Center for Environmental Research and Technology

$LiFePO_4$/C as Cathode Material for Energy Storage Devices

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Figure 1: Intermittent nature of Solar and Wind energy

Motivation:

Renewable energy sources such as solar and are essential for a sustainable future. However, solar energy technologies have the limitation of only being able to gather energy during the day when solar light is plentiful. Where coal and gasoline can produce energy no matter the time of day, solar energy will have to be stored in order to provide electricity at night. Batteries are a vital part of energy storage that will allow solar technologies to be versatile and competitive with fossil fuels. New methods of creating highly promising materials such as $LiFePO_4$ is necessary to transition from fossil fuel energy to sustainable technology.

Basics of Li-ion Batteries:

Batteries convert chemical energy into electrical energy that does useful work on the system. Every battery consists of three main components: a cathode (+ electrode), an anode (- electrode), and an electrolyte (either a liquid catalyst or an ionic conductive liquid/semi-liquid). In the particular case of lithium ion batteries, the electrolyte allows lithium ions to diffuse freely between the to electrodes. When a battery charges lithium ions will diffuse out of the cathode material and congregate near the anode. When discharging, these lithium ions will diffuse back into the crystal structure releasing an electron. This is illustrated in the figure to the right.

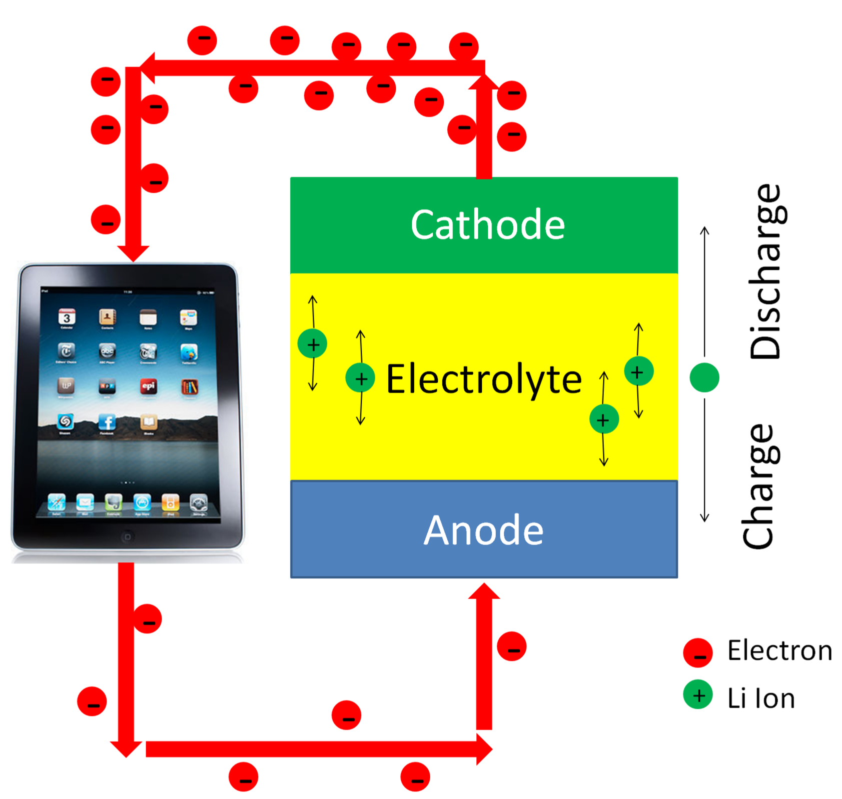

Figure 2: Operation of Li Ion Battery

Lithium Iron Phosphate:

New cathode materials are needed that can overcome the structural, electrochemical, and economic barriers that have plagued so many other cathode materials. One such cathode material that is highly promising is lithium iron phosphate ($LiFePO_4$). This material occurs naturally in a mineral called triphylite which contains lithium iron phosphate as well as lithium manganese phosphate. $LiFePO_4$ is superior to $LiCoO_2$ and other cathode materials for multiple reasons such as a comparable specific energy of 170mAh/g , longer cycling life, higher thermal stability, and superior cost effectiveness. Although this material has many advantages to other lithium based cathode materials, it has some challenges that need to be overcome before it can be successfully integrated into lithium ion batteries.

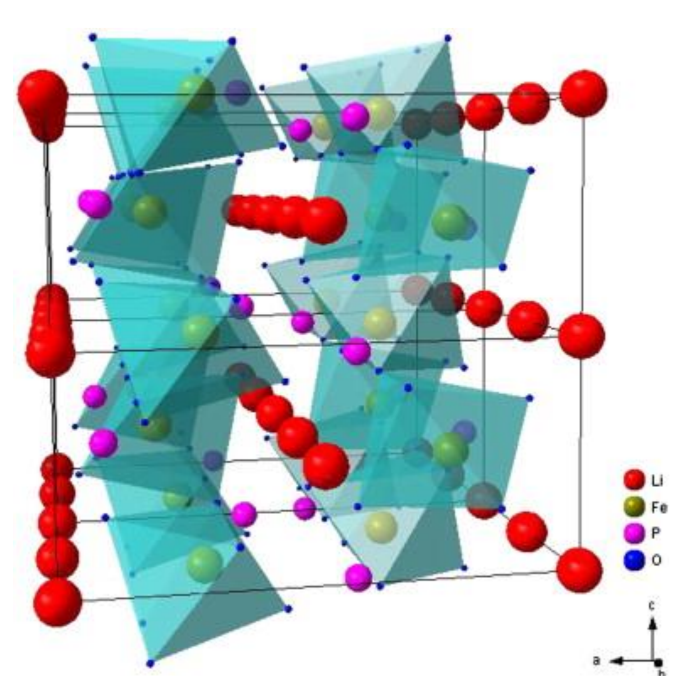

Figure 3: Crystal Structure of $LiFePO_4$

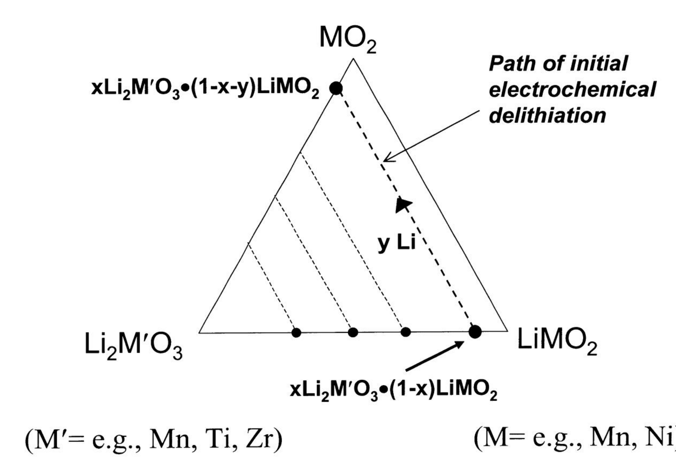

Figure 4: Current Li Ion Technologies

Current Li ion Technology:

- High energy density compared to Pb-Acid batteries
- Most commercially available batteries made of Li-metal-oxides (metal is transition metal such as Ni, Co, Mn…)
- Affects crystal structure which impacts electrical/mechanical properties
- Expensive materials and processing
- Lower potential meaning more cells needed
- Cycling problems
- Environmental unfriendly

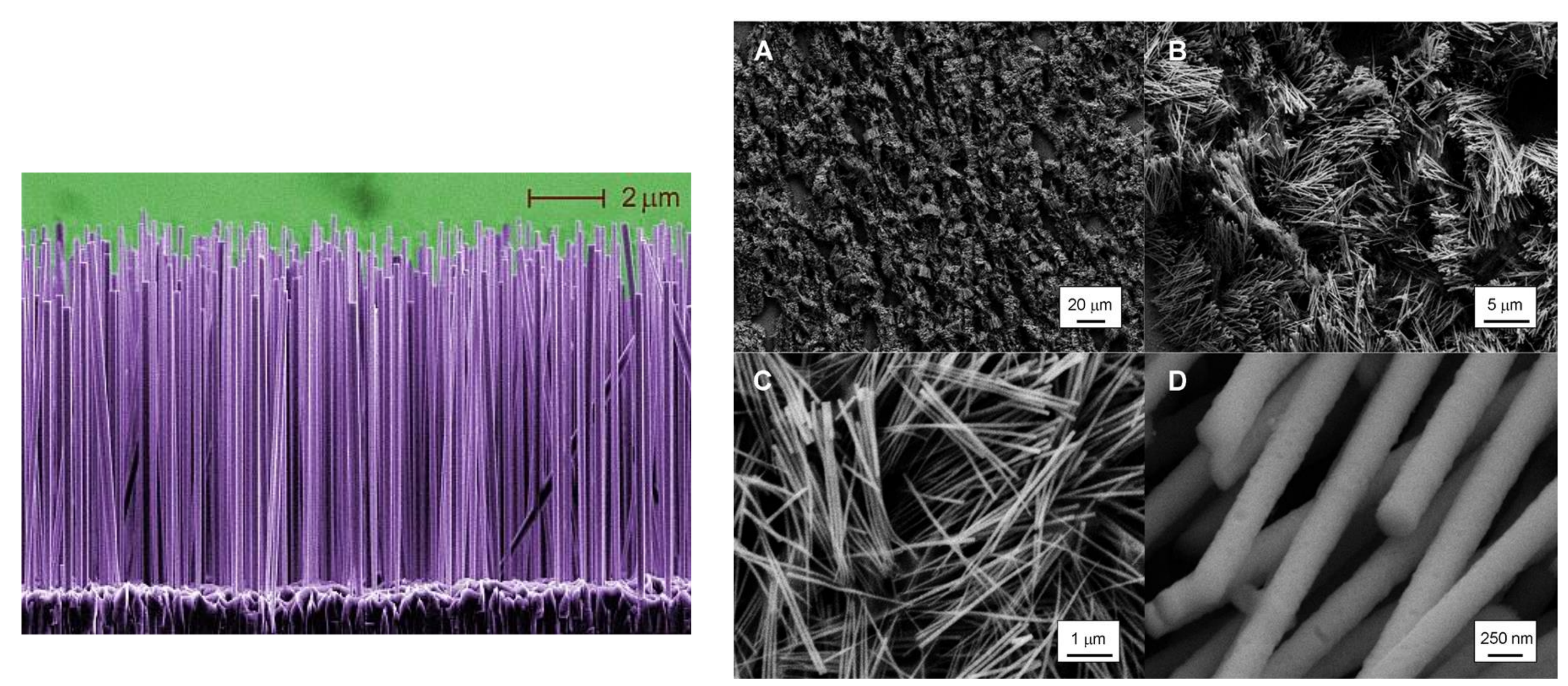

Figure 5: Examples of Nanowires synthesized by Electrochemical Deposition Process

Novel Cathode Material:

To improve cycling and capacity performance our group will synthesize carbon coated $LiFePO_4$ nanowires as a cathode material for lithium ion batteries. Increasing the surface area of the cathode material by synthesizing nanowires will allow for greater lithium ion diffusion into/out of the crystal structure, thus allowing greater performance per unit mass. Template assisted electrochemical deposition of nanowires offers easily controllable and quick growth of our material allowing an inexpensive and a superior performing cathode material to be made. In addition, carbon coating will improve the conductivity of $LiFePO_4$ in an insulating olivine phase. Chemical Vapor Deposition of carbon using sugar and polypyrrole doped with carbon black as precursors will be utilized to obtain a sp2 hybridized carbon matrix that will improve the conductivity by many orders of magnitude.

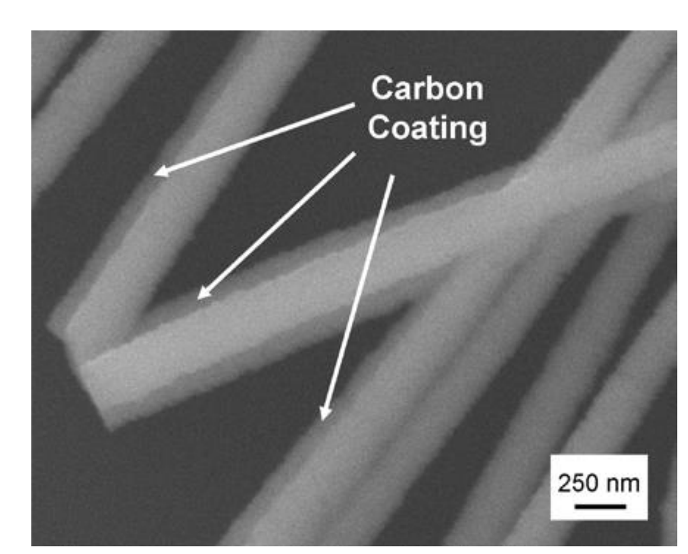

Figure 6: Carbon Coating of Nanowires

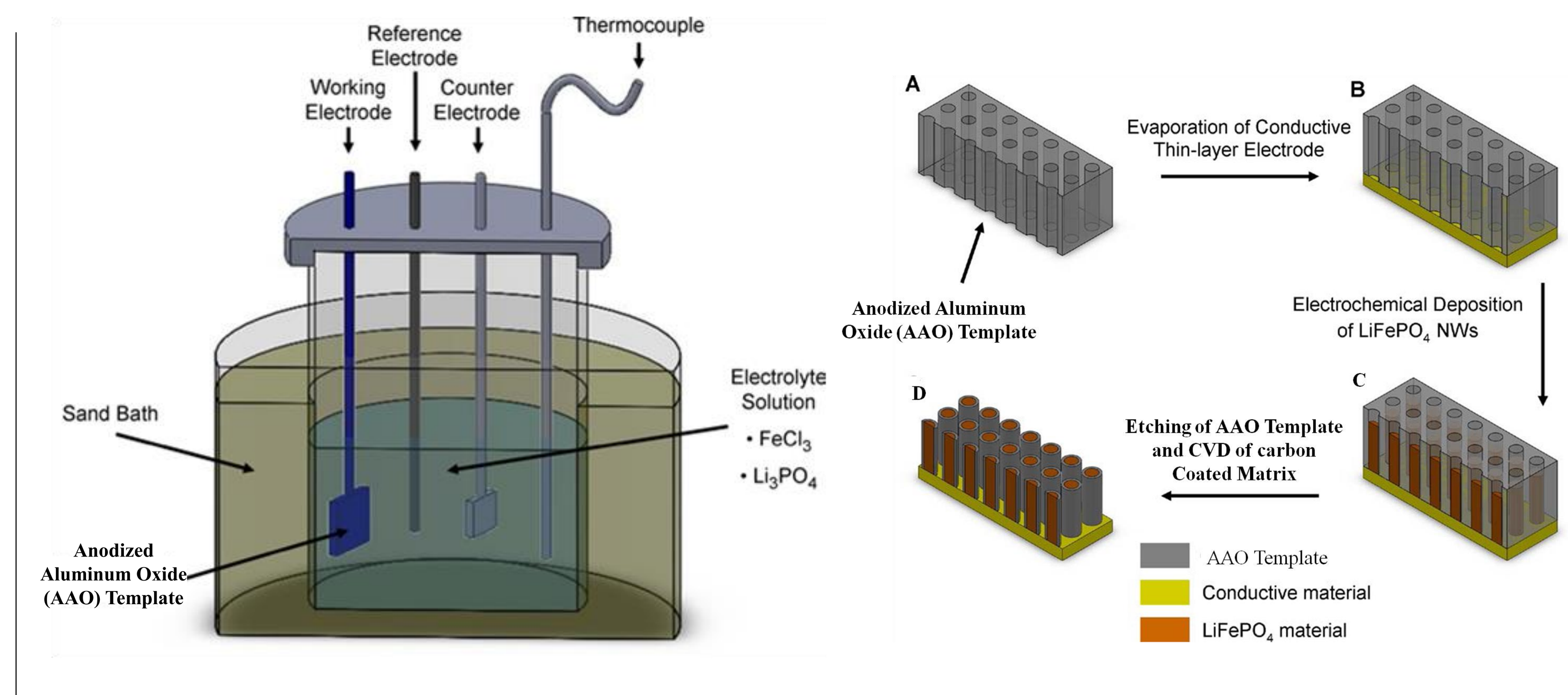

Figure 7: Experimental Electrochemical Deposition Setup and Synthesis Procedure

Method of Synthesis

- Electrochemical set up consists of three electrodes: Working (template), Reference (Ag/AgCl), Counter (Pt)
- Perform electrochemical synthesis of LiFePO4 using a commercial grade ionic liquid.
  – A: Anodized Aluminum Template (AAO)
  – B: E-Beam evaporate conductive metal on back of a AAO template
  – C: Electrochemically synthesize $LiFePO_4$ within AAO membrane
  – D: Etch AAO template to obtain $LiFePO_4$ nanowires and coat NW with carbon using CVD method

Figure 8: Chemical Vapor Depositor Reactor

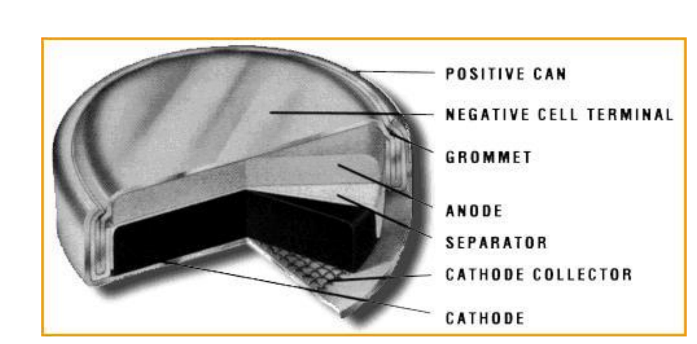

Figure 9: Coin Cell Device for Characterization

Future Work

Future work will consist of improving the efficiency of our $LiFePO_4$ cathode material by improving electrical and ionic conductivity even further. Optimization of the $LiFePO_4$/C nanowires will be confirmed by many different methods. X-Ray Diffraction (XRD) and Transmission Electron Microscope (TEM) will confirm the crystal configuration of the synthesized material; Fourier Transmission Infrared Spectroscopy (FTIR) will confirm whether or not the carbon matrix is sp2 hybridized; and the coin cell testing will measure the specific capacity of the material which is the measurement of the amount of current the battery can hold per unit mass. Once our material is optimized, collaboration with other students working on different components of a battery system, such as the anode material or electrolyte, will be vital to test the true efficiency of our material in a working device.