

DESCRIPTION

RECOMBINANT SEPARATOR

Technical Field

This invention relates to a separator for an alkaline battery and, more particularly, this invention relates to a
5 cellululosic separator for a secondary zinc ion battery such as a silver-zinc battery.

Background of the Invention

Separators play a crucial role in alkaline batteries.
10 They keep the positive and negative sides of the battery separate while letting certain ions go through and blocking others. The separator is a passive element that has to perform the same task unchanged for the life of the battery. Meanwhile, it must be able to withstand a
15 strongly alkaline environment both at ambient and elevated temperatures. In addition, it must be capable of resisting oxidative attacks.

In an alkaline battery, a separator should conduct hydroxyl ions at a sufficiently rapid rate to meet the
20 increasingly high current demands of modern electronics. Films of cellulose in the form of regenerated cellulose have been used since World War II as the separator of choice for this purpose because of its superior ability to conduct hydroxyl ions in strongly alkaline media. Its low
25 electrical resistance of 10 milliohm-in² has also led to its favor for use in zinc-based batteries, such as silver-zinc, zinc-nickel, and zinc manganese dioxide batteries. Additionally, it acts as a physical barrier to migration of other ions in the battery, such as that of zincate ions and
30 silver ions in a silver-zinc battery.

Despite its advantages as a battery separator, regenerated cellulose has some intrinsic limitations. During overcharge, an alkaline battery tends to break down water and evolve hydrogen in sufficient quantities as to materially affect the internal impedance of the battery. Unless this hydrogen is removed efficiently, a parasitic feedback results in which the battery continues to be overcharged with resultant pressure buildup and venting of hydrogen or catastrophic rupture of the battery case.

Regenerated cellulose, however, exhibits one of the lowest hydrogen permeability coefficients of known polymers, reported in the *Polymer Handbook* as $2.044 \times 10^{-15} \text{ cm}^3 \text{ cm}^{-1} \text{ s}^{-1} \text{ Pa}^{-1}$.

15 Description of the Prior Art

Prior batteries incorporate in recombinant separators comprising porous melt-blown polymer fibers that incorporate surfactants or lubricants that facilitate gas transport within a battery. U.S. Patent No. 6,054,084 describes separators for lead-acid batteries made of polytetrafluoroethylene (PTFE) fibril matrix incorporating particulate silica filler and non-evaporative lubricant as gas transport agents. Zucker in U.S. Patent No. 5,962,161 describes a recombinant separator for lead-acid batteries that comprises melt-blown polypropylene made wettable by a surfactant agent thus enabling transport of oxygen.

In U.S. Patent No. 4,919,865 Nelson teaches a method for making a composite membrane made from a mixture of polymethyl methacrylate and a cellulosic derivative, such as cellulose acetate. A gas stream containing hydrogen is selectively cleaned of the hydrogen by the presence of the methyl methacrylate. Polymethyl methacrylate is, however,

unsuitable as a battery separator capable of handling high currents because of its high electrical resistance.

Summary of the Invention

5 The separator provided by the present invention consists of a membrane having both high hydroxyl conductivity and high hydrogen transport. When the separator is placed in a silver-zinc battery, hydrogen buildup in the battery is diminished. The present invention
10 relates to a recombinant separator that is able to transport hydrogen while conducting hydroxyl ions. The separator of the invention help maintain low electrical impedance and exhibit resistance against formation of zinc dendrites. A preferred battery separator according to the
15 inventor contains a solution of cellulose having of a degree of polymerization between 200 and 1200 that is mixed with particles of a polymer having a hydrogen permeability greater than $1 \times 10^{-13} \text{ cm}^3 \text{ cm}^{-1} \text{ s}^{-1} \text{ Pa}^{-1}$. The resulting mixture is then coagulated under controlled environmental conditions
20 to produce a heterogeneous gel that when dehydrated yields a membrane useful as a recombinant battery separator.

 These and many other features and attendant advantages of the invention will become apparent as the invention becomes better understood by reference to the following
25 detailed description when considered in conjunction with the accompanying drawings.

Brief Description of the Drawings

Figure 1 is a schematic drawing of the heterogeneous recombinant separator of the invention.

Figure 2 is a spectra of cellulose.

5 Figure 3 is a spectra of ethyl cellulose; and

Figure 4 is a line scan view of the separator of the invention.

Detailed Description of the Invention

10 The recombinant separator of the invention is formed of a mixture of a hydrophilic polymer, cellulose and hydrophobic agents. The hydrophilic polymers preferably have relatively high hydrogen permeability. The mixture is then coagulated under controlled conditions to yield a
15 membrane that maintains the macroscopic properties of the two substituents.

Cellulose, with a degree of polymerization from 200 to 1200, in the form of, but not limited to, microcrystalline cellulose, cotton fiber, paper and microgranular cellulose,
20 is dissolved using a variety of different solvents. These solvents include, but are not limited to, LiCl/DMAC, trifluoroacetic acid and N-morpholine N-oxide. The applicable range in the case of LiCl/DMAC solution for the percent weight of the solution of cellulose to the solvent
25 is 1 to 11%. The cellulose may be crosslinked with standard methods and then dissolved.

A polymer having a hydrogen permeability greater than $1 \times 10^{-13} \text{ cm}^3 \text{ cm}^{-1} \text{ s}^{-1} \text{ Pa}^{-1}$ can include, but is not limited to, ethyl cellulose, polyphenyl oxide, polymethyl siloxane,
30 cellulose acetate, and gutta percha. The polymer is dissolved in a solvent that is miscible with the solvent that dissolves the cellulose, and is added either

concurrently or separately. Whether mixed concurrently or separately, a preferable concentration range of 2 to 10% weight of solvent is used..

A softener, such as glycerol or decane, may be added at this point, as long as it is soluble in the solvent. Hydrophilic fibers may also be added at this point.

The solution containing both cellulose and the high hydrogen permeability polymer is then cast into a film using a variety of techniques known to those skilled in the art of membrane fabrication. These techniques include extrusion of the solution onto a conveyor belt, casting onto a glass plate with a casting knife or casting onto a well-leveled glass plate.

An important aspect of the invention is that the controlled introduction of into the film or to the atmosphere above the solution in film form induces the formation of macroscopic domains and phase separation for both the hydrophobic and hydrophilic constituents in the cast solution. A properly formed heterogeneous gel exhibits intertwined domains. These separate domains include one that is mostly the cellulose material and one that is mostly the hydrophobic agent. In the final film the hydrophobic regions are sufficiently large as to exhibit macroscopic transport characteristic of the bulk hydrophobic polymer.

A schematic representation is shown in Figure 1 which illustrates a recombinant film 10 having a continuous cellulose phase 12 and discontinuous regions 14 that are permeable to hydrogen. It has been observed via local measurements that hydrogen readily permeates through the hydrophobic rich regions, but not the cellulose regions. Nevertheless, cellulose molecules surround the hydrophobic

regions, giving the film the zinc dendrite resistance, mechanical strength and ionic conductivity required for high performance.

5 The rate of introduction of water to the cast mixture cannot be too slow or too fast. If it is too slow, no gel will form in a meaningful amount of time. If it is too fast, the gel formed will not be cohesive, and the film will not be strong.

10 The solution can be coagulated with conventional techniques, either by exposure to ambient moisture, exposure to an alcohol atmosphere or by direct application of a water stream or alcohol stream to the resulting solution. It has been observed that an ambient atmosphere having a relative humidity range of 35 to 80% at a
15 temperature range of 15 to 30 degrees Celsius yields acceptable gels within a 1 to 3 hour range.

The coagulated cellulose material, in the form of a cohesive gel, is washed to remove the solvent and the salt. It is possible to employ alcohols mixed with water, but it
20 is preferable that the percentage of alcohol be kept below a 50% volume ratio.

After thorough washing of the resulting gel, the gel may be dried with any conventional technique such as air drying, vacuum drying or press drying.

25 Example 1

40 grams of microcrystalline cellulose (MCC, Aldrich 31,069-7) is placed in a solution of 2 kg of 5% LiCl/DMAC and heated to 120 degrees Celsius for 15 minutes. The cooled solution affords a clear solution of MCC. 5 grams
30 of ethyl cellulose (EC) is dissolved in 100 ml DMAC separately. The MCC and EC solutions are combined in a 60/40 weight ratio by polymer weight. 40 ml of the

combined solution is placed on a glass tray. Exposure to ambient moisture at 21 degrees Celsius at 55-60% relative humidity yields a cohesive gel in approximately 2 hours. This gel contains phases of MCC and EC. The gel is then
5 washed with water repeatedly until all DMAC and LiCl are removed. The gel is then dried with a press-dry, affording a film useful as a separator.

The separator film is tested for hydrogen transport using an assembly containing a mass spectrometer. A cavity
10 whose walls are made of a hydrogen impermeable material is filled with hydrogen on one side is capped with a separator film to form a tight seal around the cavity. A mass spectrometer equipped with an external probe is placed on the exposed part of the separator and the partial pressure
15 of hydrogen is read after a suitable amount of time.

Representative data after 1 minute follows:

	Membrane ID	Base H ₂ pressure	Measured H ₂ pressure
		(x 10e-10 Torr)	(x 10e-10 Torr)
	Cellulose	1.5	1.5
20	Recombinant 685b	1.5	20.9
	Recombinant 959c	1.5	89

The separators were presoaked in 50% by weight KOH for 2 minutes and placed in the above apparatus. Similar differentiation in hydrogen transport properties was
25 obtained between regenerated cellulose and recombinant separators.

The recombinant separators were placed in silver-zinc batteries with the result that the batteries were fast charged, and their impedance was indistinguishable from
30 regenerated cellulose.

Further confirmation of phase separation was obtained by performing a scanning reflective Fourier Transform

Infrared spectrograms of the film surface over a region 2500 microns in length. A Perkin Elmer Autoimage FTIR microscope was used to collect the data. For illustrative purposes a scan of plain cellulose and of plain ethyl cellulose is shown in Figures 2 and 3, respectively. The most obvious differentiation between the two spectra is the presence of a peak at 2970 cm^{-1} in the EC spectrum corresponding to a C-H stretch of the ethyl group. Figure 4 shows a plot of 100 IR scans where each scan is taken every 25 microns along a particular direction. It is observed from the spectra that agglomerated regions of EC are juxtaposed to regions that are comprised mostly of cellulose.

Furthermore, a microprobe attached to a mass spectrometer as described above, when placed on the ethyl cellulose-rich regions, detected transport of hydrogen through these regions, whereas the probe, when placed over a cellulose-rich region, failed to detect any passage of hydrogen.

Example 2

20 g of microgranular cellulose (Aldrich C6413) is dissolved in 22 kg of 5% LiCl/DMAC and heated to 130 degrees Celsius for 1 hour. The solution is cooled and then mixed with 5% by weight EC in DMAC in a 60/40 weight ratio cellulose/EC. 45 g of solution is cast and gelled with a humidifier over the glass tray. A thermohygrometer close to the tray registered 20 degrees Celsius and 65% relative humidity. After 1 hour, a cohesive gel forms, which is then rinsed to yield a solvent and salt-free gel. The gel is dried under vacuum to yield a separator that is 75 microns in thickness.

Example 3

20 g. cellulose of powder form (International Filler Corporation) of degree of polymerization 1200 is dissolved in 2 kg of 3% LiCl/DMAC. Cellulose is crosslinked by reacting with NaOH and 1,6 diiodohexane. The resulting
5 cellulose solution is mixed with 4% polyphenyl oxide in DMAC and both solutions are heated to 70 degrees Celsius and then cooled. Solutions are cast onto a conveyor belt and allowed to gel on the conveyor belt. Gel is moved to a different section where it is washed and rinsed along
10 another belt and then taken to a drying drum.

Example 4

The procedure of example was repeated except washing was performed with 50% methanol, 50% water.

It is to be realized that only preferred embodiments
15 of the invention have been described and that numerous substitutions, modifications and alterations are permissible without departing from the spirit and scope of the invention as defined in the following claims.

Claims

1. A method of forming a recombinant separator for a zinc ion battery comprising the steps of:

5 dissolving cellulose in a first solvent to form a first solution;

 dissolving a polymer having a hydrogen permeability of at least $1 \times 10^{-13} \text{ cm}^3 \text{ cm}^{-1} \text{ s}^{-1} \text{ Pa}^{-1}$ in a second solvent to form a second solution,

10 combining the solutions into a third solution forming a film of the third solution containing domains of the polymer dispersed in the cellulose; and drying the film to form said separator.

 2. A method according to claim 1 in which the domains
15 are formed in the film by coagulating the film in presence of water or alcohol.

 3. A method according to claim 3 in which water indirectly applied to the film.

 4. A method according to claim 3 in which the ambient
20 atmosphere above the film during coagulation has a relative humidity from 35 to 80%.

 5. A method according to claim 4 further including the step of maintaining the ambient atmosphere at a temperature of 15 to 30 degrees Celsius during coagulation.

25 6. A method according to claim 1 in which the film is washed to remove solvent before drying.

 7. A method according to claim 1 in which the polymer is present in the film in an amount of from 10 to 60 parts by weight of polymer to 100 parts by weight of cellulose.

30 8. A method according to claim 1 in which the cellulose is selected from the groups consisting of

microcrystalline cellulose, cotton fiber, paper,
microgranular cellulose and crosslinked cellulose.

9. A method according to claim 8 in which the
cellulose has a degree of polymerization from 200 to 2500.

5 10. A method according to claim 9 in which the
cellulose is crosslinked with a hydrocarbon bridge
containing from 2 to 12 carbon atoms between cellulose
chains.

10 11. A method according to claim 10 in which the bridge
is an alkylene bridge containing from 4 to 8 carbon atoms.

12. A method according to claim 1 in which the film is
formed by casting.

13. A method according to claim 12 in which the film
has a thickness from 10 microns to 250 microns.

15 14. A method according to claim 1 in which the first
solvent is a mixture of an inorganic salt and a polar
aprotic solvent.

15. A method according to claim 14 in which the second
solvent is a miscible polar, aprotic solvent.

20 16. A method according to claim 1 in which the polymer
is a cellulose ether.

17. A method according to claim 16 in which the
polymer is alkyl cellulose.

25 18. A method according to claim 17 in which the
polymer is ethyl cellulose.

19. A heterogeneous separator for an alkaline metal
ion, secondary battery comprising

a cellulose film resistant to alkaline electrolyte,
impermeable to zinc ions containing dispersed domains of
30 polymer that are permeable to hydrogen.

20. A separator according to claim 19 in which the polymer is present in the film in an amount of 10 to 60 parts by weight to 100 parts by weight of cellulose.

21. A separator according to claim 20 having a
5 thickness of from 10 microns to 250 microns.

22. A separator according to claim 21 in which the cellulose is selected from the group consisting of microcrystalline cellulose, cotton fiber, paper and microgranular cellulose.

10 23. A separator according to claim 22 in which the cellulose has a degree of polymerization from 200 to 2500.

24. A separator according to claim 13 in which the cellulose is crosslinked with a hydrocarbon bridge containing from 2 to 12 carbon atoms between cellulose
15 chains.

25. A separator according to claim 24 in which the bridge is an alkylene bridge containing from 4 to 8 carbon atoms.

26. A secondary, zinc ion battery comprising in
20 combination

a battery case containing

a body of alkaline electrolyte;

a zinc electrode dispersed in said body of electrolyte;

25 a counter electrode dispersed in said body of electrolyte; and

a cellulosic separator containing domains of polymer having a hydrogen permeability of at least $1 \times 10^{-13} \text{ cm}^3 \text{ cm}^{-1} \text{ s}^{-1} \text{ Pa}^{-1}$ dispersed in said body of electrolyte between
30 said electrodes.

27. A secondary zinc battery according to claim 26 in which the counter-electrode comprises silver.

28. A secondary zinc battery according to claim 26 in which the polymer is present in said separator in an amount of 10 to 60 parts by weight to 100 parts by weight of cellulose.

5 29. A secondary zinc battery according to claim 28 in which the polymer is a cellulose ether.

30. A secondary battery according to claim 29 in which the polymer is alkyl cellulose.

10 31. A secondary battery according to claim 30 in which the polymer is ethyl cellulose.