** between base **5** and shaft **3** may also be carried out in a way other than by a shaft and a screw. E.g., FIG. **2***a* shows an embodiment wherein base **5** is screwed by means of a thread **5***d* directly, i.e. without the use of a shaft, to a thread within electrode shaft **3**, whereby base **5**, gasket rings or coment **2**, membrane **1** and shaft **3** are pressed together under any pressure and seal the electrode. The section **5***e* of base **5** which is provided with thread **5***d* must of course be perforated once or repeatedly in order to make possible a contact of inner solution **4** and surface **1***b* of the membrane. This is shown by a shaded area **5***f* of FIG. **2***a*.

FIG. **4** shows an embodiment similar to that of FIG. **2**. The membrane is positioned at a higher level than in FIG. **2** and arranged between shaft **3** and base **5** which constitutes a portion of shaft **5***c*. This embodiment can be of interest if inner solution **4** of the electrode is to be in contact with a base material, e.g. a salt with which solution **4** is saturated, but a contact, e.g. at a temperature change, with or without crystallization of this salt on membrane **1** is to be avoided.

FIG. **5** shows an electrode construction wherein another ratio between the size of surface **1**a relative to the distance between inner surface **1***b* and outer surface **1***a* of membrane **1** has been chosen, than e.g. in FIG. **2**. Although the membrane thus constitutes also an intermediate ring, its shape is rather that of a perforated round plate. Guidance is in this example provided by means of a groove **1***e* on the outer edge of membrane **1**.

FIG. **6** shows the base of an electrode as shown in FIG. **2**. However the membrane used in the present case is a two-layer membrane consisting of a layer **1***d* which at **1***b* is in contact with the inner solution and a layer **1***c* which at **1**a is in contact with the solution to be measured. The advantages of the use of a membrane consisting of two or more layers are described in U.S Pat. application Ser. No. 169,674 filed Aug. 6, 1971. The said figure does not show a screwed joint which can be carried out according to the principle of FIG. **2** or FIG. **2***a*.

FIGS. **7** and **8** show two embodiments of a single-bar measuring chain with, respectively, a ring-shaped membrane (FIG. **7**) and a plate-shaped membrane (FIG. **8**). A single-bar measuring chain presents an electrode unit which has a measuring membrane and also a reference electrode, i.e. a membrane which is in contact with the solution to be measured and with the inner shunt, and also a reference electrode in a reference electrode solution. A double shaft **3** of these single-bar measuring chains consists of one piece and can be produced very simply e.g. from glass tubes, but may also consist of another material, e.g. plastic. An opening **16** (FIG. **7**) permits the replacement of portions of the electrolyte solution **14** of reference electrode **15** which have leaked through a diaphragm **17** (FIGS. **7** and **8**). The electric connection **12** to the inner shunt electrode **11** passes in FIG. **7** through a bore in shaft **6.** The connection **15**a to reference electrode **15** is tightly cemented into electrode cover **8.** The embodiment of FIG. **8** has particularly long insulation paths radially to gasket rings **2.**

FIG. **9** shows a double electrode with two ring-shaped membranes **1** and **18** which respond to different ions in the solution to be measured. Flat, plate-shaped perforated membranes may be used in place of the ring-shaped high membranes. Furthermore one of the membranes may be used as reference electrode, which is always possible when the activity of one of the ion types to be measured of the solution to be measured is constant. The shaping of an inner shaft **19** which has at its bottom end an expansion **19***a* with a guide for each of membranes **1** and **18** is particularly simple. In FIG. **9,** as in FIG. **7,** one (**12**) of the feed lines to the shunt electrodes passes through shaft **6,** the other (**21***a*) through cover **8** of the electrode. Numeral **20** indicates the electrolyte solution which is in contact with membrane **18** and shunt electrode **21.**

In the embodiments shown above there were electrodes with liquid inner electrolytes. For electrodes with inner contacting by a solid-state material, so-called "solid-state" contact, the structure and use of the membranes of the invention is very well suited. FIG. **10** shows an embodiment of such an electrode on whose membrane **1** the electric connection **22** is fastened by means of a solid state element **1f**.

The membranes used need not necessarily be ring-shaped and form a full circle of an ion-sensitive surface; they may also be installed as a "window" tapering toward the outside and having a curved or planar front surface in a round shaft or a shaft provided with planar surfaces. FIG. **11** shows e.g. an embodiment with a semicircular membrane **1** which has planar, parallel front surfaces **1***a* and **1***b*. Several different membranes of this type can be incorporated in a shaft, which is particularly simple if each has a solid state contact.

Although the invention has been described in considerable detail with reference to certain preferred embodiments thereof, it will be understood that variations and modifications can be effected within the spirit and scope of the invention as described above and as defined in the appended claims.

What is claimed is:

1. An electrode for measuring ion activities comprising:

A. an electrode shaft divided into
  1. an upper portion, and
  2. a lower portion,

B. an ion sensitive membrane between the upper and lower portions of the shaft, wherein the membrane is in the form of an annular ring, the top of the ring forming a fluid tight seal with the upper portion of the electrode shaft, the bottom of the ring forming a fluid tight seal with the lower portion of the electrode shaft,

C. means for pressing the upper and lower portions of the electrode shaft against the ring in order to maintain said fluid seals.

2. An electrode for measuring ion activities comprising:

A. an electrode shaft divided into
  (1) a hollow upper portion the lower extremity of which comprises a flat surface having a plane at

right angles to the centerline of the electrode shaft,
  (2) a lower portion the upper extremity of which comprises a flat surface having a plane at right angles to the centerline of the electrode shaft,

B. an ion sensitive membrane between the upper and lower portions of the shaft wherein the membrane is in the form of an annular ring, said ring having:
  1. an upper flat surface having a plane adapted to form a fluid tight seal with the flat surface having a plane of the upper portion of the electrode shaft,
  2. a lower flat surface having a plane adapted to form a fluid right seal with the flate surface having a plane of the lower portion of the electrode shaft,
  3. an outer surface substantially coextensive with the outer surface of the electrode shaft,
  4. an inner surface adapted to contact an ionic solution within the shaft,

C. a tension shaft fixed to the lower portion of the electrode shaft and extending through the annulus of the ring, through and beyond the hollow upper portion of the electrode shaft and extending beyond the upper extremity of the upper portion of the electrode shaft, the end of the tension shaft having threads,

D. a nut on the threads,

E. a force transmitting member slidably mounted on the tension shaft between the nut and the upper extremity of the upper portion of the electrode shaft, the force transmitting member extending laterally to contact and exert force on the upper extremity of the upper portion of the electrode shaft,

whereby turning the nut creates tension in the tension shaft and compression in the ring and the upper and lower portions of the electrode shaft thereby maintaining said fluid tight seals.

3. An electrode for measuring ion activities comprising:

A. an electrode shaft comprising:
  1. a hollow upper portion having:
    a. internal threads adjacent the lower extremity of the upper portion;
    b. a planar surface at right angles to the centerline of the electrode shaft;
  2. a lower portion having:
    a. a planar surface at right angles to the centerline of the electrode shaft; b. an externally threaded member engaging the internal threads of the upper portion;

B. an ion sensitive membrane in the form of an annular ring surrounding the externally threaded member and having:
  1. an upper planar surface forming a fluid tight seal with the planar surface of the upper portion of the shaft;
  2. a lower planar surface forming a fluid tight seal with the planar surface of the lower portion of the shaft.

4. An electrode for measuring ion activities comprising:

A. an electrode shaft divided into
  1. an upper portion, and
  2. a lower portion,

B. an ion sensitive membrane between the upper and lower portions of the shaft, wherein the membrane is in the form of an annular ring, the top of the ring forming a fluid tight seal with the upper portion of the electrode shaft, the bottom of the ring forming a fluid tight seal with the lower portion of the electrode shaft,

C. means for pressing the upper and lower portions of the electrode shaft against the ring in order to maintain said fluid seals such that the membrane and the upper and lower portions of the shaft define a first chamber,

D. a second chamber within the upper portion of the electrode shaft,

E. a sensing electrode in the first chamber, and

F. a reference electrode in the second chamber.

5. An electrode for measuring ion activities of two ions comprising:

A. an electrode shaft divided into:
   1. an upper portion,
   2. a lower portion, and
   3. an intermediate portion;

B. a first ion sensitive membrane between the upper and the intermediate portions of the shaft, and forming a first fluid tight chamber therewith;

C. a second ion sensitive membrane between the lower and the intermediate portions of the shaft and forming a second fluid tight chamber therewith;

D. means for axially compressing the two membranes and the three portions of the shaft in order to maintain the fluid tight integrity of the two chambers.

6. An electrode for measuring ion activities of two ions, comprising:

A. an electrode shaft divided into
   1. a hollow upper portion the lower extremity of which comprises a flat surface having a plane at right angles to the centerline of the electrode shaft,
   2. a lower portion the upper extremity of which comprises a flat surface having a plane at right angles to the centerline of the electrode shaft,
   3. an intermediate portion having an upper flat surface having a plane and a lower flat surface having a plane

B. a first ion sensitive membrane between the upper and intermediate portions of the shaft wherein the membrane is in the form of an annular ring, said ring having:
   1. an upper flat surface having a plane adapted to form a fluid tight seal with the flat surface having a plane of the upper portion of the shaft,
   2. a lower flat surface having a plane adapted to form a fluid tight seal with the flat surface having a plane of the intermediate portion of the shaft,

C. a second ion sensitive membrane between the lower and intermediate portions of the shaft wherein the membrane is in the form of an annular ring, said ring having:
   1. a lower flat surface having a plane adapted to form a fluid tight seal with the flat surface having a plane of the lower portion of the shaft,
   2. an upper flat surface having a plane adapted to form a fluid tight seal with the flat surface having a plane of the intermediate portion of the shaft,

D. a tension shaft fixed to the lower portion of the electrode shaft and extending through the annulus of each ring, through and beyond the hollow upper portion of the electrode shaft and extending beyond the upper extremity of the upper portion of the electrode shaft, the end of the tension shaft having threads,

E. a nut on the threads

F. a force transmitting member slidably mounted on the tension shaft between the nut and the upper extremity of the upper portion of the electrode shaft, the force transmitting member extending laterally to contact and exert force on the upper extremity of the upper portion of the electrode shaft,

wherein a first fluid tight chamber is defined by:
   1. the upper portion of the shaft,
   2. the intermediate portion of the shaft,
   3. the first membrane;

wherein a second fluid tight chamber is defined by:
   1. the lower portion of the shaft
   2. the intermediate portion of the shaft
   3. the second membrane;

whereby turning the nut creates tension in the tension shaft and compression in the rings and the upper, the lower and the intermediate portions of the electrode shaft thereby maintaining the fluid tight integrity of the chambers.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,879,279 Dated April 22, 1975

Inventor(s) Friedrich Gustav Karl Baucke

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 30, "conductor" should read -- circular --.

Column 8, line 14, "flate" should read -- flat --.

Signed and Sealed this

fourteenth **Day of** *October 1975*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks