Discovery of new solid-state materials for Li & Na ion battery

Rochish Manda[a], Lingzi Sang[b]

[a]Department of Metallurgical & Materials Engineering, Indian Institute of Technology, Kharagpur

[b]Department of Chemistry, University of Alberta, Canada | lsang@ualberta.ca

*Energy cannot be created or destroyed, but can be **converted** from one form to another.*

- First Law of Thermodynamics

Abstract

The Why ?

The future is Electric ! - both for the grid & home appliances.

› *Key concerns for a secondary battery* : Safety (thermal stability), higher energy (& power) density, long cycle life.

Safety can be improved when the traditional liquid electrolyte (organic, hence flammable) in Li/Na battery is replaced by a solid-state electrolyte (inorganic, thermally more stable).

› *Key challenges* : *Finding this solid-state electrolyte with high ionic conductivity (comparable to that of liquid electrolytes) & higher energy density.*

The How ?

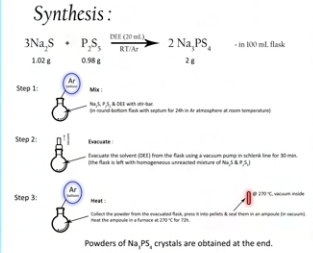
With careful selection of solid electrolyte materials & with improvement of solid electrolyte interfaces to reduce interfacial resistance with active electrodes.

Solid Electrolyte

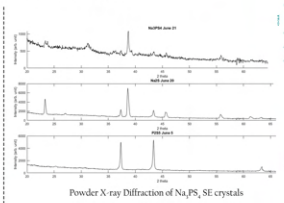
Function - Permits the flow of ions in the battery, i.e. it is *ionically conducting & electronically insulating.*

Na_3PS_4 solid electrolyte

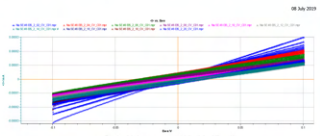
Synthesis :



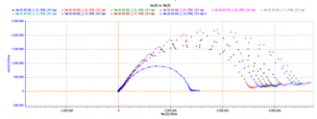
Characterization :



Powder X-ray Diffraction of Na_3PS_4 SE crystals



Cyclic Voltammetry of Na_3PS_4 SE pellet



Potentio Electrochemical Impedance Spectroscopy of Na_3PS_4 SE pellet

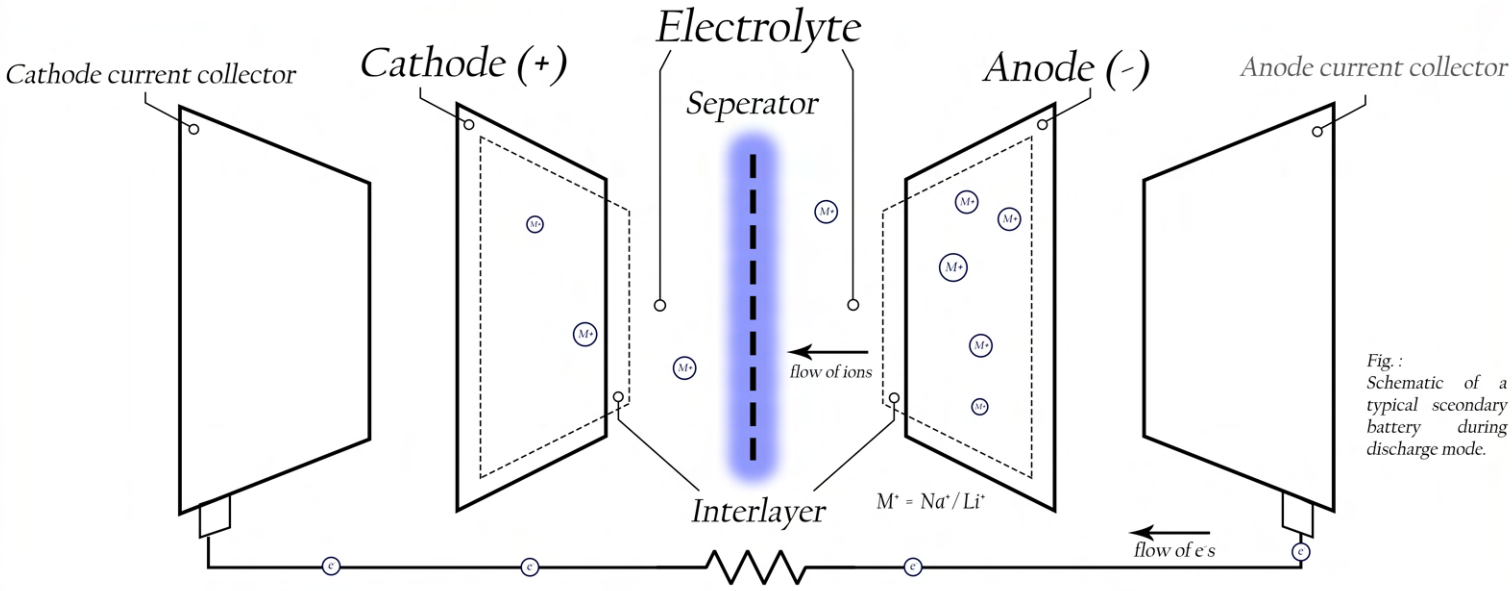


Fig. : Schematic of a typical secondary battery during discharge mode.

Active Materials

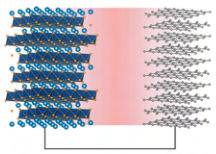
$LiMn_2O_4$ (LMO) & $LiCoO_2$ (LCO)

Function -

These materials determine the energy storage capability of the battery.

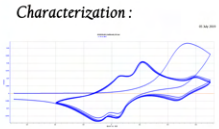
Synthesis :

1. 0.1g of carbomethoxycellulose sodium salt (binder) is stirred with 3.5 mL ultra-pure water (2.4 mL for LCO) for 72 hrs.
2. Ground powders - 0.8g of LMO/LCO & 0.1g of C are mixed vigorously in the above binder solution until the solution becomes black homogeneously.
3. The solution is then cast on an Al foil & left for heating in an oven at 150 °C.

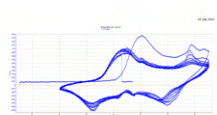


Schematic for intercalation process in active electrodes (here during discharge)

Characterization :



Cyclic Voltammetry of LMO



Cyclic Voltammetry of LCO

Interlayer

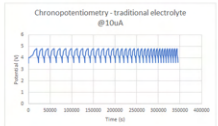
Li-TFSI (7 M)

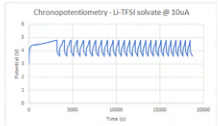
Function -

These materials increase the ionic conductivity at solid electrolyte-electrode interface, by enhancing the interfacial contact & hence decreasing the grain boundary resistance at the interface.

Characterization :

Cyclic charge-discharge technique - Traditional electrolyte ($LiPF_6$) vs solvate (Li-TFSI)





Future directions

1. Solid electrolyte -

With ever increasing demand for secondary batteries, to lower the costs of SE production, furthur research has to be carried on improving various properties of the Na_3PS_4 SE & on developing several other possible Na SE materials - by furthur increasing ionic conductivity, thermal stability & compatibility between solid electrolytes & electrodes.

2. Active materials (cathodes & anodes) -

Furthur insights into the crystal structure and electrochemistry of new active materials will be helpful in providing a platform on which future optimisation of required active materials for *Na-ion batteries* can be based upon - for higher energy density, longer cycle-life & at a much lower cost of the active materials.

3. Interlayer materials -

Since the intercalation kinetics & reductive stability are enhanced in the Li solvate (Li-TFSI), this process of designing superconcentrated organic electrolyte can also be employed in *Na-ion batteries.*

References

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Contact

Rochish Manda
Final year Undergraduate
Department of Metallurgical & Materials Engineering
IIT Kharagpur

e-mail: rochish@iitkgp.ac.in
Phone: +(91) 7477752999