Novel Nanoporous Magnesium for High-Energy Density Lithium-ion Battery Anodes

Detsi Group project by Angela Kumirai – Jumpstart for Juniors

Abstract

Mg operates at a low voltage, and Mg is highly abundant in the Earth's crust. These unique features make Mg attractive as a potential next-generation LIB anode material for EV applications. Despite these outstanding features, Mg has rarely been investigated as LIB anodes, partly because of its relatively high chemical reactivity, which makes it difficult to synthesize nanostructured Mg for battery applications. Therefore, this project is aimed at providing a foundation to the development of a novel nanoporous magnesium and investigation of its electrochemical performance as a high-energy density lithium-ion battery anode.

Background

The Detsi laboratory at the University of Pennsylvania has recently developed a novel air-free synthesis route to reactive nanostructured materials.

In this research, I lay the foundation to use a similar air-free synthesis protocol to make nanoporous Mg and investigate its performance as LIB anode.

Post-COVID, I will investigate the electrochemical performance of the synthesized nanoporous Mg as the anode in LIBs, by using this nanoporous Mg to prepare a slurry electrode, assemble coin cells, test these coin cells and study their cyclability, specific capacity, Coulombic efficiency, cycle life and calendar life.

Works Cited

1. Carbon-Coated Magnesium Ferrite Nanofibers for Lithium-Ion Battery Anodes with Enhanced Cycling Performance https://doi-org.proxy.library.upenn.edu/10.1002/ente.201600686

2. $Li_2ZnTi_3O_8$ coated with uniform lithium magnesium silicate layer revealing enhanced rate capability as anode material for Li-Ion battery https://doi.org/10.1016/j.electacta.2019.05.087

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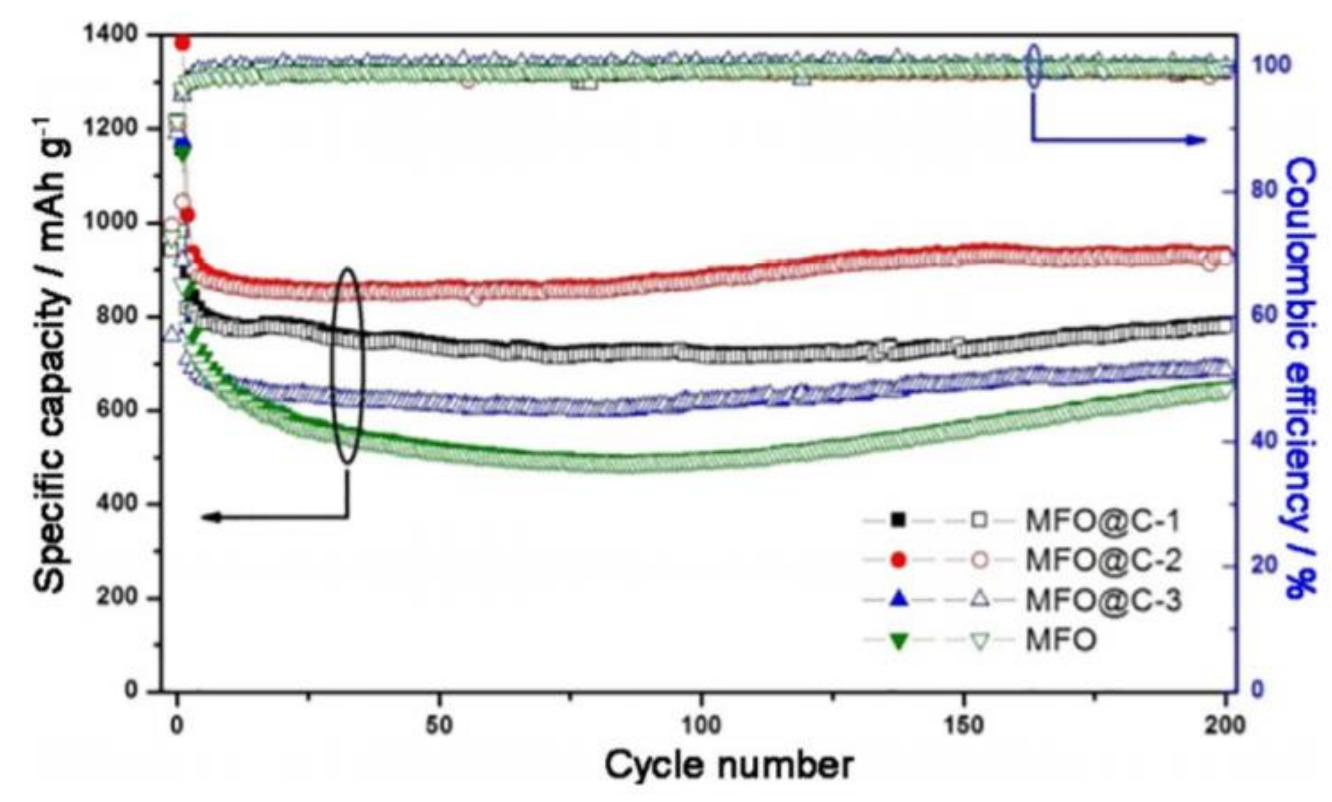

Figure 7. Cycling performance of $MgFe_2O_4$ and $MgFe_2O_4$@C nanofibers at a current density of 0.1 $A g^{-1}$.

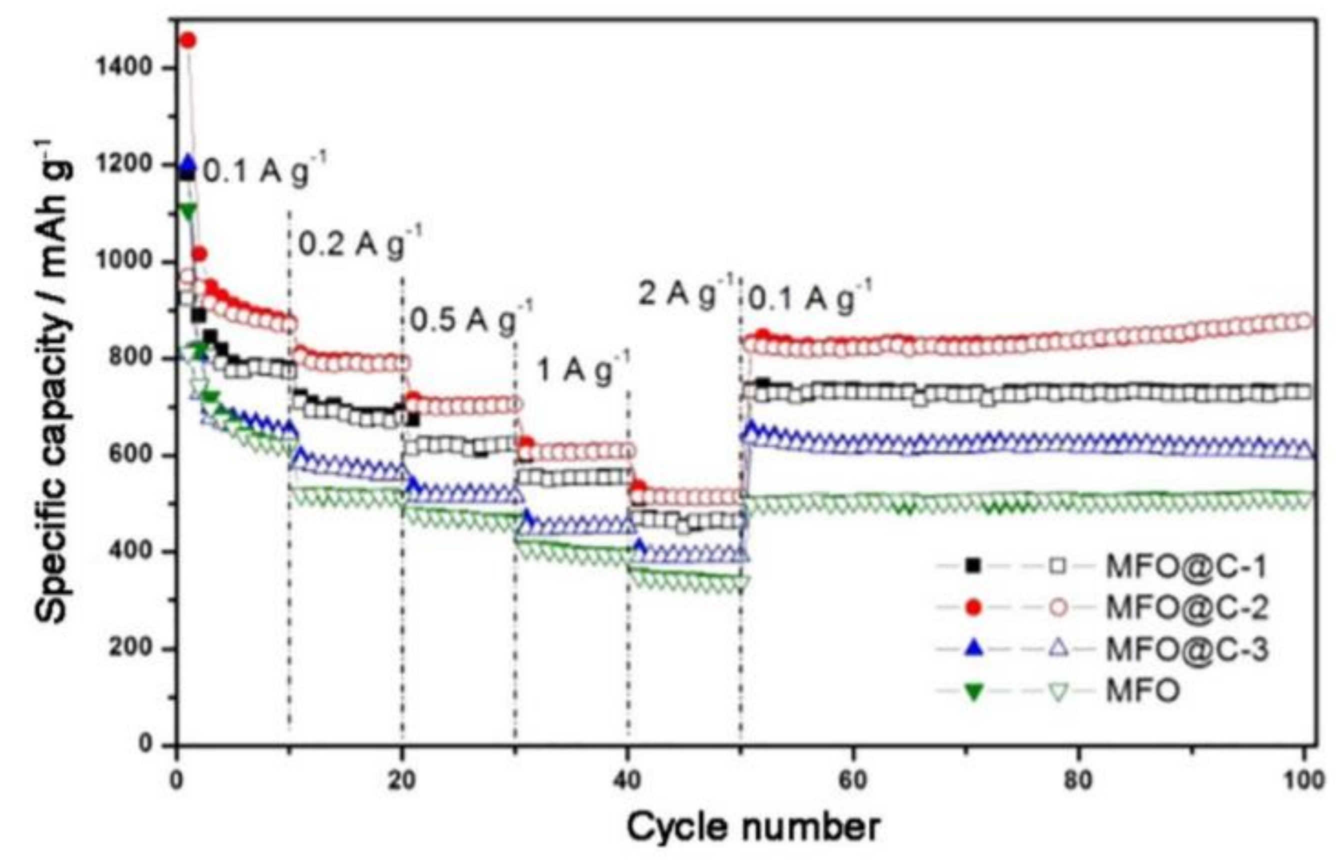

Figure 9. Rate capability of $MgFe_2O_4$ and $MgFe_2O_4$@C nanofibers with different current densities from 0.1 to 2 $A g^{-1}$.

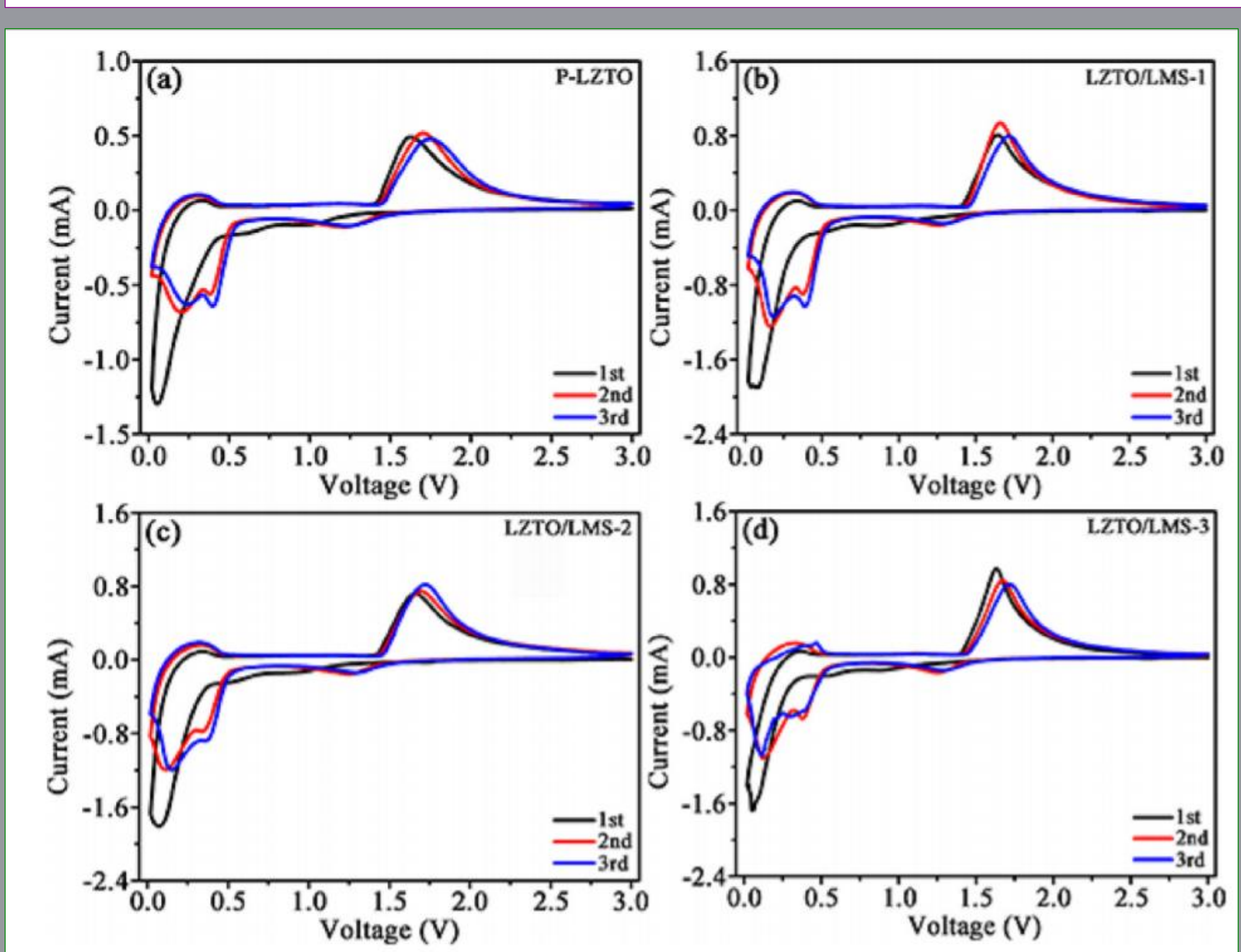

Fig. 7. CV profiles of (a) P-LZTO, (b) LZTO/LMS-1, (c) LZTO/LMS-2 and (d) LZTO/LMS-3 at 0.3 $mV s^{-1}$.

Carbon-Coated Magnesium Ferrite Nanofibres[1]

$MgFe_2O_4$ nanofibres are a potential anode for LIBs because:

- $MgFe_2O_4$ has high theoretical specific capacity of 1072 $mAh g^{-1}$.
- MgO does not react with Li, preventing the aggregation of iron oxides during the charge/discharge process
- MgO can act as a buffer during lithiation/delithiation

$MgFe_2O_4$ nanofibres with a Carbon thickness of 7nm showed improved electrochemical performance:
Refer to Figure 7 (Top)

Reversible Capacity	926 $mAh g^{-1}$
Cycles	200
Maximum Capacity Retention	88.8%
Rate Capability	514 $mAh g^{-1}$
Capacity	610 $mAh g^{-1}$
Current Density	1 $A g^{-1}$ (after 500 cycles)

Li-Mg Silicate layer as anode in Lithium Ion Batteries[2]

$Li_2ZnTi_3O_8$ (LZTO) was mixed with Lithium Magnesium Silicate (LMS) colloidal solution to form an LMS-coated LZTO. The dried solution was calcined at 750 ^{0}C.
LMS showed strong adsorbability, cohesiveness, suspensibility, chemical stability and good cation exchangeability when it used to modify $Li_2ZnTi_3O_8$ (LZTO).
Performance is attributed to the uniform LMS coating for protecting LZTO as it:

- Protects the LZTO from direct contact with electrolyte to prevent side reactions
- Improves Coulombic efficiency in initial cycle
- Improves electronic and ionic conductivities which attenuates polarization
- *Refer to Figure 9 and 7 (Bottom)*

Capacities ($mAh g^{-1}$)	Current Rates ($mA g^{-1}$)
243.3	100
217.2	200
200.5	400
183.5	800
140.4	1600
269.8	100