CLAIMS

1. Use of metal nitrates or metal nitrate hydrates as phase change materials (PCMs) with a nucleation agent based on group II metal nitrates or metal nitrate hydrates.

2. Use according to claim 1, wherein nucleation is achieved by a seeding process (i.e. addition of crystals of the same chemical identity as a component of the PCM) to overcome subcooling.

3. Use according to any preceding claim, wherein the nucleation agent is a nitrate salt with more than one distinct cation.

4. Use according to any preceding claim, wherein the nucleation agent is comprised of one or more group II metal nitrate(s) and/or metal nitrate hydrate(s).

5. Use according to any preceding claim, where the PCM is nucleated with a nucleating agent that is kept at high pressure during the melting process.

6. A method of nucleation according to claim 5, wherein the nucleation agent is a crystal of one or more components of the PCM that has been kept solid above its melting point by being in a region of high pressure in cracks on the surface of a metal sample.

7. A method of nucleation according to any of claims 5 and 6, wherein a thin metal disc with machined grooves is flexed to release the nucleation agent into the bulk PCM.

8. Use according to any preceding claim, wherein the nucleation agent comprised of a group II metal nitrate is magnesium nitrate or any hydrate form thereof.

9. Use according to any preceding claim, wherein the nucleation agent comprised of a group II metal nitrate is strontium nitrate or any hydrate form thereof.

10. Use according to any preceding claim, wherein the nucleation agent comprised of a group II metal nitrate is calcium nitrate or any hydrate form thereof.

11. Use according to any preceding claim, wherein the nucleation agent comprised of a group II metal nitrate is barium nitrate or any hydrate form thereof.

12. Use according to any preceding claim, wherein the nucleation agent is a combination of two or more group II metal nitrates, including any combination of anhydrous and hydrated forms thereof.

13. Use according to any preceding claim, wherein the nucleation agent is a combination of strontium nitrate and magnesium nitrate or any hydrate forms thereof.

14. Use according to any preceding claim, wherein the nucleation agent is a combination of calcium nitrate and magnesium nitrate or any hydrate forms thereof.

15. Use according to any preceding claim, wherein the nucleation agent is a combination of magnesium nitrate and barium nitrate or any hydrate forms thereof.

16. Use according to any preceding claim, wherein the nucleation agent is a combination of strontium nitrate and barium nitrate or any hydrate forms thereof.

17. Use according to any preceding claim, wherein the nucleation agent is a combination of strontium nitrate, barium nitrate and magnesium nitrate or any hydrate forms thereof.

18. Use according to any claim, wherein the nucleation agent is present at a concentration which is above the solubility limit in the bulk PCM.

19. Use according to any preceding claim wherein the nucleation agent is present in at least about 0.1% by weight of the PCM.

20. A PCM comprised of;

at least one metal nitrate hydrate selected from any one of or a combination of a list comprised of:

lithium nitrate, sodium nitrate, potassium nitrate, calcium nitrate, barium nitrate, scandium nitrate, zinc nitrate, copper nitrate, iron nitrate, manganese nitrate, chromium nitrate, strontium nitrate, silver nitrate, yttrium nitrate, zirconium nitrate, titanium nitrate, any lanthanide metal nitrate, ammonium nitrate, aluminium nitrate, bismuth nitrate, gallium nitrate, magnesium nitrate, lead nitrate,

and/or any hydrate form thereof;

and a nucleation agent according to any preceding claim.

21. A PCM according to claim 20, wherein the PCM aside from the nucleation agent is a mixture of more than one metal nitrate and/or metal nitrate hydrate.

22. A PCM according to any of claims 20 and 21, wherein the PCM has a melting temperature lower than that of each chosen component individually.

23. A PCM according to any of claims 20 to 22, wherein by altering the amounts of the chosen metal nitrates and/or hydrates thereof, the melting point of the PCM is capable of being tuned to a specific point within a range of values.

24. A PCM according to any of claims 20 to 23, wherein the PCM is a eutectic mixture of the chosen components.

25. A PCM according to any of claims 20 to 24, wherein the PCM is a binary, ternary or quaternary eutectic mixture of the chosen components.

26. A PCM according to any of claims 20 to 25, wherein the PCM is comprised of; between about 98% and 99.6% by weight of at least one metal nitrate hydrate, between about 0.2% and 1% by weight strontium nitrate or any hydrate thereof and between about 0.2% and 1% by weight magnesium nitrate or any hydrate thereof.

27. A PCM according to any of claims 20 to 26, wherein the PCM is comprised of: between about 0% and 99.8% by weight calcium nitrate tetrahydrate; between about 0% and 1% by weight strontium nitrate tetrahydrate; between about 0% and 1% by weight magnesium nitrate hexahydrate; between about 0% and 1% by weight barium nitrate; between about 0% and 99.8% by weight lithium nitrate trihydrate; between 0% and 50% by weight manganese nitrate tetrahydrate; between about 0% and 99.8% by weight manganese nitrate hexahydrate; between about 0% and 99.8 % by weight zinc nitrate hexahydrate; between about 0% and 99.8% by weight copper nitrate hexahydrate; between about 0% and 40% by weight copper nitrate trihydrate; between about 0% and 40% by weight copper nitrate hemipentahydrate; between about 0% and 99.8% by weight iron nitrate nonahydrate; between about 0% and 10 % by weight sodium nitrate; and between about 0% and 30 % by weight potassium nitrate.

28. A PCM according to any of claims 20 to 27, wherein the PCM is comprised of, about 99.2% by weight calcium nitrate tetrahydrate, about 0.4% by weight strontium nitrate tetrahydrate and about 0.4% by weight magnesium nitrate hexahydrate.

29. A PCM according to any of claims 20 to 28, wherein the PCM is comprised of; about 99.3% by weight calcium nitrate tetrahydrate, about 0.3% by weight barium nitrate and about 0.4% by weight magnesium nitrate hexahydrate.

30. A PCM according to any of claims 20 to 29, wherein the PCM is comprised of; about 99.4% by weight calcium nitrate tetrahydrate, about 0.3% by weight strontium nitrate and about 0.3% by weight magnesium nitrate dihydrate.

31. A PCM according to any of claims 20 to 31, wherein the PCM is comprised of; about 57.2% by weight calcium nitrate tetrahydrate, about 42.0% by weight lithium nitrate trihydrate, about 0.4% by weight magnesium nitrate hexahydrate and about 0.4% by weight strontium nitrate tetrahydrate.

32. A PCM according to any of claims 20 to 31, wherein the PCM is comprised of; about 40.0% by weight calcium nitrate tetrahydrate, about 29.4% by weight lithium nitrate trihydrate, about 29.8% by weight copper nitrate hexahydrate, about 0.4% by weight magnesium nitrate hexahydrate and about 0.4% by weight strontium nitrate tetrahydrate.

33. A PCM according to any of claims 20 to 32, wherein the PCM is comprised of; about 32.1% by weight calcium nitrate tetrahydrate, about 23.5% by weight lithium nitrate trihydrate, about 23.8% by weight copper nitrate hexahydrate, about 19.8% by weight zinc nitrate hexahydrate, about 0.4% by weight magnesium nitrate hexahydrate and about 0.4% by weight strontium nitrate tetrahydrate.

34. A PCM according to any of claims 20 to 33, wherein the PCM is comprised of; about 24.0% by weight calcium nitrate tetrahydrate, about 17.6% by weight lithium nitrate trihydrate, about 17.9% by weight copper nitrate hexahydrate, about 39.7% by weight manganese nitrate hexahydrate, about 0.4% by weight magnesium nitrate hexahydrate and about 0.4% by weight strontium nitrate tetrahydrate.

35. A PCM according to any of claims 20 to 34, wherein the PCM is comprised of; about 39.7% by weight calcium nitrate tetrahydrate, about 59.5% by weight copper nitrate hexahydrate, about 0.4% by weight strontium nitrate tetrahydrate and about 0.4% by weight magnesium nitrate hexahydrate.

~~36. A PCM according to any of claims 20 to 35, wherein the PCM is comprised of; about 59.5% by weight calcium nitrate tetrahydrate, about 39.7% by weight zinc nitrate hexahydrate, about 0.4% by weight strontium nitrate tetrahydrate and about 0.4% by weight magnesium nitrate hexahydrate.~~

~~37. A PCM according to any of claims 20 to 36, wherein the PCM is comprised of; about 44.6% by weight calcium nitrate tetrahydrate, about 54.6% by weight iron nitrate nonahydrate, about 0.4% by weight strontium nitrate tetrahydrate and about 0.4% by weight magnesium nitrate hexahydrate.~~

~~38. A PCM according to any of claims 20 to 37, wherein the PCM is comprised of; about 69.4% by weight zinc nitrate hexahydrate, about 29.8% by weight lithium nitrate trihydrate, about 0.4% by weight strontium nitrate tetrahydrate and about 0.4% by weight magnesium nitrate hexahydrate.~~

~~39. A PCM according to any of claims 20 to 38, wherein the PCM is comprised of; about 39.7% by weight iron nitrate nonahydrate, about 34.1% by weight calcium nitrate tetrahydrate, about 25.4% by weight lithium nitrate trihydrate, about 0.4% by weight magnesium nitrate hexahydrate and about 0.4% by weight strontium nitrate tetrahydrate.~~

~~40. A PCM according to any of claims 20 to 39, wherein the PCM is comprised of; about 14.7% by weight manganese nitrate hexahydrate, about 83.3% by weight zinc nitrate hexahydrate, about 1% by weight strontium nitrate and about 1% by weight barium nitrate.~~

~~41. A method of increasing the rate of crystallisation of a PCM according to any preceding claim by mechanical manipulation of nucleation centres including agitation, recirculation, pumping, sonication, or combinations thereof.~~

~~42. A method of increasing the rate of crystallisation according to claim 41 where one or more growing crystallites are dispersed throughout the PCM.~~

~~43. A method of increasing the rate of crystallisation according to any of claims 41 and 42 where a nucleation agent is dispersed throughout the PCM.~~

44. A method of increasing the rate of crystallisation according to any of claims 41 to 43 where one or more growing crystallites are divided into a greater number of smaller crystallites.

45. A method of preparing a PCM according to any of claims 20 to 40 comprising:

providing at least one metal nitrate hydrate and at least one other metal nitrate and/or metal nitrate hydrate, and

heating the mixture above the melting transition temperature of one or more of the components and stirring to form a single pourable liquid.

46. A method of preparing a PCM according to claim 45, wherein an anhydrous metal nitrate and/or a metal nitrate hydrate of a lower hydration number than is desired in the final PCM composition is used in place of one or more metal nitrate hydrate(s) with the addition of an amount of water to give the final PCM composition.

47. A method of preparing a PCM according to any of claims 45 and 46, wherein a metal nitrate hydrate with a higher hydration number than is desired in the PCM composition is used, and the excess water removed by or saturated with one or more anhydrous metal nitrate(s) and/or lower hydrate metal nitrate salt(s) to give the final PCM composition.

48. A method of preparing a PCM according to any of claims 45 to 47, wherein a metal nitrate solution is used, and the excess water removed or saturated with one or more anhydrous metal nitrate(s) and/or lower hydrate metal nitrate salt(s) to give the final PCM composition.

49. A method of preparing a PCM according to any of claims 45 to 48, wherein the metal nitrate and/or metal nitrate hydrate has been synthesised or produced by reaction.

50. A method of preparing a PCM according to any of claims 45 to 49, wherein the PCM is formed by neutralisation of nitric acid by the corresponding basic metal salt in the presence of the correct amount of water to achieve a specific composition.

51. A method of preparing a PCM according to any of claims 45 to 50, wherein the PCM is formed by neutralisation of nitric acid by the corresponding metal bases in the presence of excess water which is then removed or saturated with one or more

~~anhydrous metal nitrate(s) and/or lower hydrate metal nitrate salt(s) to give the final PCM composition.~~

~~52. A method of preparing a PCM according to any of claims 45 to 51, wherein any anion other than nitrate is removed by ion exchange, or precipitation with an appropriate metal salt followed by physical separation.~~

CLAIMS

1. A PCM comprised of:

calcium nitrate tetrahydrate; and

a nucleation agent wherein the nucleation agent is comprised of a mixture comprised of a combination of:

magnesium nitrate or any hydrate form thereof; and

strontium nitrate or any hydrate form thereof.

2. A PCM according to claim 1, wherein the PCM comprises:

between about 98% to 99.6% by weight of calcium nitrate tetrahydrate;

between about 0.2% to 1% by weight of strontium nitrate or any hydrate thereof;

between about 0.2% to 1% by weight of magnesium nitrate or any hydrate thereof.

3. A PCM according to any preceding claim, wherein the PCM has a melting temperature lower than that of each chosen component individually.

4. A PCM according to any preceding claim, wherein by altering the amounts of the chosen metal nitrates and/or hydrates thereof, the melting point of the PCM is capable of being tuned to a specific point within a range of values.

5. A PCM according to any preceding claim, wherein the PCM is a eutectic mixture of the chosen components; and optionally

wherein the PCM is a binary, ternary or quaternary eutectic mixture of the chosen components.

6. A PCM according to any preceding claim, wherein the PCM is comprised of:

about 99.2% by weight calcium nitrate tetrahydrate, about 0.4% by weight strontium nitrate tetrahydrate and about 0.4% by weight magnesium nitrate hexahydrate;

about 99.4% by weight calcium nitrate tetrahydrate, about 0.3% by weight strontium nitrate and about 0.3% by weight magnesium nitrate dihydrate;

about 57.2% by weight calcium nitrate tetrahydrate, about 42.0% by weight lithium nitrate trihydrate, about 0.4% by weight magnesium nitrate hexahydrate and about 0.4% by weight strontium nitrate tetrahydrate;

about 40.0% by weight calcium nitrate tetrahydrate, about 29.4% by weight lithium nitrate trihydrate, about 29.8% by weight copper nitrate hexahydrate, about 0.4% by weight magnesium nitrate hexahydrate and about 0.4% by weight strontium nitrate tetrahydrate;

about 32.1% by weight calcium nitrate tetrahydrate, about 23.5% by weight lithium nitrate trihydrate, about 23.8% by weight copper nitrate hexahydrate, about 19.8% by weight zinc nitrate hexahydrate, about 0.4% by weight magnesium nitrate hexahydrate and about 0.4% by weight strontium nitrate tetrahydrate;

about 24.0% by weight calcium nitrate tetrahydrate, about 17.6% by weight lithium nitrate trihydrate, about 17.9% by weight copper nitrate hexahydrate, about 39.7% by weight manganese nitrate hexahydrate, about 0.4% by weight magnesium nitrate hexahydrate and about 0.4% by weight strontium nitrate tetrahydrate;

about 39.7% by weight calcium nitrate tetrahydrate, about 59.5% by weight copper nitrate hexahydrate, about 0.4% by weight strontium nitrate tetrahydrate and about 0.4% by weight magnesium nitrate hexahydrate;

about 59.5% by weight calcium nitrate tetrahydrate, about 39.7% by weight zinc nitrate hexahydrate, about 0.4% by weight strontium nitrate tetrahydrate and about 0.4% by weight magnesium nitrate hexahydrate;

about 44.6% by weight calcium nitrate tetrahydrate, about 54.6% by weight iron nitrate nonahydrate, about 0.4% by weight strontium nitrate tetrahydrate and about 0.4% by weight magnesium nitrate hexahydrate; or

about 39.7% by weight iron nitrate nonahydrate, about 34.1% by weight calcium nitrate tetrahydrate, about 25.4% by weight lithium nitrate trihydrate, about 0.4% by weight magnesium nitrate hexahydrate and about 0.4% by weight strontium nitrate tetrahydrate.

7. A PCM according to any preceding claim, wherein the nucleation agent is present in at least about 0.1% by weight of the PCM.

8. A method of preparing a PCM according to any preceding claim comprising:

providing a mixture of calcium nitrate tetrahydrate; and

and a nucleation agent wherein the nucleation agent is a mixture comprised of a combination of:

magnesium nitrate or any hydrate form thereof; and

strontium nitrate or any hydrate form thereof;

and

heating the mixture above the melting transition temperature of one or more of the components and stirring to form a single pourable liquid.

9. A method of preparing a PCM according to claim 8, wherein an anhydrous metal nitrate and/or a metal nitrate hydrate of a lower hydration number than is desired in the final PCM composition is used in place of one or more metal nitrate hydrate(s) with the addition of an amount of water to give the final PCM composition; and optionally

wherein a metal nitrate hydrate with a higher hydration number than is desired in the PCM composition is used, and the excess water removed by or saturated with one or more anhydrous metal nitrate(s) and/or lower hydrate metal nitrate salt(s) to give the final PCM composition.

10. A method of preparing a PCM according to any of claims 8 to 9, wherein a metal nitrate solution is used, and the excess water removed or saturated with one or more anhydrous metal nitrate(s) and/or lower hydrate metal nitrate salt(s) to give the final PCM composition.

11. A method of preparing a PCM according to any of claims 8 to 10, wherein the metal nitrate and/or metal nitrate hydrate has been synthesised or produced by reaction.

12. A method of preparing a PCM according to any of claims 8 to 11, wherein the PCM is formed by neutralisation of nitric acid by the corresponding basic metal salt in the presence of the correct amount of water to achieve a specific composition.

13. A method of preparing a PCM according to any of claims 8 to 12, wherein the PCM is formed by neutralisation of nitric acid by the corresponding metal bases in the presence

of excess water which is then removed or saturated with one or more anhydrous metal nitrate(s) and/or lower hydrate metal nitrate salt(s) to give the final PCM composition.

14. A method of preparing a PCM according to any of claims 8 to 13, wherein any anion other than nitrate is removed by ion exchange, or precipitation with an appropriate metal salt followed by physical separation.

15. A method of preparing a PCM according to any of claims 8 to 14, wherein anhydrous strontium nitrate and water corresponding to about 4 equivalents with respect to the strontium nitrate are added to form the mixture.