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FLOW BATTERY WITH THERMAL ACTIVATION

Abstract

A battery system includes an anode circuit configured to urge a flow of anolyte therethrough to an anode side of an electrode and a cathode circuit configured to urge a flow of catholyte therethrough to a cathode side of the electrode. An electric circuit is operably connected to the electrode to utilize electrical energy generated via a chemical reaction between the flow of anolyte and the flow of catholyte at the electrode. The flow of anolyte is driven through the anode circuit by thermal expansion and/or thermal contraction of one or more components of the anode circuit. The flow of catholyte is driven through the cathode circuit by thermal expansion and/or thermal contraction of one or more components of the cathode circuit.

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Background/Summary

BACKGROUND

[0001] Exemplary embodiments pertain to the art of power generation and storage, and in particular to flow batteries for, for example, aircraft and space applications.

[0002] A flow battery, also known as a redox flow battery, is a type of electrochemical cell in which chemical energy is provided by two chemical components dissolved in liquids that are pumped through the system on separate sides of a membrane. Ion transfer inside of the cell occurs through the membrane while both liquids circulate in their own respective spaces. The ion transfer results in a flow of electrical current through an external circuit operably connected to the membrane. This electrical current can then be utilized as desired. The liquids utilized in the cell are stored externally, generally in respective tanks, and are pumped through the cell or cells.

[0003] Interest in flow batteries has increased considerably with increasing storage needs of renewable energy sources. High-capacity flow batteries, which have large tanks of electrolytes, are capable of storing a large amount of electrical energy.

BRIEF DESCRIPTION

[0004] In one exemplary embodiment, a battery system includes an anode circuit configured to urge a flow of anolyte therethrough to an anode side of an electrode and a cathode circuit configured to urge a flow of catholyte therethrough to a cathode side of the electrode. An electric circuit is operably connected to the electrode to utilize electrical energy generated via a chemical reaction between the flow of anolyte and the flow of catholyte at the electrode. The flow of anolyte is driven through the anode circuit by thermal expansion and/or thermal contraction of one or more components of the anode circuit. The flow of catholyte is driven through the cathode circuit by thermal expansion and/or thermal contraction of one or more components of the cathode circuit.

[0005] Additionally or alternatively, in this or other embodiments at least one of the anode circuit and the cathode circuit include a chamber formed from a first thermally activated material having a first coefficient of thermal expansion. The chamber is configured to change perimetrical shape when a temperature of an interior of the chamber is increased.

[0006] Additionally or alternatively, in this or other embodiments the chamber is at least partially formed from a second thermally activated material having a second coefficient of thermal expansion less than the first coefficient of thermal expansion to effect the change in perimetrical shape of the interior of the chamber.

[0007] Additionally or alternatively, in this or other embodiments positioning of the second thermally activated material in a chamber wall of the chamber varies around the perimeter of the chamber.

[0008] Additionally or alternatively, in this or other embodiments at a first perimetrical location, the second thermally activated material is positioned at an interior side of the chamber wall.

[0009] Additionally or alternatively, in this or other embodiments at a second perimetrical location, the second thermally activated material is positioned at an exterior side of the chamber wall.

[0010] Additionally or alternatively, in this or other embodiments the chamber is formed by one or more additive manufacturing processes.

[0011] Additionally or alternatively, in this or other embodiments the battery system is absent an electrically or mechanically driven pump to urge the flow of anolyte or the flow of catholyte toward the electrode.

[0012] Additionally or alternatively, in this or other embodiments the electric circuit is operably connected to the electrode via one or more current collectors disposed at the electrode.

[0013] Additionally or alternatively, in this or other embodiments the electrical energy is generated via ion transfer at the electrode.

[0014] In another exemplary embodiment, a method of operating a battery system includes urging a flow of anolyte through an anode circuit to an anode side of an electrode, urging a flow of catholyte through a cathode circuit to a cathode side of the electrode, and generating electrical energy at the

electrode via a chemical reaction between the flow of anolyte and the flow of catholyte at the electrode. The flow of anolyte is driven through the anode circuit by thermal expansion and/or thermal contraction of one or more components of the anode circuit. The flow of catholyte is driven through the cathode circuit by thermal expansion and/or thermal contraction of one or more components of the cathode circuit.

[0015] Additionally or alternatively, in this or other embodiments at least one of the anode circuit and the cathode circuit include a chamber formed from a first thermally activated material having a first coefficient of thermal expansion. The chamber is configured to change perimetrical shape when a temperature of an interior of the chamber is increased.

[0016] Additionally or alternatively, in this or other embodiments the chamber is at least partially formed from a second thermally activated material having a second coefficient of thermal expansion less than the first coefficient of thermal expansion to effect the change in perimetrical shape of the interior of the chamber.

[0017] Additionally or alternatively, in this or other embodiments a positioning of the second thermally activated material is varied in a chamber wall of the chamber around the perimeter of the chamber.

[0018] Additionally or alternatively, in this or other embodiments at a first perimetrical location, the second thermally activated material is positioned at an interior side of the chamber wall.

[0019] Additionally or alternatively, in this or other embodiments at a second perimetrical location, the second thermally activated material is positioned at an exterior side of the chamber wall.

[0020] Additionally or alternatively, in this or other embodiments the chamber is formed by one or more additive manufacturing processes.

[0021] Additionally or alternatively, in this or other embodiments the battery system is absent an electrically or mechanically driven pump to urge the flow of anolyte or the flow of catholyte toward the electrode.

[0022] Additionally or alternatively, in this or other embodiments the electric circuit is operably connected to the electrode via one or more current collectors disposed at the electrode.

[0023] Additionally or alternatively, in this or other embodiments the electrical energy is generated via ion transfer at the electrode.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

[0025] FIG. **1** is a schematic illustration of an exemplary embodiment of a flow battery;

[0026] FIG. **2** is another illustration of an exemplary embodiment of a flow battery;

[0027] FIG. **3** is a partially illustration of an embodiment of a chamber wall in a first state;

[0028] FIG. **4** is a partial illustration of an embodiment of a chamber wall in a second state;

[0029] FIG. **5** is a partial cross-sectional view of an embodiment of a chamber in a first state; and

[0030] FIG. **6** is a partial cross-sectional view of an embodiment of a chamber in a second state.

DETAILED DESCRIPTION

[0031] A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

[0032] Referring to FIG. **1**, shown is a schematic of an exemplary embodiment of a flow battery **10**. The flow battery **10** includes an anode circuit **12** through which a volume of anolyte **14** is circulated via an anode tank **15**, and a cathode circuit **16** through which a volume of catholyte **18** is circulated via a cathode tank **19**. The anode circuit **12** and the cathode circuit **16** are interconnected at an electrode **20**, which in some embodiments is a porous electrode **20** having a membrane **21**

separating an anode side **20a** of the electrode **20** from a cathode side **20b** of the electrode **20**. As the anolyte **14** and the catholyte **18** are circulated through the respective anode circuit **12** and the cathode circuit **16**, ions are transferred at the electrode **20** generating an electric current that is collected at current collectors **22** of the electrode **20**. The current collectors **22** are connected to an external electric circuit **24** to utilize the flow of electrical energy.

[0033] Referring now to FIG. 2, in some embodiments, the flow of anolyte **14** is urged between a first anode chamber **26** and a second anode chamber **28**, with the electrode **20** disposed along an anode pathway **30** between the first anode chamber **26** and the second anode chamber **28**.

Similarly, the flow of catholyte **18** is urged between a first cathode chamber **32** and a second cathode chamber **34**, with the electrode **20** disposed along a cathode pathway **36** between the first cathode chamber **32** and the second cathode chamber **34**. In some embodiments, an anode control valve **38** is located along the anode pathway **30** to control or meter the flow of anolyte **14** along the anode pathway **30**, and a cathode control valve **40** may be positioned along the cathode pathway **36** to similarly control or meter the flow of catholyte **18** along the cathode pathway **36**. The flows of anolyte **14** and catholyte **18** are urged along the respective pathways **30** and **36** by volumetric expansion and contraction of the chambers **26**, **28**, **32**, **34**.

[0034] Referring now to FIGS. 3 and 4, construction of the chambers **26**, **28**, **32**, **34** will now be described. For the sake of clarity, construction of the first anode chamber **26** will be described, and one skilled in the art will readily appreciate that the other chambers **28**, **32** and **34** may be similarly constructed. The chamber **26** utilizes a thermally adaptive material with a thermal expansion coefficient such that with increasing temperature of the chamber **26**, such as from inflow of high temperature anolyte **14** into the chamber **26**, the internal volume of the chamber **26** is increased. Thermally adaptive materials change shape when temperature varies. The variation may result from environmental changes or from, for example, electric heating or cooling. In some embodiments, the thermal adaptive materials utilized may include one or more of plastics with a gradient of thermal expansion produced by composition change, added fibers or filling, multi-metallic (bimetallic) materials with gradient of composition, and shape memory alloys.

[0035] Similarly, outflow of the anolyte **14** results in a lower internal temperature of the chamber **26** and the internal volume of the chamber **26** decreases. To control the expansion and contraction of the chamber **26**, the structure is reinforced in selected locations with a second material, a reinforcing material **42** that is non-uniformly dispersed in the first material **44** of the chamber **26**. The second material **42** has a second coefficient of thermal expansion that is less than a first coefficient of thermal expansion of the first material **44**. This selective dispersing of the second material **42** in the first material **44** results in a non-uniform shape change of the chamber **26** when under thermal expansion.

[0036] An example of this is illustrated in FIGS. 3 and 4, which illustrate a portion of a chamber wall **46** the chamber **26**. In the embodiment of FIG. 3, the second material **42** is concentrated at a first side **48** of the chamber wall **46**, while a second side **50** of the chamber wall **46** does not include the second material **42** and thus is substantially unreinforced. In this unheated state, the portion of the chamber wall **46** has a length **L1**. Referring now to FIG. 4, when the chamber wall **46** is heated due to, for example, an inflow of hot anolyte or catholyte, the chamber wall **46** expands non-uniformly. The second side **50** increases in length to a length **L2**, while the first side **48**, due to placement of the reinforcement second material **42**, increases in length to a length **L3**, which is less than **L2**. This results in an increase in curvature of the chamber wall **46**. In some embodiments, the non-uniform dispersal of the second material **42** in the chamber wall **46** is accomplished via additive manufacturing of the chamber **26**.

[0037] Referring now to FIG. 5 and FIG. 6, the placement of the selective reinforcement may be varied around a perimeter or circumference of the chamber **26**. As illustrated in the cross-sectional views of FIG. 5 and FIG. 6, at the sides **56** of the cross-section as shown, the second material **42** is concentrated at an exterior side **52** of the chamber wall **46**, while the second material **42** is

relatively absent from an interior side 54 of the chamber wall 46. At a top 58 and bottom 60 of the cross-section shape, however, the configuration may be substantially reversed in that the second material 42 is concentrated at the interior side 54 of the chamber wall 46, while the second material is relatively absent from the exterior side 52 at these locations. When the chamber 46 is subjected to heating, as illustrated in FIG. 6, the curvature of the chamber wall 46 increases at the top 58 and bottom 60 portions, while at the sides 56 the chamber wall 46, the curvature of the chamber wall 46 decreases. This selective placement of the second material 42 in the chamber wall 46 results in shape change of the chamber 26 due to thermal effects, and in turn pumps the anolyte and catholyte into and out of the chambers 26, 28, 32, 34.

[0038] Pumping of the anolyte and the catholyte via the shape change of the chambers c 26, 28, 32, 34 allows for operation of the flow battery 10 without additional pumps, thus reducing complexity of the flow battery 10. Further, the flow battery 10 is activated by thermal energy, no electrical input is needed to activate the thermal battery 10. Exclusion of additional pump mechanisms also increases reliability of the flow battery 10 and reduces weight.

[0039] The term “about” is intended to include the degree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application.

[0040] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.

[0041] While the present disclosure has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the present disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the essential scope thereof. Therefore, it is intended that the present disclosure not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this present disclosure, but that the present disclosure will include all embodiments falling within the scope of the claims.

Claims

1. A battery system, comprising: an anode circuit configured to urge a flow of anolyte therethrough to an anode side of an electrode; a cathode circuit configured to urge a flow of catholyte therethrough to a cathode side of the electrode; and an electric circuit operably connected to the electrode to utilize electrical energy generated via a chemical reaction between the flow of anolyte and the flow of catholyte at the electrode; wherein the flow of anolyte is driven through the anode circuit by thermal expansion and/or thermal contraction of one or more components of the anode circuit; and wherein the flow of catholyte is driven through the cathode circuit by thermal expansion and/or thermal contraction of one or more components of the cathode circuit.
2. The battery system of claim 1, wherein at least one of the anode circuit and the cathode circuit include a chamber formed from a first thermally activated material having a first coefficient of thermal expansion, the chamber configured to change perimetrical shape when a temperature of an interior of the chamber is increased.
3. The battery system on claim 2, wherein the chamber is at least partially formed from a second thermally activated material having a second coefficient of thermal expansion less than the first coefficient of thermal expansion to effect the change in perimetrical shape of the interior of the chamber.

- 4.** The battery system of claim 3, wherein positioning of the second thermally activated material in a chamber wall of the chamber varies around the perimeter of the chamber.
 - 5.** The battery system of claim 4, wherein at a first perimetrical location, the second thermally activated material is disposed at an interior side of the chamber wall.
 - 6.** The battery system of claim 4, wherein at a second perimetrical location, the second thermally activated material is disposed at an exterior side of the chamber wall.
 - 7.** The battery system of claim 2, wherein the chamber is formed by one or more additive manufacturing processes.
 - 8.** The battery system of claim 1, wherein the battery system is absent an electrically or mechanically driven pump to urge the flow of anolyte or the flow of catholyte toward the electrode.
 - 9.** The battery system of claim 1, wherein the electric circuit is operably connected to the electrode via one or more current collectors disposed at the electrode.
 - 10.** The battery system of claim 1, wherein the electrical energy is generated via ion transfer at the electrode.
 - 11.** A method of operating a battery system, comprising: urging a flow of anolyte through an anode circuit to an anode side of an electrode; urging a flow of catholyte through a cathode circuit to a cathode side of the electrode; and generating electrical energy at the electrode via a chemical reaction between the flow of anolyte and the flow of catholyte at the electrode; wherein the flow of anolyte is driven through the anode circuit by thermal expansion and/or thermal contraction of one or more components of the anode circuit; and wherein the flow of catholyte is driven through the cathode circuit by thermal expansion and/or thermal contraction of one or more components of the cathode circuit.
 - 12.** The method of claim 11, wherein at least one of the anode circuit and the cathode circuit include a chamber formed from a first thermally activated material having a first coefficient of thermal expansion, the chamber configured to change perimetrical shape when a temperature of an interior of the chamber is increased.
 - 13.** The method of claim 12, further comprising at least partially forming the chamber from a second thermally activated material having a second coefficient of thermal expansion less than the first coefficient of thermal expansion to effect the change in perimetrical shape of the interior of the chamber.
 - 14.** The method of claim 13, further comprising varying a positioning of the second thermally activated material in a chamber wall of the chamber around the perimeter of the chamber.
 - 15.** The method of claim 14, wherein at a first perimetrical location, the second thermally activated material is disposed at an interior side of the chamber wall.
 - 16.** The method of claim 14, wherein at a second perimetrical location, the second thermally activated material is disposed at an exterior side of the chamber wall.
 - 17.** The method of claim 12, further comprising forming the chamber by one or more additive manufacturing processes.
 - 18.** The method of claim 11, wherein the battery system is absent an electrically or mechanically driven pump to urge the flow of anolyte or the flow of catholyte toward the electrode.
 - 19.** The method of claim 11, wherein the electric circuit is operably connected to the electrode via one or more current collectors disposed at the electrode.
 - 20.** The method of claim 11, further comprising generating the electrical energy via ion transfer at the electrode.
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