Claims

1. A method of charging and/or discharging a sulphur based battery, comprising:

a) limiting a charge and/or discharge specific capacity of the battery based on

$$specific\ capacity\ (limit) = total\ specific\ capacity \times \frac{n}{16}$$

wherein the total specific capacity is the specific capacity of the battery derived from complete charging and/or discharging; and

n is a number of electrons transferred in redox reactions between sulphur and/or its chemical species thereof; and

b) limiting a charge and/or discharge voltage of the battery based on a rate of change of voltage relative to an electric parameter of the battery, in which the rate of change represents a transition between redox reactions of sulphur and/or its chemical species thereof.

2. The method according to claim 1, wherein the limit of the charge and/or discharge specific capacity of the battery is adjustable in a stepwise manner based on the number of electrons transferred in redox reactions between sulphur and/or its chemical species thereof; and/or

Wherein the limit of the charge and/or discharge specific capacity of the battery is adjustable in real time during operation of the battery.

3. The method according to claim 1 or 2, wherein n is an even number.

4. The method according to any one of claims 1 to 3, wherein when the total specific capacity is about 1,675 mAh/g(S), each electron transfer is characterised by a specific capacity of about 104 mAh/g(S).

5. The method according to any one of claims 1 to 4, wherein the 6 electron redox reaction between sulphur and/or its chemical species thereof is selected from:

$$S_6^{2-}{}_{(\sim 75\%)} \leftrightarrow S_4^{2-} \leftrightarrow S_3^{2-} \leftrightarrow S_2^{2-} \leftrightarrow S^{2-}{}_{(\sim 35\%)}$$

$$S_8 \leftrightarrow S_8^{2-} \leftrightarrow S_6^{2-} \leftrightarrow S_4^{2-}$$

wherein when the battery is limited to a 6 electron redox reaction, the specific capacity is limited to about 628 mAh/g(S);

wherein the 8 electron redox reaction between sulphur and/or its chemical species thereof is selected from:

$$S_6^{2-} \leftrightarrow S_4^{2-} \leftrightarrow S_3^{2-} \leftrightarrow S_2^{2-} \leftrightarrow S^{2-}_{(\sim 35\%)}$$

$$S_8 \leftrightarrow S_8^{2-} \leftrightarrow S_6^{2-} \leftrightarrow S_4^{2-} \leftrightarrow S_{2\text{-}3}^{2-}$$

and wherein the specific capacity is limited to about 837.5 $mAh/g_{(S)}$;

wherein the 10 electron redox reaction between sulphur and/or its chemical species thereof is selected from:

$$S_{8(60\%)} \leftrightarrow S_8^{2-} \leftrightarrow S_6^{2-} \leftrightarrow S_4^{2-} \leftrightarrow S_3^{2-} \leftrightarrow S_2^{2-} \leftrightarrow S^{2-}_{(35\%)}$$

and wherein the specific capacity is limited to about 1,046.9 $mAh/g_{(S)}$;

wherein the 12 electron redox reaction between sulphur and/or its chemical species thereof is selected from:

$$S_8 \leftrightarrow S_8^{2-} \leftrightarrow S_6^{2-} \leftrightarrow S_4^{2-} \leftrightarrow S_3^{2-} \leftrightarrow S_2^{2-} \leftrightarrow S^{2-}_{(50\%)}$$

and wherein the specific capacity is limited to about 1,256 $mAh/g_{(S)}$.

6. The method according to any one of claims 1 to 5, wherein the limit of the charge and/or discharge voltage of the battery is adjustable in a stepwise manner based on the type of redox reactions between sulphur and/or its chemical species thereof; and/or wherein the limit of the charge and/or discharge voltage of the battery is adjustable in real time during operation of the battery.

7. The method according to any one of claims 1 to 6, wherein the voltage is limited based on a rate of change of charge relative to voltage;

wherein the rate of change of charge relative to voltage is a first order derivative of a current-voltage function, wherein the voltage is limited based on a negative peak in a first order derivative of a current-voltage function.

8. The method according to claim 7, wherein the current-voltage function is obtained from a cyclic voltammetry measurement.

9. The method according to any one of claims 1 to 6 , wherein the voltage is limited based on a rate of change of charge relative to voltage;

wherein the rate of change of charge relative to voltage is a second order derivative of a capacity-voltage function, wherein the voltage is limited based on a negative peak in a second order derivative of a capacity-voltage function.

10. The method according to claim 9, wherein the voltage is limited based on an intersect of extrapolated tangents at a deflection point or inflection point of a capacity-voltage function;
wherein the capacity-voltage function is obtained from a galvanic charge (GChg) plot.

11. The method according to any one of claims 1 to 10, wherein when the battery is limited to a 6 electron redox reaction, the charge voltage is limited to about 2.3 V to about 2.5 V or preferably about 2.33 V or about 2.42 V;
wherein when the battery is limited to a 8 electron redox reaction, the charge voltage is limited to about 2.3 V to about 2.4 V or preferably about 2.33 V or about 2.37 V; and
wherein when the battery is limited to a 10 electron redox reaction, the charge voltage is limited to about 2.3 V to about 2.4 V or preferably about 2.37 V.

12. The method according to any one of claims 1 to 11, wherein the sulphur based battery is an alkali metal-sulfur battery, alkaline-earth metal-sulfur battery, alloy-sulfur battery, or a metal-sulfur battery wherein the metal is selected from aluminium, vanadium, titanium, molybdenum, iron, niobium, or tungsten.

13. The method according to claim 12, wherein the alkali metal is selected from Li, Na, K, or a combination thereof.

14. The method according to claim 12, wherein the alkaline-earth metal is selected from Mg, Ca, Sr, Ba, or a combination thereof.

15. The method according to claim 12, wherein the alloy is selected from Li-Sn, Li-Mg, Li-B, Fe-Co, Li-Si, Li-Hg, Li-Al, sodium alloy, aluminium alloy, potassium alloy and magnesium alloy.

16. A battery management system, wherein the battery management system is configured to:

a) limit a charge and/or discharge specific capacity of the battery based on

$$specific\ capacity\ (limit) = total\ specific\ capacity \times \frac{n}{16}$$

wherein the total specific capacity is the specific capacity of the battery derived from complete charging and/or discharging; and

n is a number of electrons transferred in redox reactions between sulphur and/or its chemical species thereof; and

b) limit a charge and/or discharge voltage of the battery based on a rate of change of voltage relative to an electric parameter of the battery, in which the rate of change represents a transition between redox reactions of sulphur and/or its chemical species thereof.

17. The battery management system according to claim 16, wherein the limit of the charge and/or discharge specific capacity of the battery is adjustable in a stepwise manner based on the number of electrons transferred in redox reactions between sulphur and/or its chemical species thereof.

18. The battery management system according to claim 16 or 17, wherein the limit of the charge and/or discharge voltage of the battery is adjustable in a stepwise manner based on the type of redox reactions between sulphur and/or its chemical species thereof.

19. The battery management system according to any one of claims 16 to 18, wherein the limit to the specific capacity and/or voltage is adjustable by a control means.

20. The battery management system according to any one of claims 16 to 19, wherein the limit to the specific capacity and/or voltage is adjustable by a user.