Production of Lithium Iron Phosphate (LFP) using sol-gel synthesis

Techno-economic analysis of the scale-up of LFP production

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Abstract

Lithium Iron Phosphate (LFP) battery production has long been dominated by China but that is set to change due to a number of patents expiring in 2022. This opens the possibility of UK based manufacturing and will help to **meet the rising demand for energy storage** as the UK moves to a net zero future. The cathode material of a lithium-ion battery can account for approximately 40-50% of the total battery cost [1], however, with the current **increase in lithium prices**, this is now closer to 60%. This project explores the production of LFP using **sol-gel deposition** which is shown to produce product with increased homogeneity. A **process flow diagram** has been devised and **reactor conditions** including **volume, batch time** and **conversion** explored for the **scale-up** of the process. Cost analysis is done to see the effects of the changing markets.

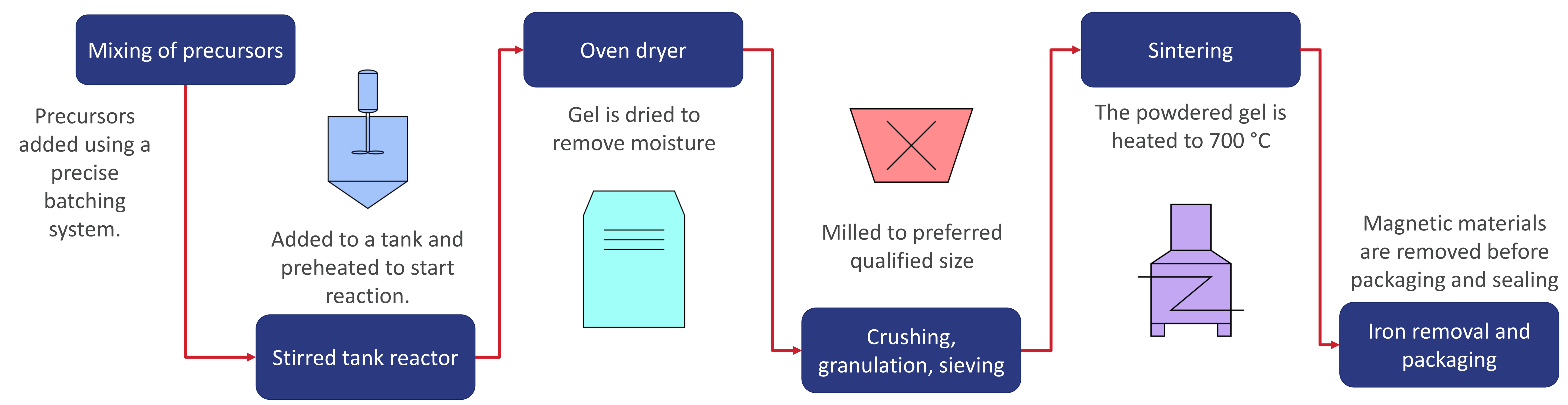
Motivation

- LFP is hailed due to its **high theoretical capacity** (170 mAh/g), high thermal and **chemical stability**, **lower cost** compared to other types and **non-toxicity** [2].
- **Applications** of LFP include EVs, hybrid electric vehicles (HEVs), electric bicycles and power tools.
- LFP is **cobalt free.**
- LFP is expected to take up 40% of the global battery market by 2030.

Scope

The flow diagram outlines the process for large scale production in which **LiOH**, **$FeSO_4$** and **H_3PO_4** are used as precursors. The reactor parameters consider the system from the stirred tank reactor to the sintering step.

Flow diagram



Methods

- **Conversion** was calculated as a function of the **heat of reaction** and **specific heat capacities** of the reactants.
- Using a **batch reactor system** coupled with a **3D diffusion model of kinetics** [3] provided a realistic basis for the system.
- The batch reactor **design equation** was used to calculate volume and batch time a capacity plant of **20 GWh.** This was then explored for different capacity plants of 0.5-20 GWh.

$$t = N_{A0} \cdot \int_0^x \frac{dX}{-r_A \cdot V}$$

- **Costing** of the sol-gel process is carried out. This is used to inform what effect **fixed cost**, **raw materials, natural gas as fuel** and the reactor volume has on the final LFP **cost of production**

Results and Conclusions

- Figure 1 depicts that the maximum conversion reached after the final sintering step is 60%.
- During scale up, batch time decreases as reactor volume increases as shown in Figure 2, therefore increasing costs.
- For a 20 GWh capacity plant, a larger volume of reactor of 150m³ is needed to achieve sensible total batch times of approx. 40 hours for the process.
- Figure 3 shows that price fluctuations of +/- 20% of LiOH followed by natural gas has the greatest effect on the final LFP cost of production. FeSO4 was neglected as it had negligible effect.
- In total, for a 20GWh plant, the cost of LFP is $9.76 per kg produced.
- With these calculations, a 20GWh plant is feasible and will help meet the UK demand of producing 10 giga-factories by 2040, as is predicted by The Faraday Institution [4].

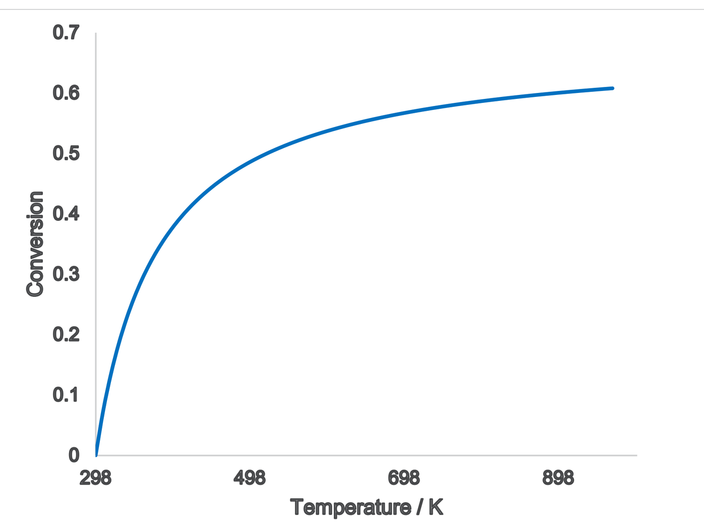


Figure 1: Conversion against temperature graph for the conversion of LiOH to LFP.

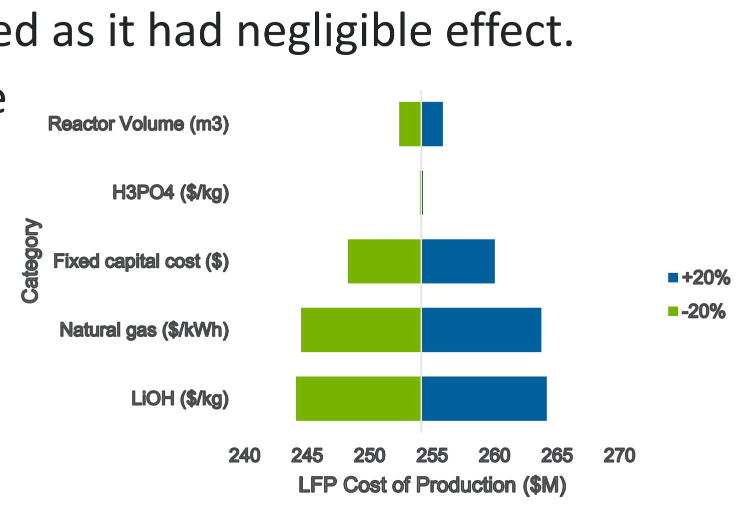


Figure 3: Sensitivity analysis of the cost of production of LFP based on various parameters.

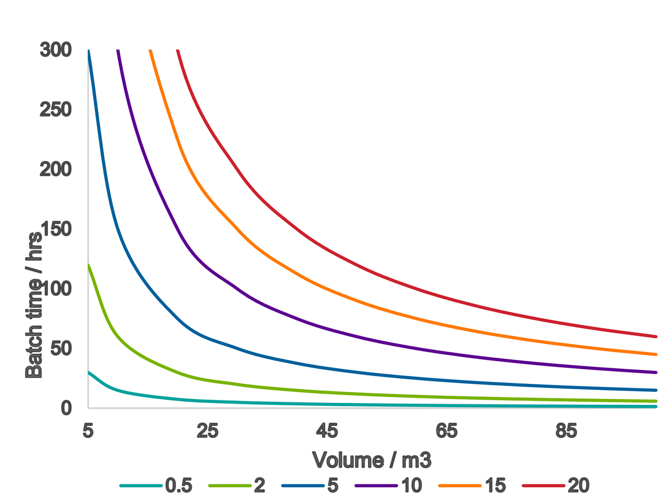


Figure 2: Sensitivity analysis of the cost of production of LFP based on various parameters.

Impact / Next steps

- Using **computer modelling** saves **time, reduces costs** and **environmental impact** during scale up.
- Next step is to conduct **in-depth design** of other **unit operations** which could help facilitate LFP production in the UK.
- Consider what the total **energy demand** of production will be and how much of that can be sourced from **renewable sources**.
- **Environmental impacts** and **lifecycle analysis** of LFP, particularly its precursors which could be regenerated from spent batteries.
- Explore commercial value of other production methods such as **solvo/hydrothermal**.

References

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4. "UK Electric Vehicle and Battery Production Potential to 2040", *The Faraday Institution*, 2022. [Online]. Available: https://www.faraday.ac.uk/ev-economics-study-2022/. [Accessed: 08- Sep- 2022].

Intern bio

Aiman is entering her 4th year of Chemical Engineering at The University of Sheffield.

My interests lie in energy and this project has sparked my interest in battery energy storage and introduced me to new modelling techniques. I am interested in helping to decarbonise the world through my work and hope to be a part of engineering a sustainable future.

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