

Claims

1. A thermal control system comprising an inorganic phase change material and an organic phase change material.
- 5 2. The thermal control system according to claim 1, wherein the inorganic phase change material and the organic phase change material are physically mixed with each other.
3. The thermal control system according to claim 1, wherein the inorganic phase change material forms a first layer and the organic phase change material forms a second layer, whereby the first layer and the second layer are physically distinct from each other.
- 10 4. The thermal control system according to any one of the preceding claims, wherein the organic phase change material and the inorganic phase change material are present at a ratio in the range of 1:1 to 1:5 by weight.
5. The thermal control system according to claim 3 or 4, wherein the first layer and the second layer are separated by a layer of fluid or are in direct contact with each other.
- 15 6. The thermal control system according to any one of claims 3 to 5, wherein the first layer is the inner layer and the second layer is the outer layer, or the first layer is the outer layer and the second layer is the inner layer, relative to an item to be cooled, wherein the inner layer at least partially surrounds the item to be cooled, and the outer layer at least partially surrounds the inner layer.
- 20 7. The thermal control system according to any one of claims 3 to 6, wherein the outer layer and inner layer are of the same temperature, or wherein the outer layer is of a relatively lower temperature than the inner layer.
8. The thermal control system according any one of claims 3 to 7, wherein the organic phase change material and the inorganic phase change material is independently present at a thickness in the range of 5 mm to 3 cm.
- 25 9. The thermal control system according to any one of the preceding claims, wherein the inorganic phase change material comprises a salt and a first additive.
10. The thermal control system according to claim 9, wherein the salt comprises a first metal selected from group 1, group 2, group 7, group 8, group 9, group 10, group 12 or group 13 of the Periodic Table of Elements, and an anion.
- 30 11. The thermal control system according to claim 9 or 10, wherein the inorganic phase change material comprises 5 wt% to 35 wt% salt.
12. The thermal control system according to any one of claims 9 to 11, wherein the first additive is a nano-sized material, a micro-sized material or a mixture thereof.

13. The thermal control system according to claim 12, wherein the thermal conductivity of the first additive is in the range of about 0.005 W/(m*K) to about 0.07 W/(m*K).
14. The thermal control system according to any one of claims 9 to 13, wherein the inorganic phase change material comprises:
- 5 about 70 wt% to about 80 wt% water;
- about 15 wt% to about 25 wt% $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$
- about 3 wt% to about 4 wt% NaCl;
- about 0.2 wt% to about 0.7 wt% porous silica microstructure; and
- about 0.5 wt% to about 1.5 wt% carbon fiber nanostructure,
- 10 such that the total wt% of each component adds to 100 wt%.
15. The thermal control system according to claim 14, wherein the inorganic phase change material comprises:
- about 75 wt% water;
- about 20 wt% $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$
- 15 about 3.5 wt% NaCl;
- about 0.5 wt% porous silica microstructure; and
- about 1 wt% carbon fiber nanostructure.
16. The thermal control system according to any one of the preceding claims, wherein the organic phase change material comprises a hydrocarbon and a second additive.
- 20 17. The thermal control system according to claim 16, wherein the hydrocarbon is an optionally functionalized aliphatic.
18. The thermal control system according to claim 17, wherein the organic phase change material comprises about 50 wt% to about 98 wt% hydrocarbon.
19. The thermal control system according to any one of claims 17 or 18, wherein the second
- 25 additive is a nano-sized material, a micro-sized material or a mixture thereof.
20. The thermal control system according to any one of claims 16 to 19, wherein the thermal conductivity of the second additive is in the range of about 20-50 W/(m*K).
21. The thermal control system according to any one of claims 16 to 20, wherein the organic phase change material comprises:

- about 65 wt% to about 75 wt% $C_{11}H_{24}$ hydrocarbon;
- about 15 wt% to about 25 wt% $C_{12}H_{26}$ hydrocarbon;
- about 2.5 wt% to about 7.5 wt% $C_{13}H_{28}$ hydrocarbon;
- about 1.5 wt% to about 2.5 wt% carbon nanotube; and [
- 5 about 2.5 wt% to about 3.5 wt% copper nanoparticle,
- such that the total wt% of each component adds to 100 wt%.
22. The thermal control system according to any one of claims 16 to 21, wherein the organic phase change material comprises:
- 10 about 5 wt% to about 15 wt% hydrocarbon selected from the group consisting of $C_{10}H_{22}$, $C_{11}H_{24}$ and $C_{14}H_{30}$;
- about 25 wt% to about 35 wt% $C_{12}H_{26}$ hydrocarbon;
- about 55 wt% to about 65 wt% $C_{13}H_{28}$ hydrocarbon; and
- about 0.5 wt% to about 2 wt% carbon nanostructure;
- such that the total wt% of each component adds to 100 wt%.
- 15 23. The thermal control system according to any one of the preceding claims comprising:
- about 35 wt% to about 40 wt% water;
- about 7.5 wt% to about 12.5 wt% $CaCl_2 \cdot 6H_2O$
- about 1.5 wt% to about 2 wt% NaCl;
- about 0.1 wt% to about 0.35 wt% porous silica microstructure;
- 20 about 0.25 wt% to about 0.75 wt% carbon fiber nanostructure,
- about 32.5 wt% to about 37.5 wt% $C_{11}H_{24}$ hydrocarbon;
- about 7.5 wt% to about 12.5 wt% $C_{12}H_{26}$ hydrocarbon;
- about 1.25 wt% to about 3.75 wt% $C_{13}H_{28}$ hydrocarbon;
- about 0.75 wt% to about 1.25 wt% carbon nanotube; and
- 25 about 1.25 wt% to about 1.75 wt% copper nanoparticle,
- such that the total wt% of each component adds to 100 wt%.

24. The thermal control system according to any one of claims 1 to 22 comprising:

- about 37.5 wt% water;
- about 10 wt% $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$
- about 1.75 wt% NaCl;
- 5 about 0.25 wt% porous silica microstructure;
- about 0.5 wt% carbon fiber nanostructure;
- about 35 wt% $\text{C}_{11}\text{H}_{24}$ hydrocarbon;
- about 10 wt% $\text{C}_{12}\text{H}_{26}$ hydrocarbon;
- about 2.5 wt% $\text{C}_{13}\text{H}_{28}$ hydrocarbon;
- 10 about 1 wt% carbon nanotube; and
- about 1.5 wt% copper nanoparticle.

25. The thermal control system according to any one of claims 1 to 22 comprising::

- about 35 wt% to about 40 wt% water;
- about 7.5 wt% to about 12.5 wt% $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$
- 15 about 1.5 wt% to about 2 wt% NaCl;
- about 0.1 wt% to about 0.35 wt% porous silica microstructure;
- about 0.25 wt% to about 0.75 wt% carbon fiber nanostructure,
- about 2.5 wt% to about 7.5 wt% hydrocarbon selected from the group consisting of $\text{C}_{10}\text{H}_{22}$, $\text{C}_{11}\text{H}_{24}$ and $\text{C}_{14}\text{H}_{30}$;
- 20 about 12.5 wt% to about 17.5 wt% $\text{C}_{12}\text{H}_{26}$ hydrocarbon;
- about 27.5 wt% to about 32.5 wt% $\text{C}_{13}\text{H}_{28}$ hydrocarbon; and
- about 0.25 wt% to about 1 wt% carbon nanostructure;
- such that the total wt% of each component adds to 100 wt%.

26. The thermal control system according to any one of the preceding claims, further comprising
- 25 a thermally insulating material at least partially surrounding the inorganic phase change material and the organic phase change material.

27. The thermal control system according to claim 26, comprising an inner thermally insulating material which at least partially surrounds the inorganic and organic phase change material, and an outer thermally insulating material which at least partially surrounds the inner phase change material.
- 5 28. A method of preparing a thermal control system, the method comprising the step of contacting an inorganic phase change material with an organic phase change material.
29. The method according to claim 28, wherein the contacting step results in direct contact between the inorganic phase change material and the organic phase change material.
- 10 30. The method according to claim 28, wherein the contacting step comprises the step of bringing the inorganic phase change material and the organic phase change material together with a layer of fluid in between.
31. The method according to any one of claims 28 to 30, further comprising the step of at least partially surrounding an item to be cooled with the inorganic phase change material and the organic phase change material.
- 15 32. The method according to any one of claims 28 to 31, further comprising the step of at least partially surrounding the inorganic phase change material and the organic phase change material with a thermally insulating material.
- 20 33. A method for maintaining a temperature of an item, the method comprising the step of providing a thermal control system comprising an inorganic phase change material and an organic phase change material.
34. The method according to claim 33, further comprising the step of contacting or at least partially surrounding an item to be cooled with the thermal control system.
- 25 35. The method according to claim 34, further comprising the step of pre-cooling the organic phase change material and/or the inorganic phase change material to a temperature below -15 °C prior to contacting with the item to be cooled.