$FeCo_2O_4$ as an Anode Material for Lithium Ion Batteries

Chelsea Wong Jiahui
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Source: http://www.mythosetregia.com/2016/11/dead-batteries.html

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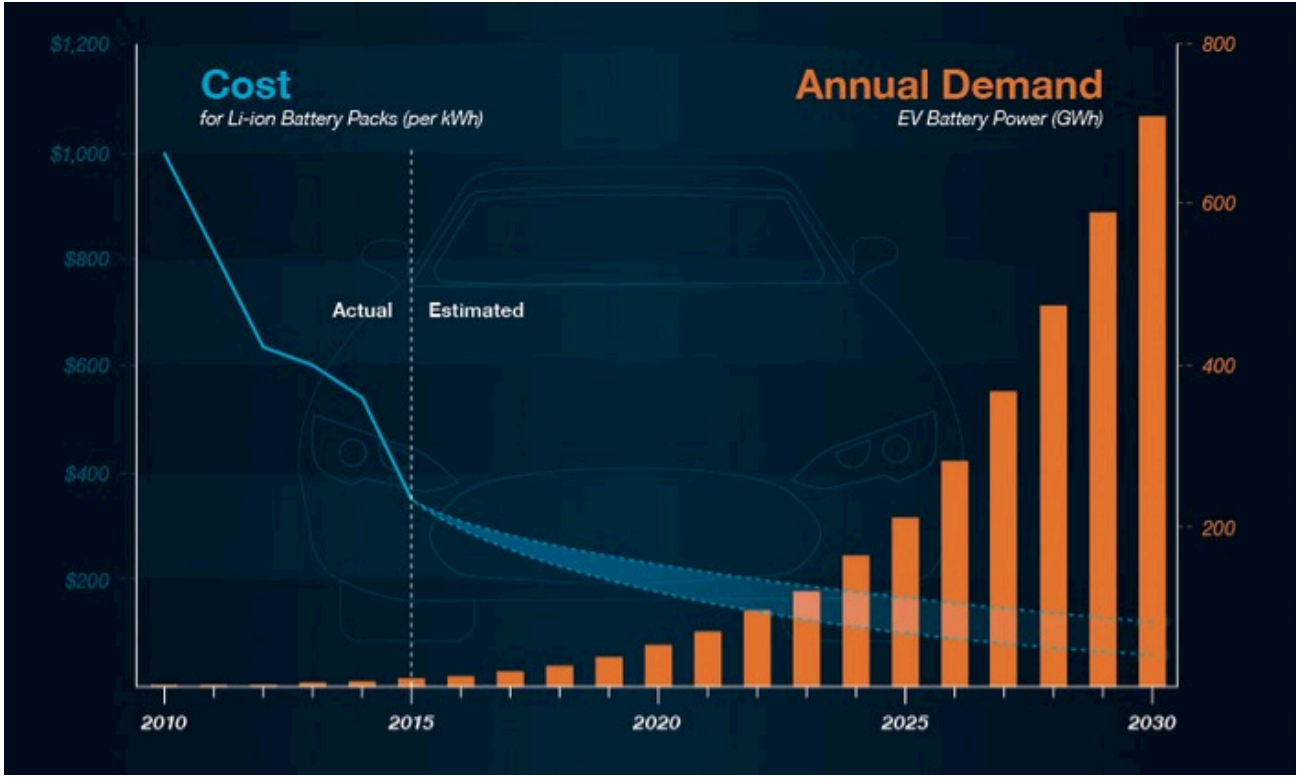
What are Lithium Ion Batteries (LIBs) good for?

Commonly used in portable electronic appliances due to their:

- High energy density
- High power
- Ability to go through multiple charge-discharge cycles

Source: https://www.linkedin.com/pulse/my-quest-towards-finding-right-combination-electronic-asghar

What are Lithium Ion Batteries (LIBs) good for?



Source: https://www.valuewalk.com/2016/08/surging-demand-lithium-ion-batteries/

What are some disadvantages of LIBs?

- Low capacity retention (High capacity fade)
- High production cost
- Unsafe

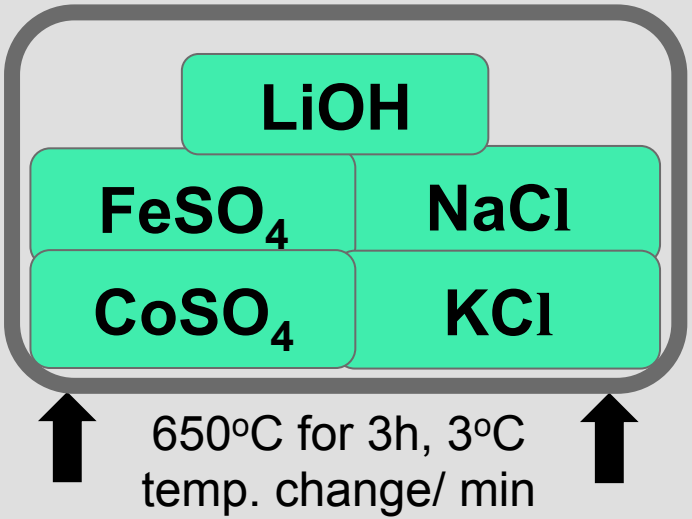
Research Goal

- Tackle the problem of low capacity
- Create an anode that has a higher capacity than Graphite (Commercial anode)

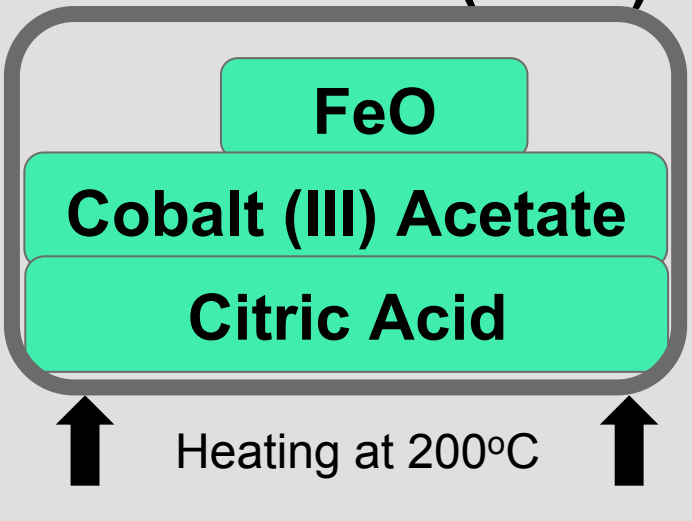
Why $FeCo_2O_4$?

- Theoretical capacity of 789mAh/g
- Earlier work showed $FeCo_2O_4$ synthesised by the urea combustion method has an initial capacity of 827 mAh/g
- Use low cost methods:
  - Molten Salt Method (MSM)
  - Citric Acid Combustion Method (CAC)

Synthesis of $FeCo_2O_4$ by Molten Salt Method (MSM)



Synthesis of $FeCo_2O_4$ by Citric Acid Combustion (CAC)



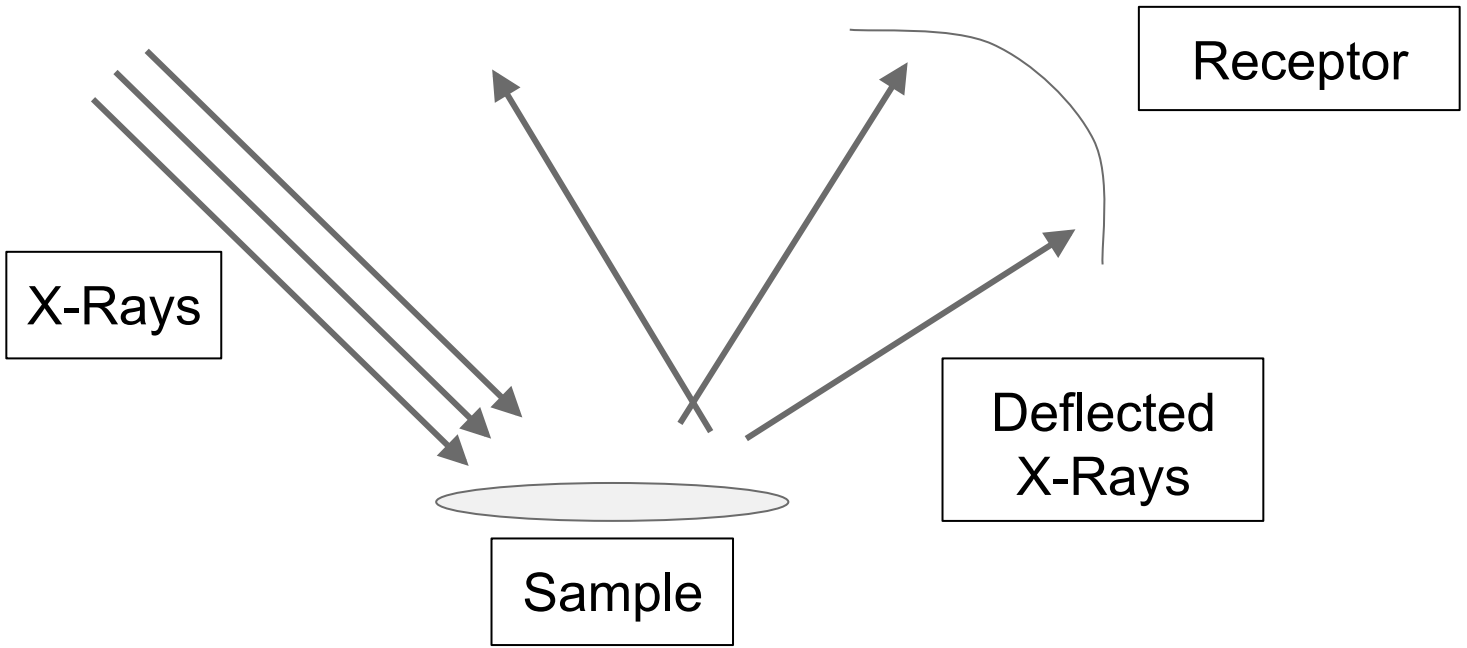
Characterisation

X-Ray Diffraction (XRD)
Phases

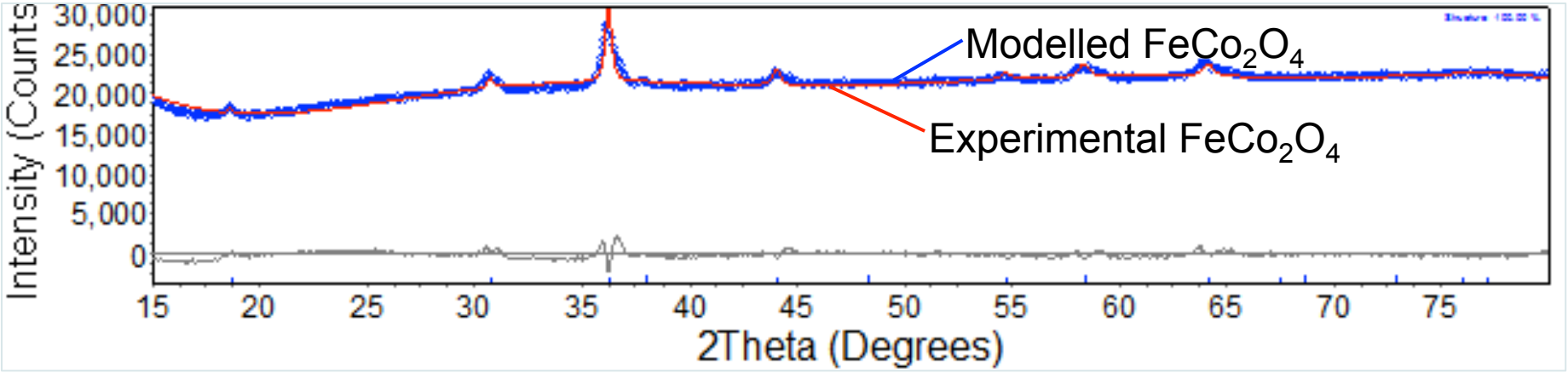
Scanning Electron Microscopy (SEM)
Surface Morphology

Characterisation

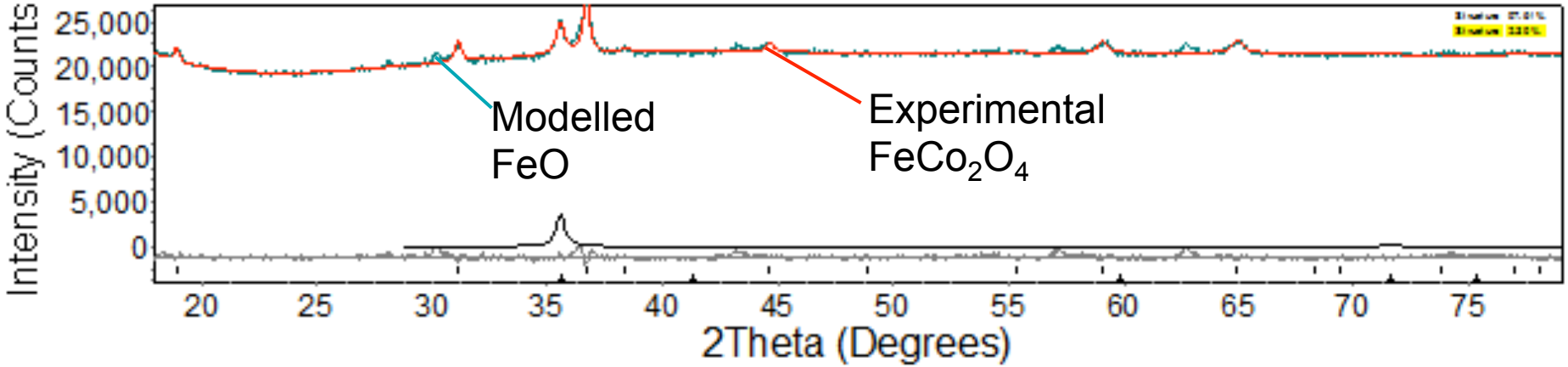
- X-Ray Diffraction (XRD) → Phases

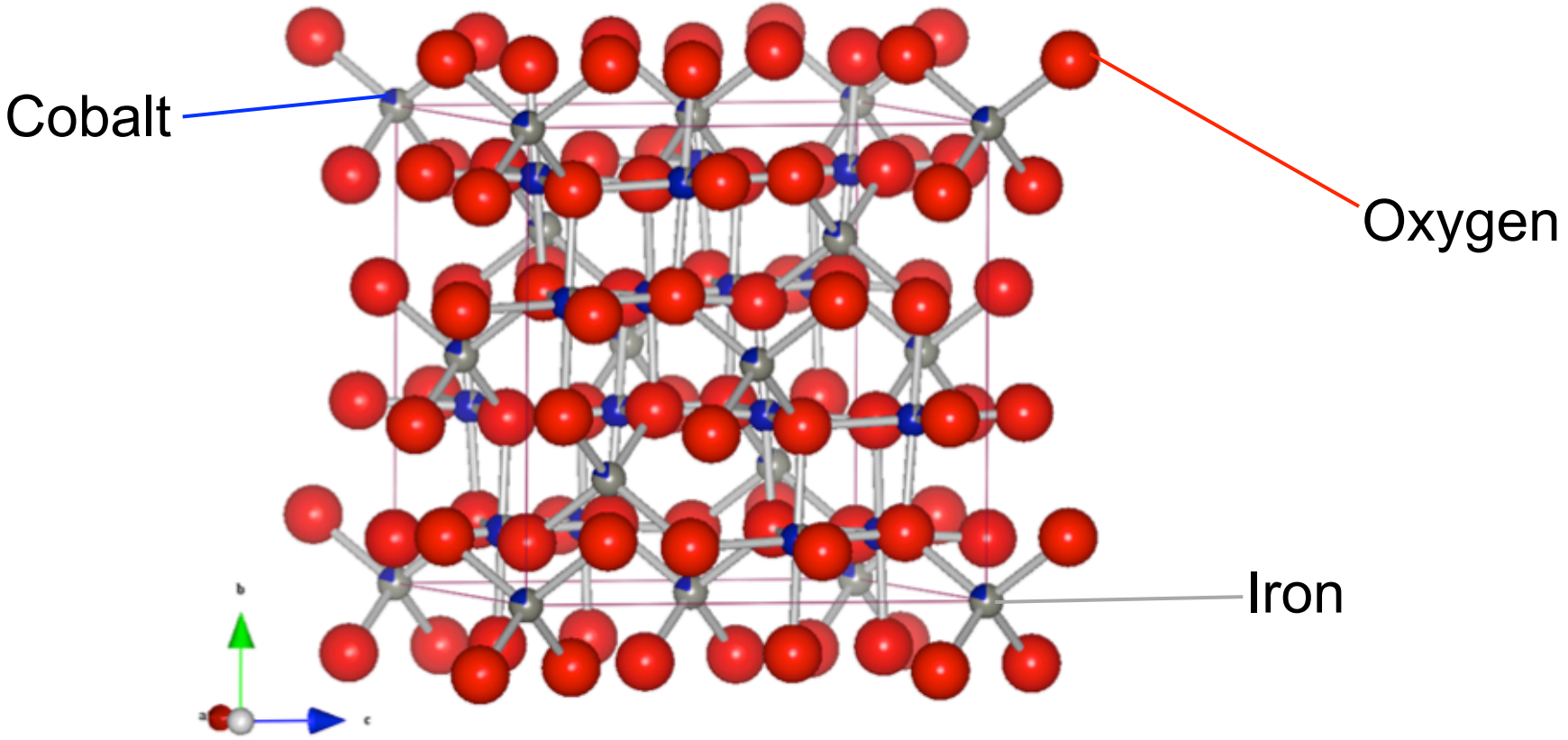


XRD Pattern of $FeCo_2O_4$ synthesised by MSM



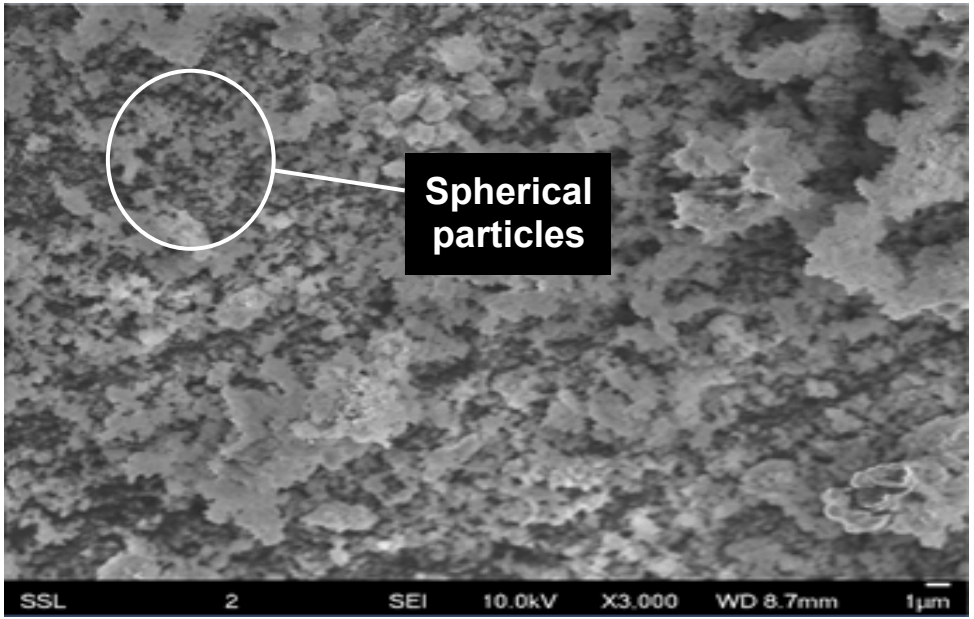
XRD Pattern of $FeCo_2O_4$ synthesised by CAC




Cobalt
Oxygen
Iron
b
a
c

Characterisation

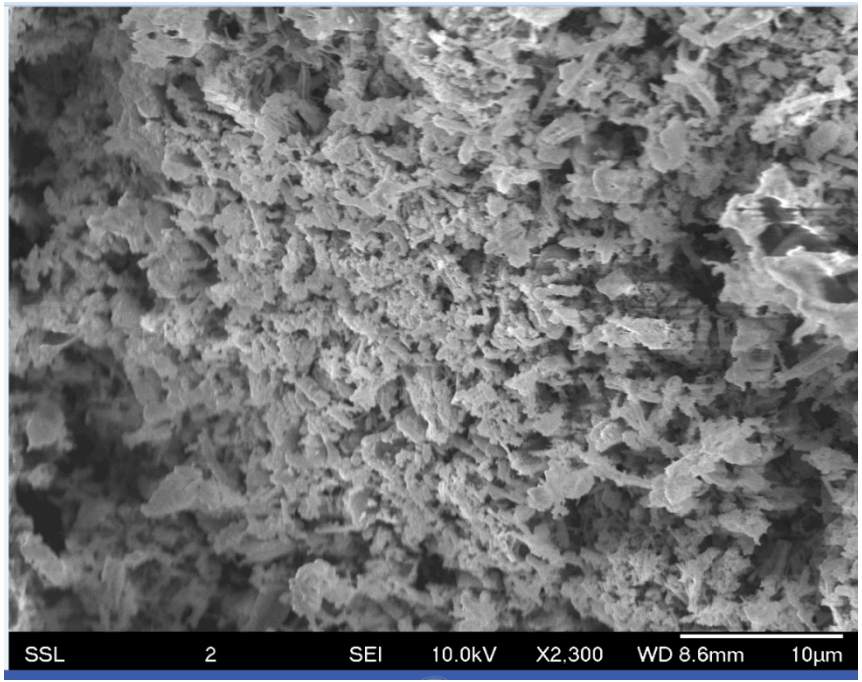
- Scanning Electron Microscopy (SEM)
- Identify structure and surface morphology

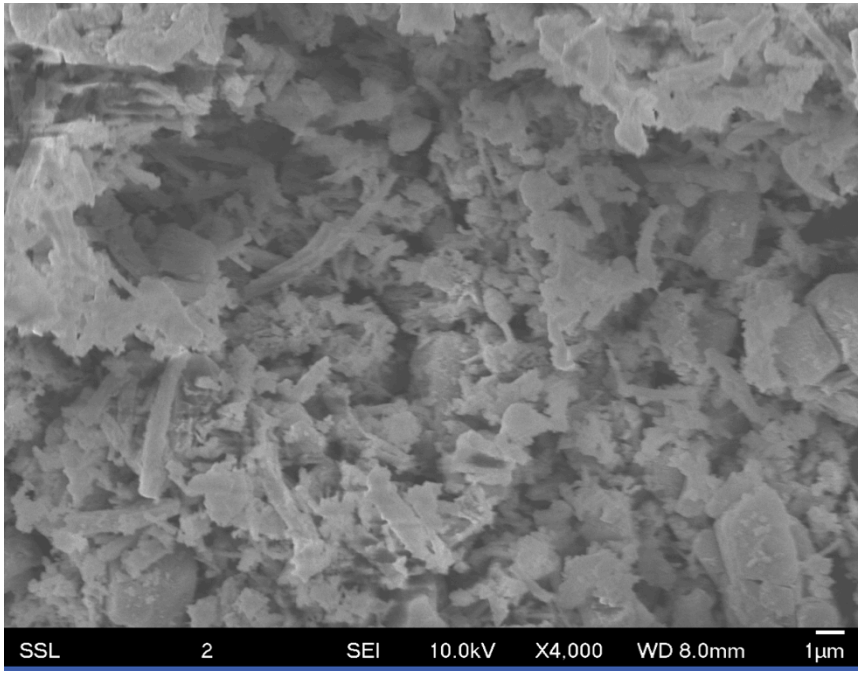


Molten Salt Method

- Nearly spherical particles can be seen.
- Average size of the particles is around 0.5 micrometers

Citric Acid Combustion





- Porous structure
- Fusion of irregular particles

Making of Slurry

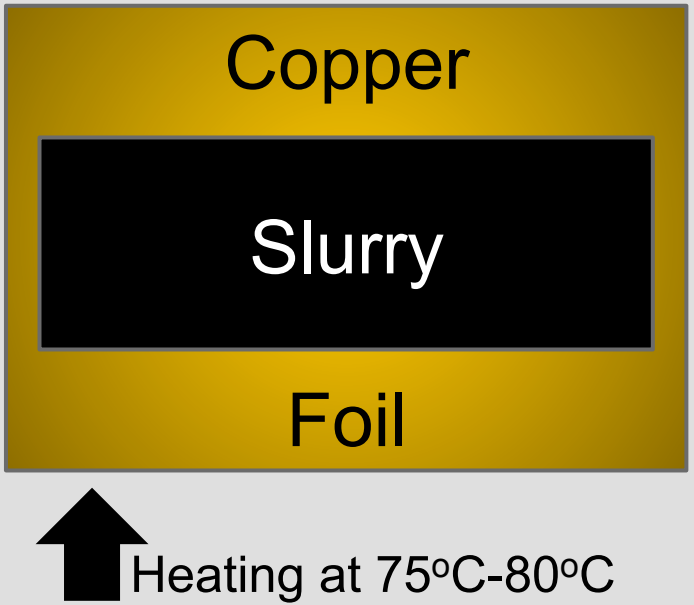
$FeCo_2O_4$ +

NMP +

Super P Carbon +

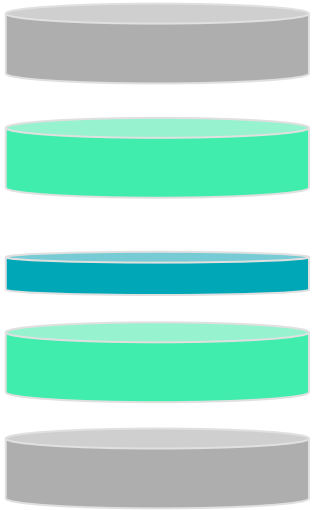
PVDF Binder

Fabrication of Anode



Coin Cell Pressing

Coin cell was assembled and pressed in argon filled glove box



Top Lid

Lithium Metal

Polymer Separator

$FeCo_2O_4$

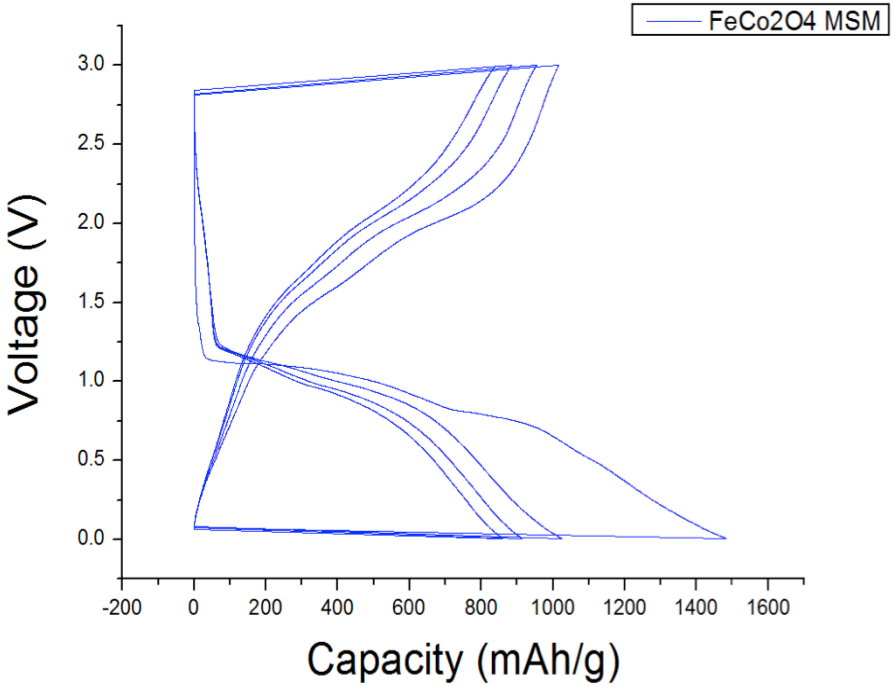
Coin Cell Cup (CR2016)

Battery Testing

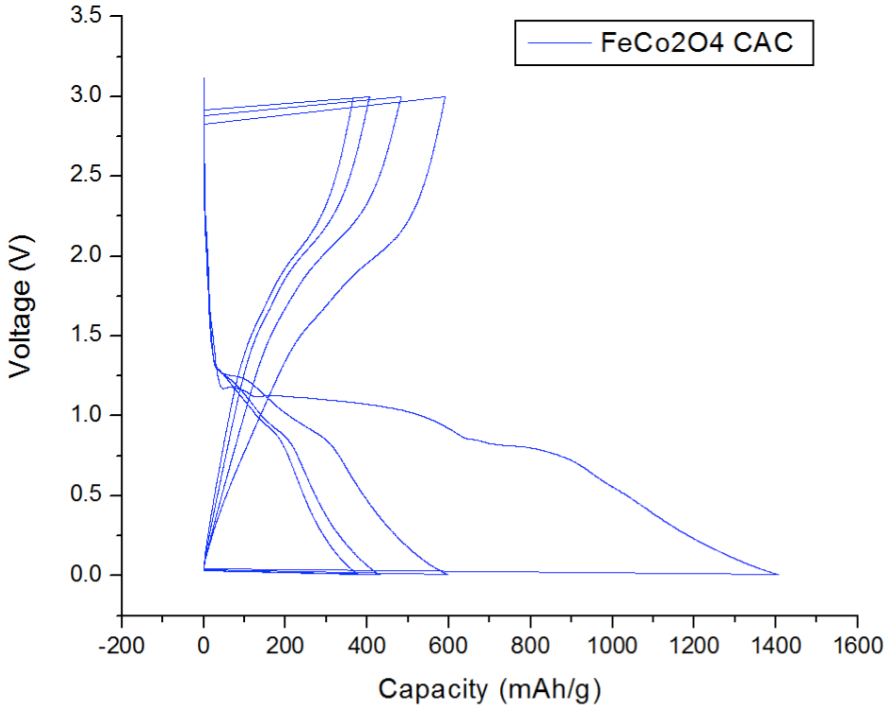
Galvanostatic Cycling

Electrochemical Impedance Spectroscopy

Graph of Voltage against Capacity for 1st, 2nd, 5th and 10th Charge-Discharge cycles (MSM)

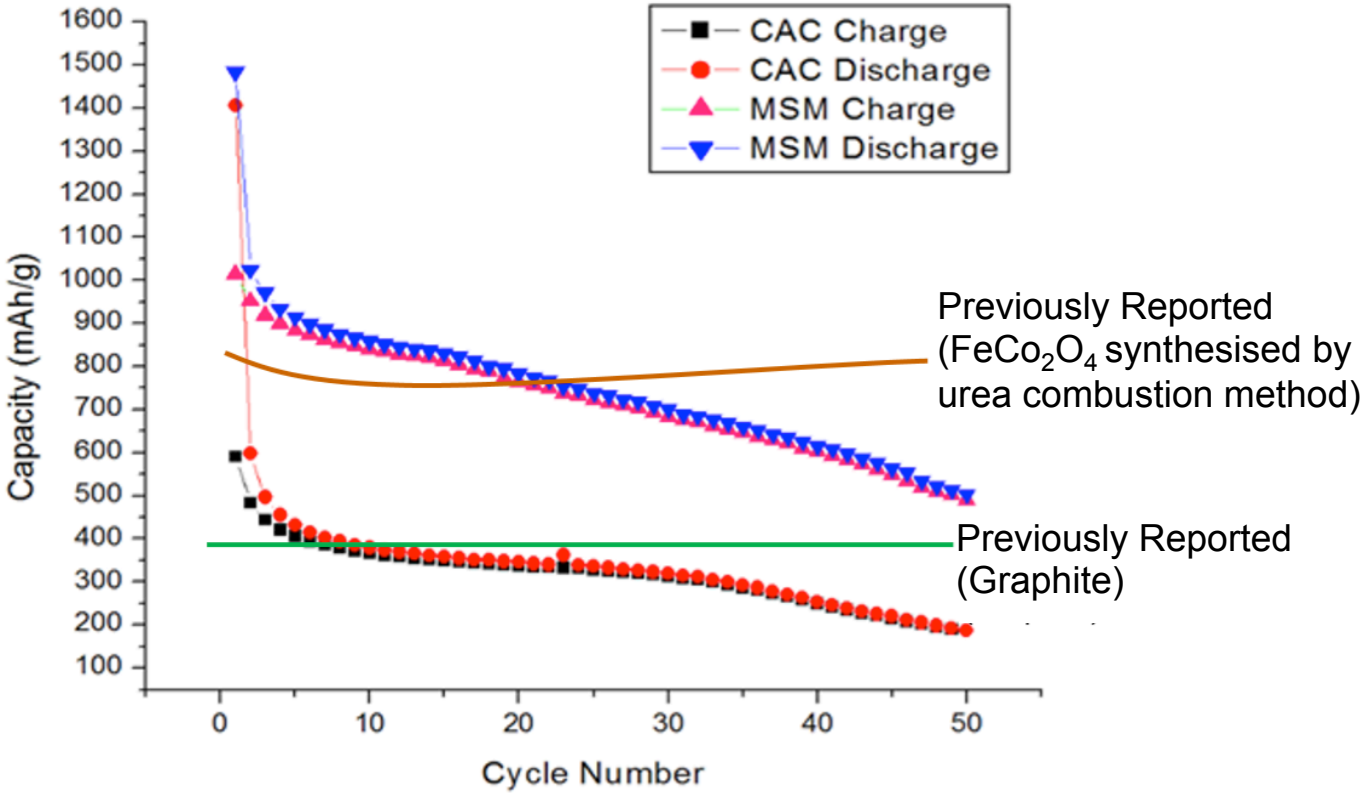


Cycle Number (Step)	Previously Reported ($FeCo_2O_4$)	1 (Discharge)	2 (Discharge)
Capacity / mAh/g	827	≈1490	≈1025
Cycle Number (Step)	Previously Reported (Graphite)	5 (Discharge)	10 (Discharge)
Capacity / mAh/g	372	914.05	859.09

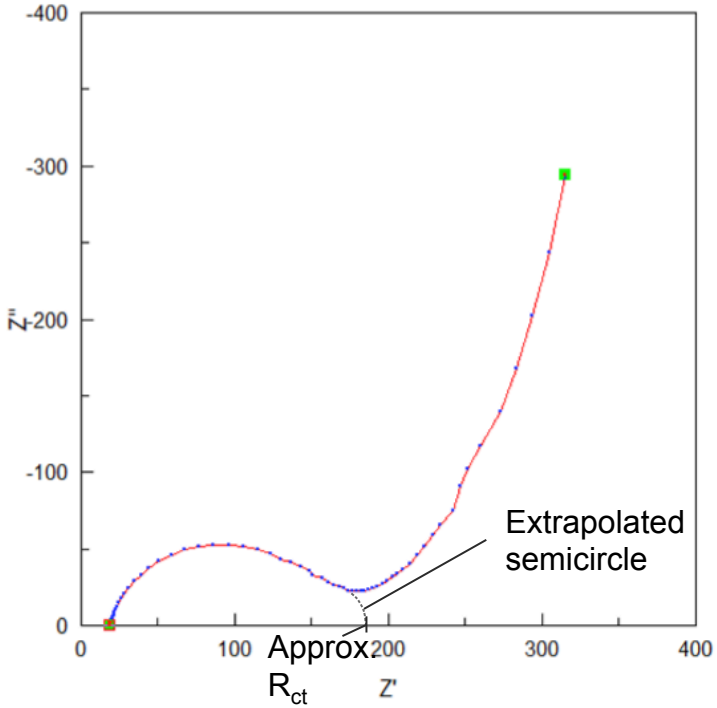


Graph of Voltage against Capacity for 1st, 2nd, 5th and 10th Charge-Discharge cycles (CAC)

Cycle Number (Step)	Previously Reported ($FeCo_2O_4$)	1 (Discharge)	2 (Discharge)
Capacity / mAh/g	827	≈1400	598.55
Cycle Number (Step)	Previously Reported (Graphite)	5 (Discharge)	10 (Discharge)
Capacity / mAh/g	372	431.15	379.45

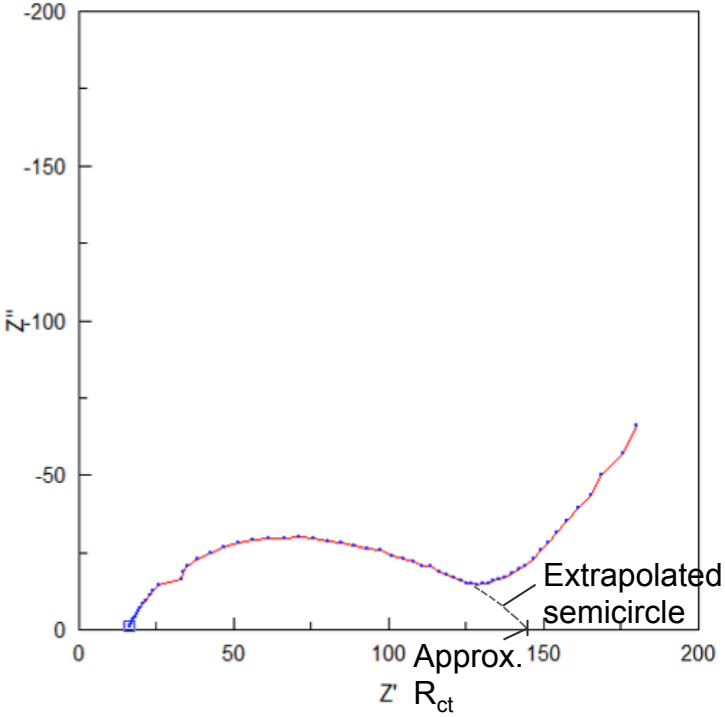


Graph of Charge-Discharge Capacities against cycle number and previously reported capacity graphs (MSM, CAC, previously reported by Sharma et. al and graphite by Li Jun et. al)



Nyquist Plot of impedance on complex plane (MSM)

R_{ct} is approximately 180Ω



Nyquist Plot of impedance on complex plane (CAC)

R_{ct} is approximately 150Ω

Conclusion

- Successful synthesis and characterisation of $FeCo_2O_4$
- Both have potential to replace graphite
  - High 1st cycle capacity, but high mean capacity fade and R_{ct}
- MSM proved to be a more effective method of synthesis
  - MSM had much higher cyclic stability than by CAC
  - Could be due to structural and morphological differences affected by purity of the sample

Future Work

- Investigate the usage of different methods or metal salts to synthesise $FeCo_2O_4$ (Chemical/ Physical)
- Investigate the effect of varying the temperature of melting the reactants of $FeCo_2O_4$
- Investigate why $FeCo_2O_4$ could have an experimental capacity so much greater than previously reported
- Investigate the introduction of a carbon coating on the anode

Acknowledgements

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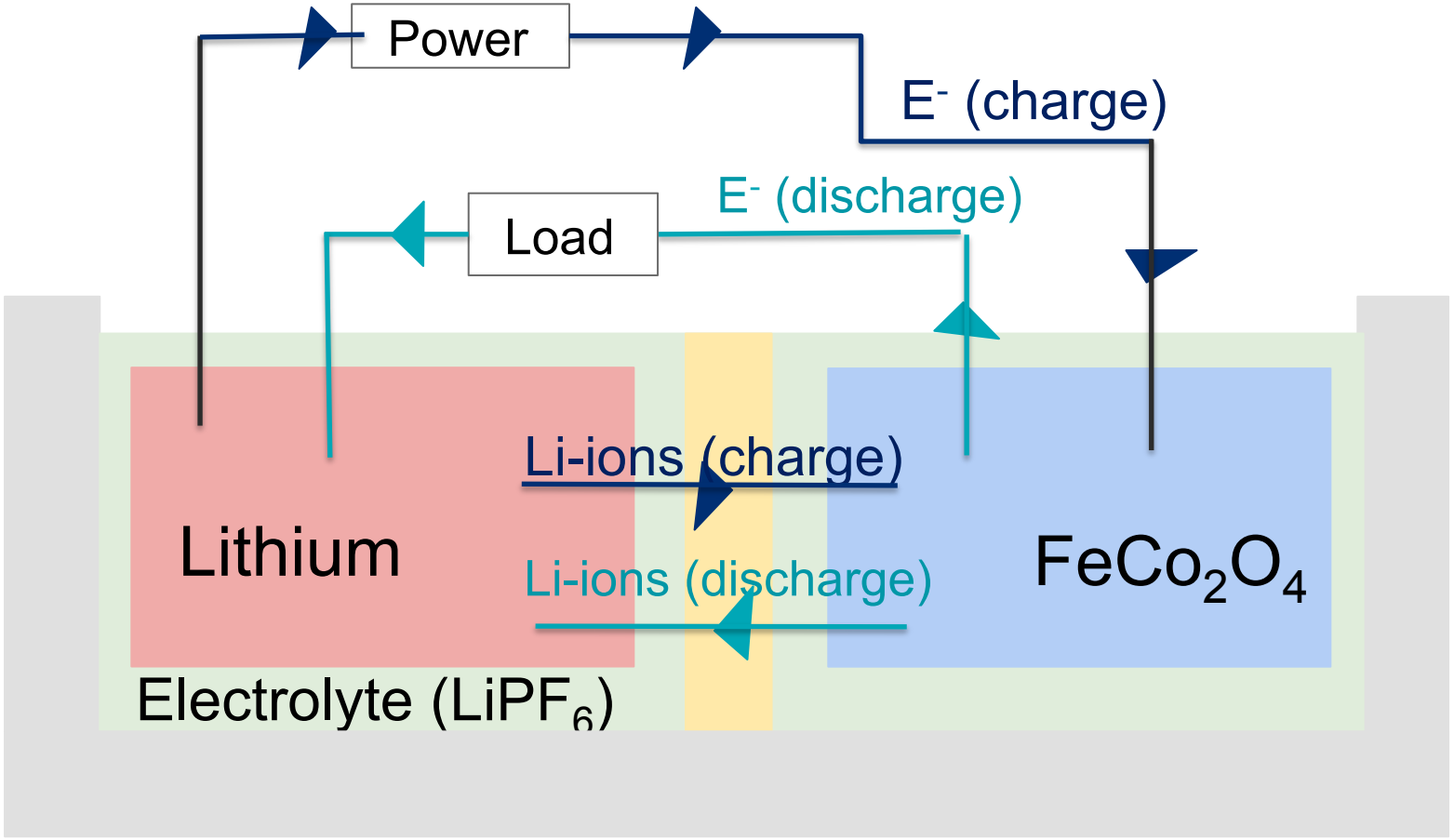
- All members of the Advanced Batteries Lab and National Junior College

Key References

- Reddy, M. V., Rao, G. V., & Chowdari, B. V. (2013). Metal Oxides and Oxysalts as Anode Materials for Li Ion Batteries. *Chemical Reviews,113*(7), 5364-5457. doi:10.1021/cr3001884
- Darbar, D., Reddy, M., Sundarrajan, S., Pattabiraman, R., Ramakrishna, S., & Chowdari, B. (2016). Anodic electrochemical performances of MgCo2O4 synthesized by oxalate decomposition method and electrospinning technique for Li-ion battery application. *Materials Research Bulletin,73*, 369-376. doi:10.1016/j.materresbull.2015.09.025
- Sharma, Y., Sharma, N., Subbarao, G., & Chowdari, B. (2008). Studies on spinel cobaltites, $FeCo_2O_4$ and $MgCo_2O_4$ as anodes for Li-ion batteries. *Solid State Ionics,179*(15-16), 587-597. doi:10.1016/j.ssi.2008.04.007
- Reddy, M., Tung, B. D., Yang, L., Minh, N. D., Loh, K., & Chowdari, B. (2013). Molten salt method of preparation and cathodic studies on layered-cathode materials Li(Co0.7Ni0.3)O2 and Li(Ni0.7Co0.3)O2 for Li-ion batteries. *Journal of Power Sources, 225, 374-381. doi:10.1016/ j.jpowsour.2012.07.009*
- Li, J., Murphy, E., Winnick, J., & Kohl, P. (2001). Studies on the cycle life of commercial lithium ion batteries during rapid charge–discharge cycling. *Journal of Power Sources,102*(1-2), 294-301. doi:10.1016/s0378-7753(01)00821-7

Thank you!


Power
E- (charge)
E- (discharge)
Load
Li-ions (charge)
Lithium
Li-ions (discharge)
FeCo2O4
Electrolyte (LiPF6)