The Decaying Battery

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Introduction

A battery has an important function in our everyday lives as it powers our phones, computers, laptops, and cars, it also has a simple function, charging and discharging. Over time the battery decays from the amount of discharging and charging it has done. An example of this could be your phone, when you first get it, it wouldn't need to be charged for about 2 - 4 days. But after a year, you'd notice that your phone needs to be charged nearly every day. This is because of the structural degradation of the battery. And it is caused when active ions are inserted into an intercalation material (battery) causing a change in the materials lattice structure and parameters. These structural transformations generate volume changes and strain in the material. With repeated intercalation, the internal stress and changes in volume weaken the structural integrity of the materia, in turn causing things such as micro cracks and ultimately failing.

Objective & Impact of Professor's Research

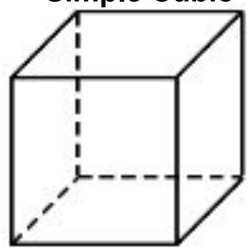
My professor's research focuses on figuring out how to mitigate structural disgregation so batteries can last longer. My mentor is currently working on a new material at an atomic level that will allow better compatibility with the cathode material of a battery and the ions. This will reduce the volume change after intercalation, reducing the coherency stress on the cathode. When this is done it will lead to batteries being more efficient as they can last longer, saving people money and time as they won't have to buy batteries as often for things like remotes, phones, etc.

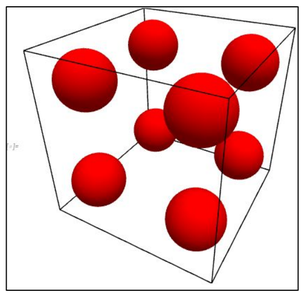
Skills Learned

After starting SHINE I learned some new skills that I will definitely use in the future. One skill I learned was how to make physical and software models with Mathematica that will enable me to get a basic understanding of how atomic structures and work appear. I also gained the skills of identifying the components of a battery and their purposes.

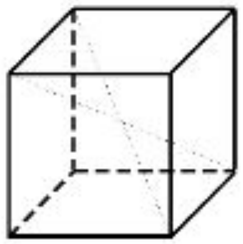
Basic Lattice **Mathematica** (Simple Visualizations)

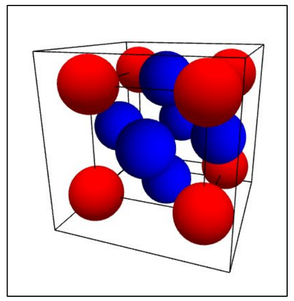
SC
Simple Cubic



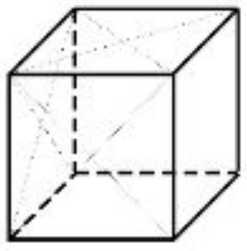


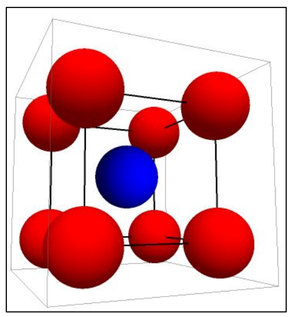
BCC
Body Centered Cubic





FCC
Face Centered Cubic





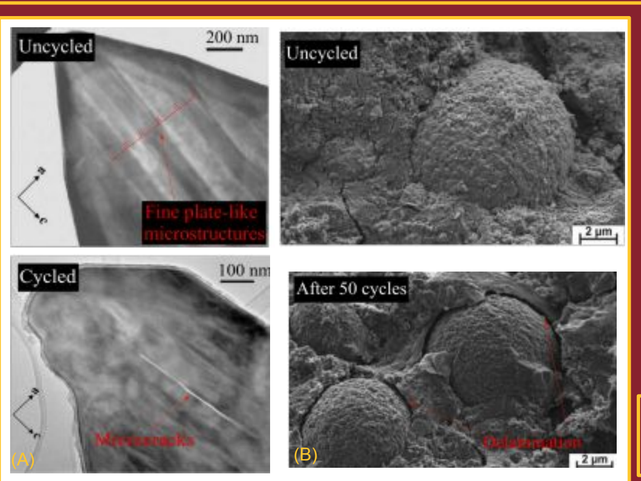
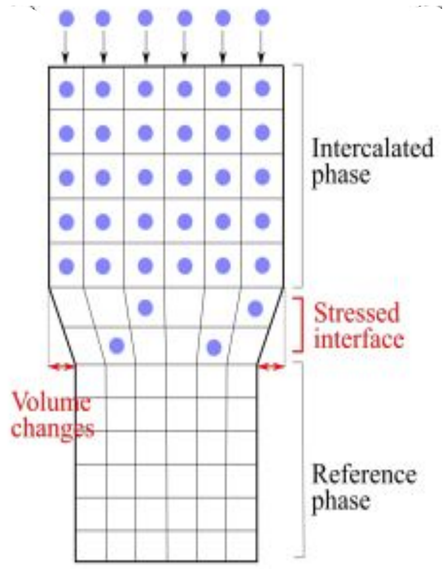
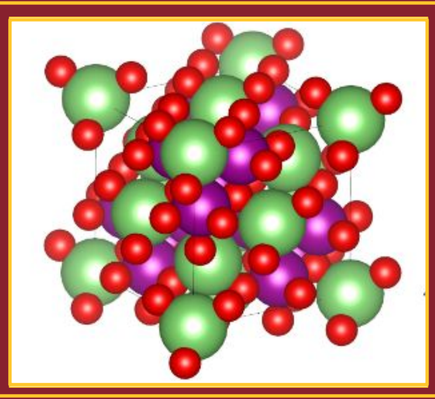


Figure A: A image of an microstructure in a battery that has a visible white line, that line is a micro crack after intercalation
Figure B: An image of a compound that has delaminated from volume changes after 50 cycles of intercalation

Lattice Structure



A diagram of the intercalation process of a cathode in a battery. The blue dots represent the ions that are being inserted into the cathode of the battery. When the top half is full the volume begins to change and it causes stress in the cathode.



A visualization of the face centered cubic cathode compound $LiMn_2O_4$, using Mathematica

Advice for future students

My advice for students of thinking of applying to SHINE is that they should and it's worth it. They get a wealth of new knowledge over the course of 7 weeks and will learn new useful skills that you'd most likely use in the future. This is a unique opportunity that will enable you to look further into a STEM field or find a new interest in a field. And my final advice is that when you're in SHINE, try to soak up as much as you can from this special opportunity.

Acknowledgements/Reference

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Balakrishna, Ananya Renuka. "Crystallographic design of intercalation materials." *arXiv preprint arXiv:2204.04525* (2022).