Energetic of Hydrothermal Synthesis

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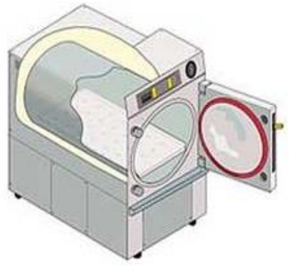
Objectives and Hypothesis

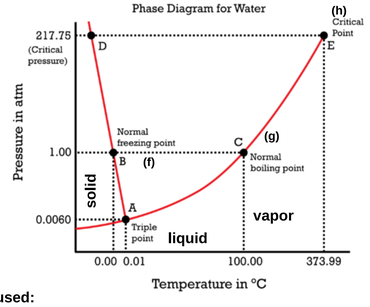
I. Objectives: determine the rationale behind using low-temperature processing (Hydrothermal) vs high temperature processing (Pyrothermal) for energy efficient materials production.

II. Hypothesis: hydrothermal processing enables low temperature which subsequent to low energy creating more sustainable process. However the consideration of other ingredients for example the solvent is needed in the energy accounting to have a full energetic sum.

Introduction and Motivation

- Traditional manufacturing create materials around 1000°C using Pyrothermal processing (solid-state reactions).
- There is another way to make materials at low temperature and that way is called Hydrothermal.
- Hydrothermal method exploits the properties of water dissolution of minerals to crystallize inorganic materials and it happens a thousand degrees lower than solid-state.
- A sustainable process meet the needs of the present work without compromising the needs of future ones.
- Low-temperature hydrothermal synthesis use the properties of water under different conditions to produce crystalline substances conditions inside of an autoclave.
- Embodied energy is the required energy to produce a material from its raw state.





Selected examples to demonstrate how hydrothermal is used:

(f) Curing cement T = 25°C, P ≈ 1.00 atm

(g) Aluminum Oxide (Al_2O_3) T = 200°C, P ≈ 17.7 atm

(g) LFP batteries ($LiFePO_4$) T = 200°C, P ≈ 17.7 atm

(h) Recycled CFRP T = 400°C, P ≈ 276.34 atm

(h) Synthesizing cement T= 400°C, P ≈ 276.34 atm

Methodology

Literature review to understand hydrothermal synthesis and study the energetic requirements for processes to answer the following questions;

- If the energetics of hydrothermal synthesis are good, why its not more prevalent?
- Can low-temperature hydrothermal synthesis be low energy/sustainable process? If not, can still used?
- How does the embodied energy of raw materials affect total process energetics?

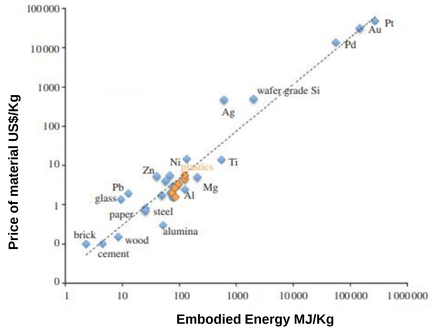
Results and Conclusions

- The sustainability of low-temperature hydrothermal synthesis depends on the material to be created and his embodied energy so it can not be used on the creation of every material.

[1]

$$E_T = Q_p e_p + Q_s e_s$$

[2]Embodied energy (Eq.1); total energy input corresponding to synthesized and processed material E_T is the total energy for a given material, Q_p e_p are the demand of the primary production material and his embodied energy and Q_s e_s are the the demand of the secondary production material and his embodied energy.



[2]Fig. 1 This graph represents how the embodied energy is directly proportional to the cost of the last product.

- There are materials that allows to be created by both methods like Calcium Silicate and the embodied energy is the determinant of which process is more sustainable.

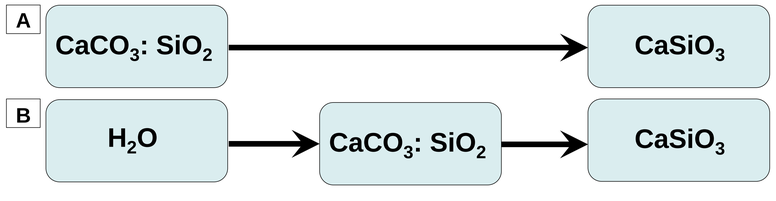


Fig. A. Illustrate the pyrothermal process to create Calcium Silicate. Fig. B. Illustrate the hydrothermal process to create Calcium Silicate.

- For the hydrothermal method its necessary to heat the mixture, also heat and vaporize water [3](depending on the quantity of water used, this step can require more energy than the whole solid-state process).
- For the pyrothermal method its only necessary to heat the mixture at high temperatures (700-1000°C).
- A way to reduce the energy requirements is decreasing the temperature changes during the process.
- [3]Another way to reduce the energy requirements is using waste products and waste energy.

Future Work

- Numerically calculate (perform life-cycle analysis) on energetics of hydrothermal synthesis to be able to calculate the additional energetics of hydrothermal systems.
- Numerically calculate (techno-economic analysis) on hydrothermal and pyrothermal processes on additional hydrothermal systems:

Carbonate Cement (CaSiO3) by supercritical, Hydrothermal (non-super), Hydrothermal vapor and Pyrothermal.

References

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