PacifiCan-MMRI Accelerating Circular Economy (ACE) TechBrief Report

THE UNIVERSITY OF BRITISH COLUMBIA

Materials & Manufacturing Research Institute

Project title: $Li_4Ti_5O_{12}$-Hard carbon composite anode for fast-charging Lithium-Ion batteries

Industry partner(s): Tycor UPS

Researchers: Hamidreza Saneifar, Jian Liu

Introduction & Background:

Lithium-ion batteries with fast-charging capability have broad applications in electric vehicles and large-scale energy storage systems. $Li_4Ti_5O_{12}$ batteries are one of the most promising fast-charging technology due to the good structural and electrochemical stability of $Li_4Ti_5O_{12}$ anode. However, $Li_4Ti_5O_{12}$ anode has several limitations, such as relatively low energy density and high cost, hindering the market penetration of $Li_4Ti_5O_{12}$ batteries. The objective of this collaborative project between Dr. Liu's group at the University of British Columbia (UBC) and Tycor UPS aimed at developing a hybrid $Li_4Ti_5O_{12}$/hard carbon anode for fast-charging Li-ion batteries. The mixing of hard carbon with $Li_4Ti_5O_{12}$ was expected to increase the specific capacity and power density of the anode and potentially lower the materials cost due to the use of hard carbon. The success of this project would deliver new fast-charging battery chemistry, facilitate manufacturing of the fast-charging batteries, accelerate the broad adoption of renewables, and increase grid resilience.

Relevance to Circular Economy:

This research adopts hard carbon derived from hemp into anode materials to improve the fast-charging capability of LTO-based Li-ion batteries. This work represents a promising approach for upcycling hemp waste into high-value-added hard carbon anode materials for Li-ion battery applications.

Methodology:

Hard carbon was obtained by pyrolysis of hemp wastes at 800 °C in Ar gas for 5 hours. The $Li_4Ti_5O_{12}$/hard carbon (LTO/HC) with different ratios was used as the anode materials in Li-ion coin cells. The average loading of LTO/HC active materials was about 10 mg cm^{-2}. Commercial cathode electrodes were cut into circular discs for half-cell and full-cell configurations. LTO-HC composite electrodes with 10 wt%, 20 wt%, 30 wt%, and 40 wt% of HC was labeled as LTO-HC10, LTO-HC20, LTO-HC30, and LTO-HC40, respectively. The active material loading of NMC 333, NMC 532, NMC 622, and NMC 811 cathodes were about 12.81, 11.86, 10.86, and 10.16 mg cm^{-2}, respectively. Coin-type cells (2032) were assembled in an argon-filled glove box (<0.01 ppm of water and oxygen contents) using an NMC electrode as the cathode, lithium foil (for half cell) or LTO and LTO-HC (for full cell) as the anode, a Celgard 2320 separator and 150 µl of electrolyte (1 M $LiPF_6$, EC:DMC). The negative to the positive ratio for full cells was tuned to be 1:1. The electrical conductivity of the LTO and LTO-HC electrodes was performed using a 4-point probe technique on a Keithley 6220 DC precision current source (Signatone).

Results & Discussion:

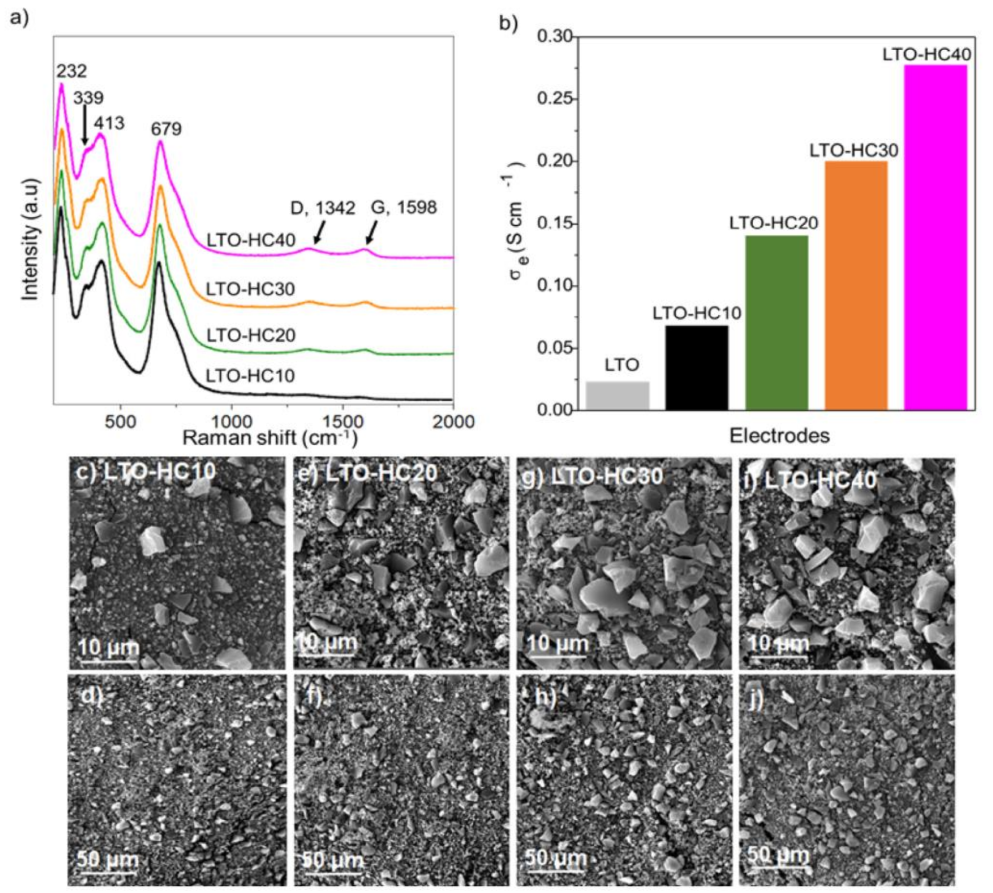

Figure 1: A) Raman spectra b) electronic conductivity (σe) values and c-j) SEM images of LTO-HC composites with different HC ratios: c) and d) LTO-HC 10 (10 wt% HC), e) and f) LTO-HC 20 (20 wt% HC), g) and h) LTO-HC 30 (30 wt% HC), and i) and j) LTO-HC 40 (40 wt% HC).

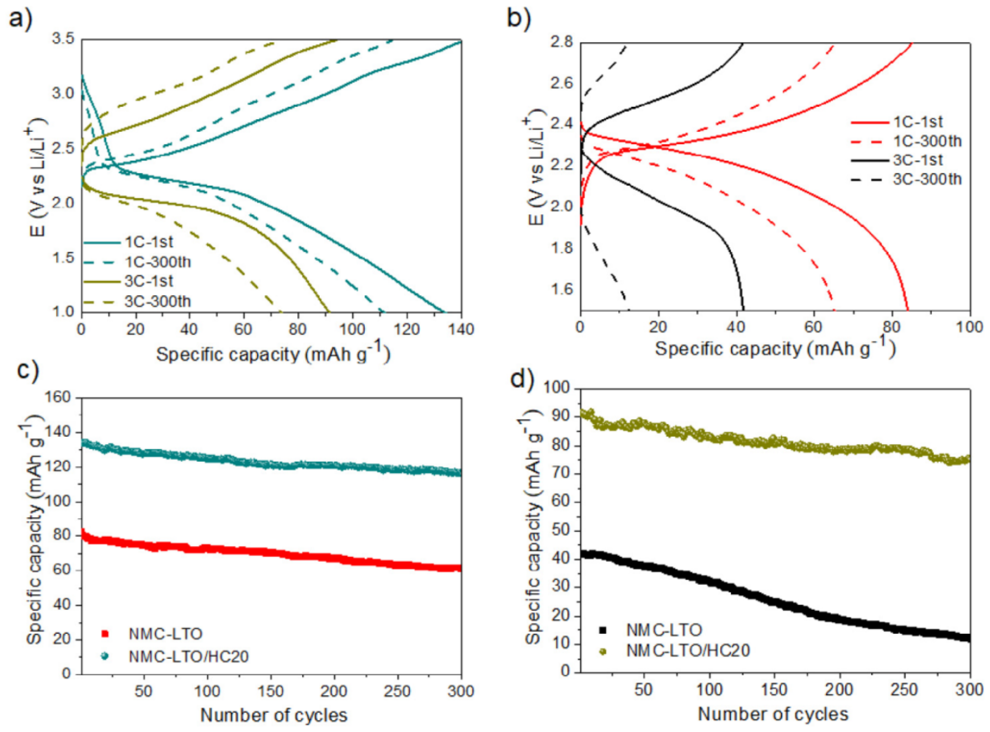

Figure 2: First and 300th charge–discharge profiles of the (a) NMC-LTO-HC20 and (b) NMC/LTO and (c and d) corresponding cycling performance of full cells at 1C and 3C.

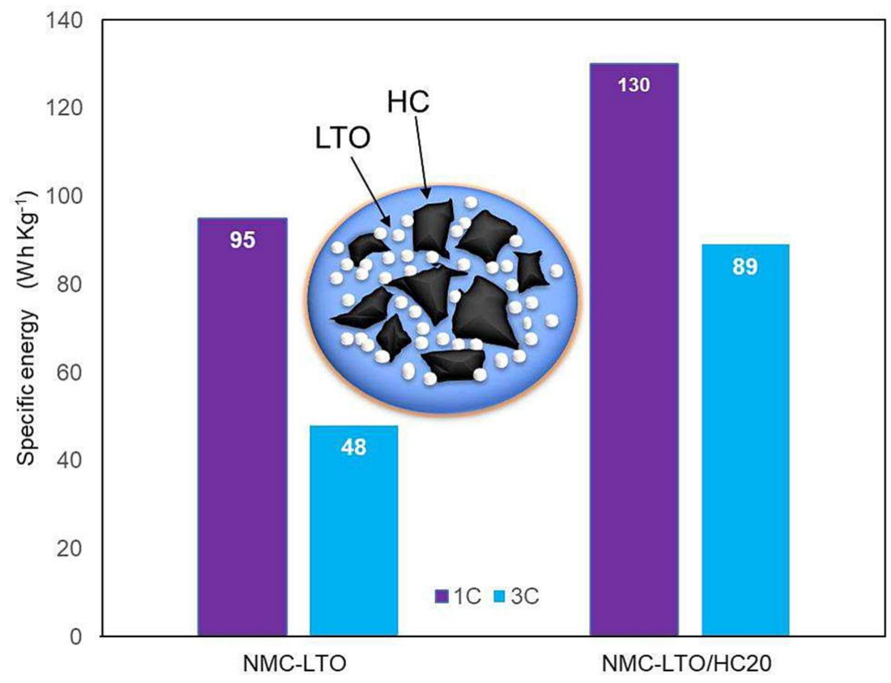

Figure 3:A full cell of NCM/LTO-HC20 exhibited capacity retention of 82% and 79% over 300 cycles and specific energy of 130 and 89 Wh kg^{-1} at 1C and 3C, respectively.

Conclusion & Next Steps:

The LTO-HC composite anode with 20 wt% HC exhibited the highest specific capacity of 147 mAh g^{-1}, superior cycling stability (89 % capacity retention over 400 cycles), and rate performance. The HC addition improved the specific energy of the Li-ion batteries from 95 to 130 Wh kg^{-1} at 1C and from 48 to 89 130 Wh kg^{-1} at 3C. As the next step, the industry partner will validate the LTO-HC chemistry in industry-scale cylindrical cells and plan the production plan for the fast-charging batteries.

Further reading: H. Saneifar, J. Liu. Journal of Electroanalytical Chemistry, 929 (2023) 117100. https://doi.org/10.1016/j.jelechem.2022.117100

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