METHODS AND SYSTEMS FOR TREATMENT OF LIME TO FORM VATERITE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of US Provisional Application No. 62/981,266, filed February 25, 2020, which is incorporated herein by reference in its entirety in the present disclosure.

BACKGROUND

[0002] Carbon dioxide (CO_2) emissions have been identified as a major contributor to the phenomenon of global warming. CO_2 is a by-product of combustion and it creates operational, economic, and environmental problems. It may be expected that elevated atmospheric concentrations of CO_2 and other greenhouse gases can facilitate greater storage of heat within the atmosphere leading to enhanced surface temperatures and rapid climate change. In addition, elevated levels of CO_2 in the atmosphere may also further acidify the world's oceans due to the dissolution of CO_2 and formation of carbonic acid. The impact of climate change and ocean acidification may likely be economically expensive and environmentally hazardous if not timely handled. Reducing potential risks of climate change requires sequestration and avoidance of CO_2 from various anthropogenic processes.

SUMMARY

[0002a] In an aspect of the present disclosure, there is provided a method to form calcium carbonate comprising vaterite, comprising:

(i) calcining limestone to form lime wherein the lime comprises soft burnt lime and a gaseous stream comprising carbon dioxide;

(ii) dissolving the lime in an aqueous solution comprising N-containing inorganic salt, N-containing organic salt, or combination thereof, to produce an aqueous solution comprising calcium salt; and

(iii) treating the aqueous solution comprising calcium salt with the gaseous stream comprising carbon dioxide to form a precipitation material comprising calcium carbonate, wherein the calcium carbonate comprises vaterite.

[0002b] In another aspect of the present disclosure, there is provided a system to form calcium carbonate comprising vaterite, comprising:

(i) a calcining reactor configured to calcine limestone to form lime wherein the lime comprises soft burnt lime and a gaseous stream comprising carbon dioxide;

WHAT IS CLAIMED IS:

1. A method to form calcium carbonate comprising vaterite, comprising:

(i) calcining limestone to form lime wherein the lime comprises soft burnt lime and a gaseous stream comprising carbon dioxide;

(ii) dissolving the lime in an aqueous solution comprising N-containing inorganic salt, N-containing organic salt, or combination thereof, to produce an aqueous solution comprising calcium salt; and

(iii) treating the aqueous solution comprising calcium salt with the gaseous stream comprising carbon dioxide to form a precipitation material comprising calcium carbonate, wherein the calcium carbonate comprises vaterite.

2. The method of claim 1, wherein the N-containing inorganic salt is selected from the group consisting of ammonium halide, ammonium sulfate, ammonium sulfite, ammonium nitrate, ammonium nitrite, and combination thereof.

3. The method of claim 2, wherein the ammonium halide is ammonium chloride.

4. The method of any one of the preceding claims, wherein the N-containing organic salt is salt of N-containing organic compound selected from the group consisting of aliphatic amine, alicyclic amine, heterocyclic amine, and combination thereof.

5. The method of any one of the preceding claims, wherein the aqueous solution further comprises ammonia; and/or molar ratio of the N-containing inorganic salt or N-containing organic salt : lime is between 0.5:1-2:1 or 2.5:1.

6. The method of any one of the preceding claims, wherein the dissolving step is under one or more dissolution conditions selected from the group consisting of temperature between 30-200^{o}C; pressure between 0.1-10 atm; N-containing salt wt% in water between 0.5-50%; and combination thereof.

7. The method of any one of the preceding claims, wherein the dissolving step further produces a gaseous stream comprising ammonia and the method further comprises (iv) recovering the gaseous stream comprising carbon dioxide and the gaseous stream comprising ammonia and subjecting the gaseous streams to a cooling process to condense a second aqueous solution comprising ammonium bicarbonate, ammonium carbonate, ammonia, ammonium carbamate, or combination thereof; and (v) treating the aqueous solution comprising calcium salt with the second aqueous solution comprising ammonium bicarbonate, ammonium carbonate, ammonia, ammonium carbamate, or combination thereof to form the precipitation material.

8. The method of claim 7, wherein the gaseous stream comprising ammonia further comprises water vapor and/or further comprises between 20-90% water vapor.

9. The method of claim 7 or 8, wherein the cooling process is under one or more cooling conditions comprising temperature between 0-100^{o}C; pressure between 0.5-50 atm; pH of the aqueous solution between 8-12; ratio of CO_2:NH_3 between 0.1:1-20:1; or combination thereof.

10. The method of any one of the preceding claims, wherein the treating step is under one or more precipitation conditions selected from the group consisting of pH of the aqueous solution of between 7-9, temperature of the solution between 20-60^{o}C, residence time of between 5-60 minutes, and combination thereof.

11. The method of any one of the preceding claims, wherein the aqueous solution comprising calcium salt further comprises solid.

12. The method of claim 11, further comprising separating the solid from the aqueous solution before the treatment step by filtration and/or centrifugation.

13. The method of claim 12, further comprising adding the solid back to the precipitation material as filler.

14. The method of claim 11, wherein the solid is not separated from the aqueous solution and the aqueous solution is subjected to the treatment step to produce the precipitation material further comprising the solid.

15. The method of any one of the claims 11-14, wherein the solid comprises silicate, iron oxide, alumina, or combination thereof.

16. The method of claim 14 or 15, wherein the solid is between 1-40 wt% in the precipitation material.

17. The method of any one of the preceding claims, further comprising removing and optionally recovering residual N-containing salt from supernatant aqueous solution and/or removing and optionally recovering residual N-containing salt from the precipitation material.

18. The method of claim 17, further comprising recovering the residual N-containing salt from the supernatant aqueous solution using recovery process selected from the group consisting of thermal decomposition, pH adjustment, reverse osmosis, multi-stage flash, multi-effect distillation, vapor recompression, distillation, and combination thereof.

19. The method of claim 17, further comprising heating the precipitation material between 300-360^{o}C to evaporate the residual N-containing salt from the precipitation material with optional recovery by condensation of the N-containing salt.

20. The method of any one of the preceding claims, wherein the vaterite is stable vaterite or reactive vaterite.

21. The method of any one of the preceding claims, wherein the precipitation material comprises reactive vaterite and the method further comprises adding water to the precipitation material comprising reactive vaterite and transforming the reactive vaterite to aragonite wherein the aragonite sets and hardens to form cement, cementitious product, or non-cementitious product.

22. The method of any one of the preceding claims, further comprising adding an additive to the aqueous solution or to the precipitation material, wherein the additive is selected from the group consisting of fatty acid ester, sodium decyl sulfate, lauric acid, sodium salt of lauric acid, urea, citric acid, sodium salt of citric acid, phthalic acid, sodium salt of phthalic acid, taurine, creatine, dextrose, poly(n-vinyl-1-pyrrolidone), aspartic acid, sodium salt of aspartic acid, magnesium chloride, acetic acid, sodium salt of acetic acid, glutamic acid, sodium salt of glutamic acid, strontium chloride, gypsum, lithium chloride, sodium chloride, glycine, sodium citrate dehydrate, sodium bicarbonate, magnesium sulfate, magnesium acetate, sodium polystyrene, sodium dodecylsulfonate, poly-vinyl alcohol, and combination thereof.

23. The method of any one of the preceding claims, wherein the vaterite is unimodal, bimodal, or multimodal distribution of a particulate composition with an average particle size of between 0.1-100 micron.

24. The method of any one of the preceding claims, further comprising blending the precipitation material with Ordinary Portland Cement (OPC), aggregate, or combination thereof.

25. The method of any one of the preceding claims, further comprising mixing the precipitation material with an admixture selected from the group consisting of set accelerator, set retarder, air-entraining agent, foaming agent, defoamer, alkali-reactivity reducer, bonding admixture, dispersant, coloring admixture, corrosion inhibitor, damp-proofing admixture, gas former, permeability reducer, pumping aid, shrinkage compensation admixture, fungicidal admixture, germicidal admixture, insecticidal admixture, rheology modifying agent, finely divided mineral admixture, pozzolan, aggregate, wetting agent, strength enhancing agent, water repellent, reinforced material, and combination thereof.

26. The method of claim 25, wherein the reinforced material is a fiber made of zirconia, aluminum, glass, steel, carbon, ceramic, grass, bamboo, wood, fiberglass, synthetic material, or combination thereof.

27. A system to form calcium carbonate comprising vaterite, comprising:

(i) a calcining reactor configured to calcine limestone to form lime wherein the lime comprises soft burnt lime and a gaseous stream comprising carbon dioxide;

(ii) a dissolution reactor configured for dissolving the lime in an aqueous N-containing salt solution to produce an aqueous solution comprising calcium salt; and

(iii) a treatment reactor configured for treating the aqueous solution comprising calcium salt with the gaseous stream comprising carbon dioxide to form a precipitation material comprising calcium carbonate, wherein the calcium carbonate comprises vaterite.