A Pre-Sodiation Strategy for Na-Ion Batteries

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Introduction

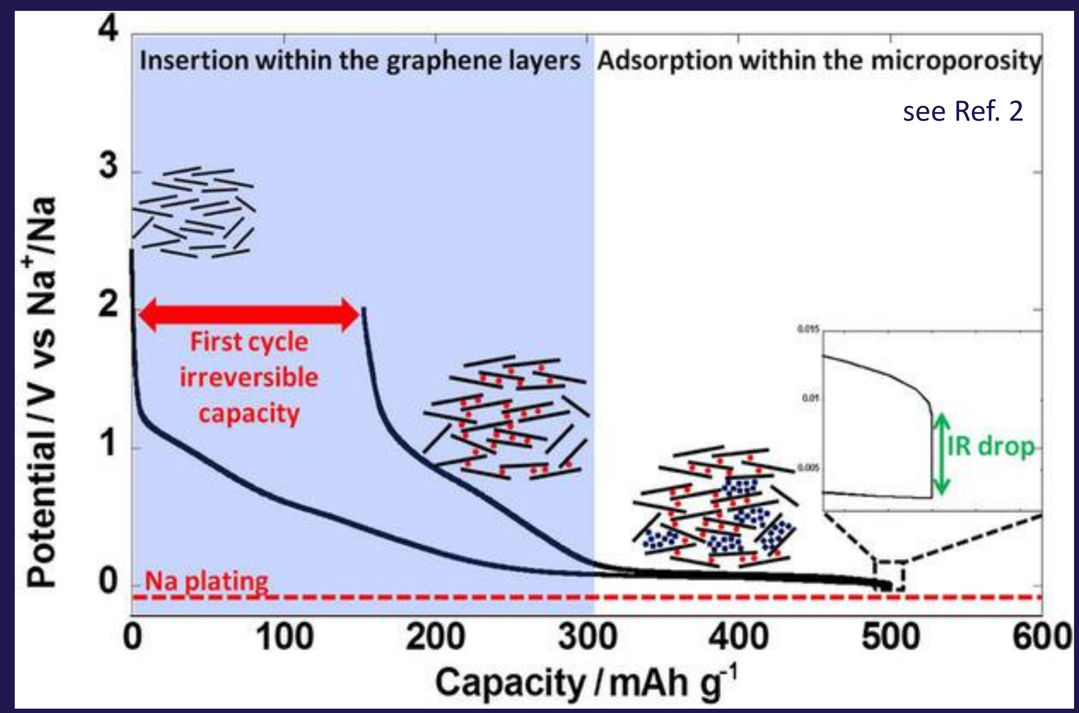
Since sodium is widely available and sodium-ion batteries (SIBs) are relatively cheap, they are seen as a promising candidate for next-generation energy storage systems. The cathode provides sodium to every source in the SIB system. However, anodes like hard carbon (HC) inevitably consume active Na^+ from the cathode during the initial charging process due to the formation of solid electrolyte interphase (SEI) films because of irreversible side reactions. One crucial strategy to deal with this issue is the presodiation of electrodes to compensate the irreversible sodium loss. Until now, various compounds such as Na_2CO_3, $Na_2C_2O_4$, $Na_2C_4O_4$, $NaNO_2$, Na_3P, and NaN_3 have been explored as sacrificial sodium compensation additives for SIBs [1].

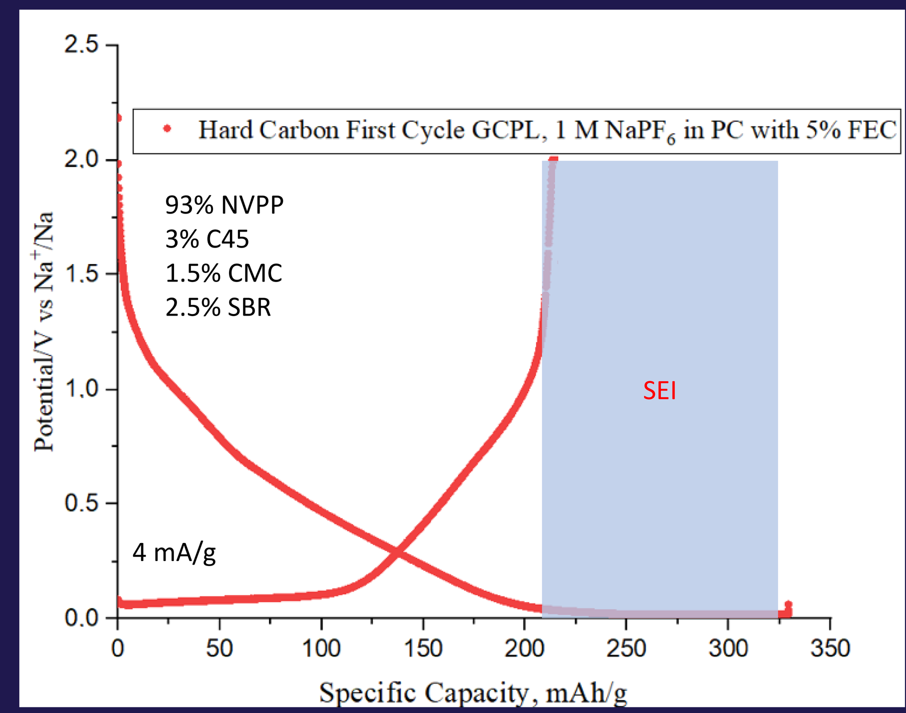
This study, part of the 4NiB project funded by the German Federal Ministry of Education and Research (BMBF), investigates the effects of presodiation additives on the performance of Na-ion cells with hard carbon (HC) anode and $Na_7V_4(P_2O_7)_4(PO_4)$ (NVPP) cathode. The materials have been synthesized by collaborators from (Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg) ZSW, Ulm.

Methods

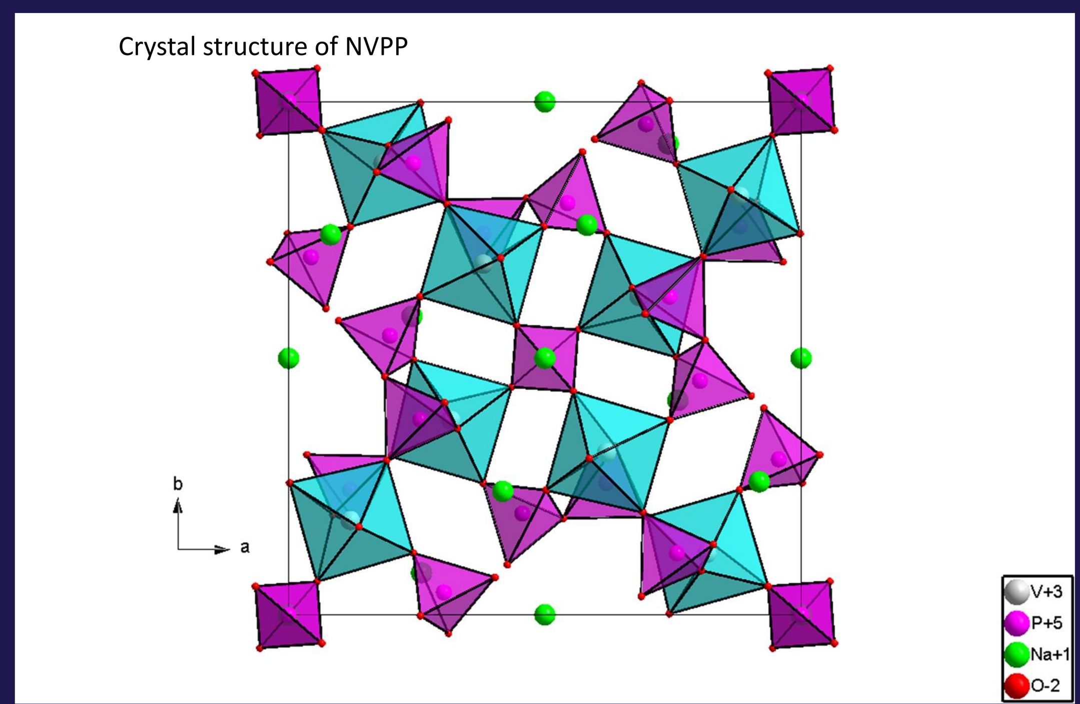
- The prepared electrodes were assembled into coin cells in an argon-filled glove box. The cells were assembled for the half cell configuration for the NVPP cathode, with a separator and electrolyte consisting of 1 M $NaPF_6$ in propylene carbonate (PC) with 5% fluoroethylene carbonate (FEC). The coating for the P2-$Na_{0.66}Fe_{0.33}Mn_{0.66}O_2$ (NFMO) material was using for full cell configuration.

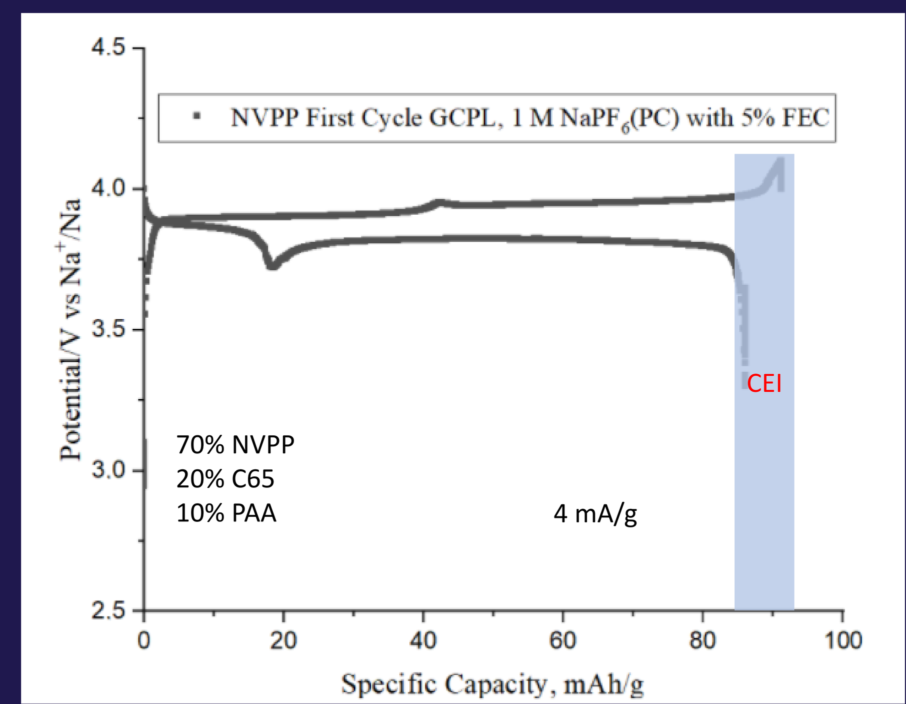
Irreversible Capacity on The Hard Carbon



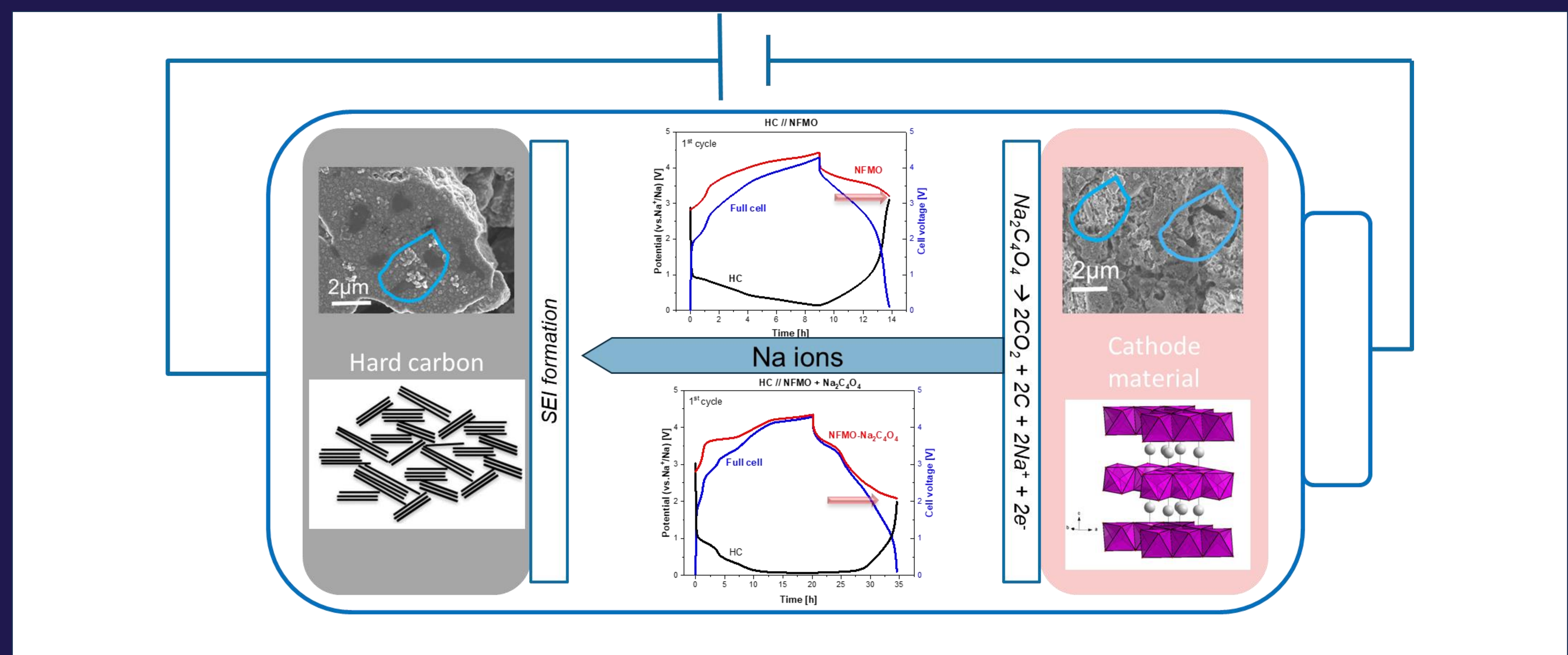


Irreversible Capacity on The NVPP





Presodiation Approach for The Full Cell



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- Electrochemical characterization was done by cyclic voltammetry (CV) and Galvanostatic cycling with potential limitation (GCPL) to evaluate the cycling stability and capacity retention of the cells over multiple charge-discharge cycles.
- Post-Mortem analysis are planned using X-ray diffraction analysis (XRD), scanning electron microscopy (SEM) to observe the structural changes and surface characteristics of the electrodes respectively, X-ray photoelectron spectroscopy (XPS) will be conducted to obtain information on the elemental composition and chemical states of the materials.

Results

Preliminary work was done with the full cell system, containing layered oxide P2-$Na_{0.66}Fe_{0.33}Mn_{0.66}O_2$ as a positive electrode and hard carbon as a negative electrode.

- Presodiation approach increases the discharge capacity of full cell from 33.3 mAh/g to 77.2 mAh/g.
- Suppression of P2 - P´2 transition and reduction of stacking fault region through the addition of $Na_2C_4O_4$.
- Improved kinetics.
- Increased cathode porosity.
- Lower impedance upon cycling.
- Thicker SEI with $Na_2C_4O_4$ additive.

Discussion

The results of this study highlight the effectiveness of $Na_2C_4O_4$ as a presodiation additive in enhancing the performance of Layered Oxide//HC Na-ion cells. The primary challenge in sodium-ion batteries (SIBs) is the initial sodium loss due to the formation of solid electrolyte interphase (SEI) films and irreversible side reactions at the anode, which significantly reduces the overall energy density. By incorporating $Na_2C_4O_4$, this study for NVPP//HC full cell aims to address this issue and improve the efficiency and stability of SIBs.

Acknowledgment

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