Operando Neutron Imaging for Next-Generation Solid State Batteries: A Direct Visualization of Li-ion Transport in Sulfide Materials (IBAp-0226)

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Solid State Batteries

Motivation

+ enhance safety

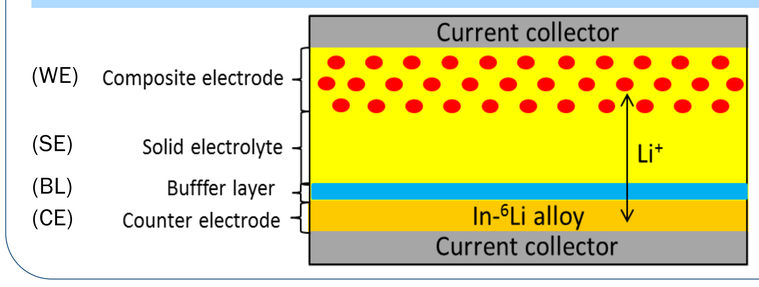
+ increase energy density

Challenges

- Ion transport limitations in composite electrodes

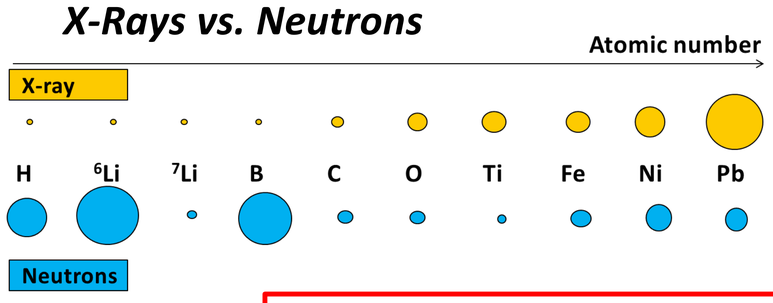
- Battery life depends on **mechanical integrity** :

! SOLID-SOLID INTERFACES !



Experimental Setup for Neutron Radiography

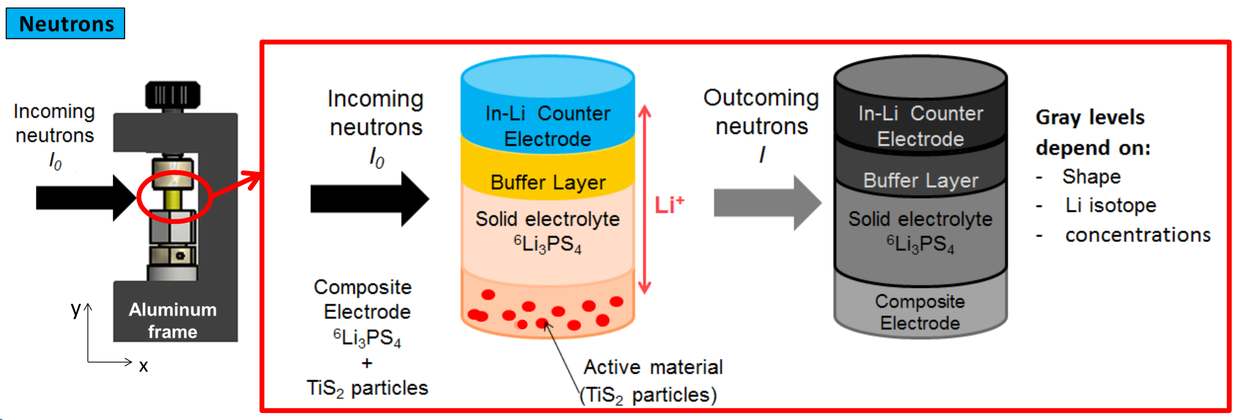
X-Rays vs. Neutrons



Natural Li: 93% Li^7 + 7% Li^6

σ Li^6 >>>> σ Li^7

^{6}Li improves contrast



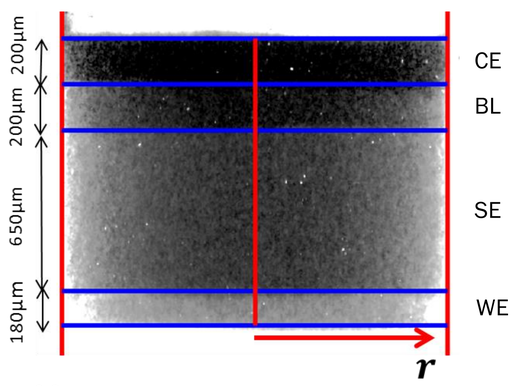
Spatial Resolution

- X : 5.4 µm/pixel
- Y : 2.7 µm/pixel

Time Resolution

1 image every 30s

^{6}Li Quantification from Neutron Imaging

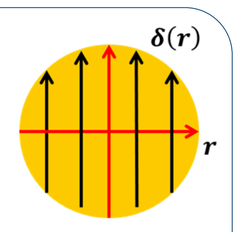


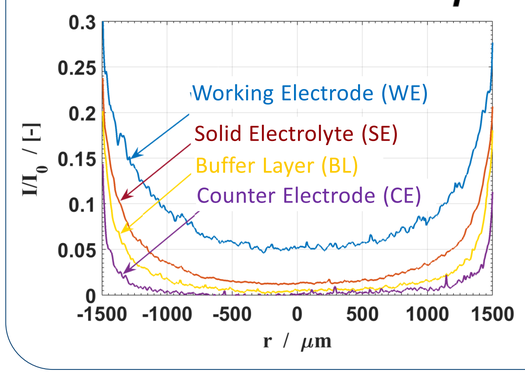
Lambert-Beer's law

$$n_{Li}(r) = -ln\left(\frac{I}{I_0}\right)/\left(\sigma \cdot \delta(r)\right) \qquad (Eq.\ 1)$$

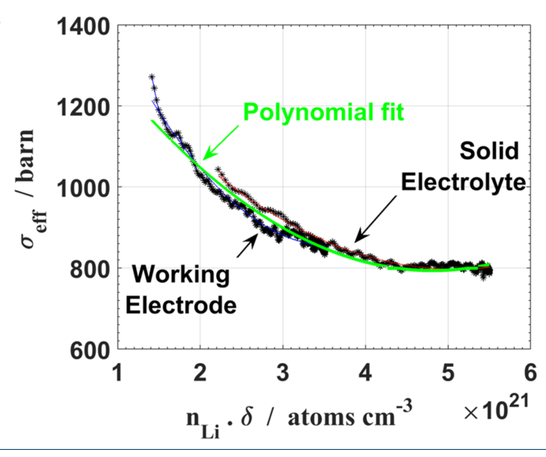
2 **unknowns** in Eq. 1 !

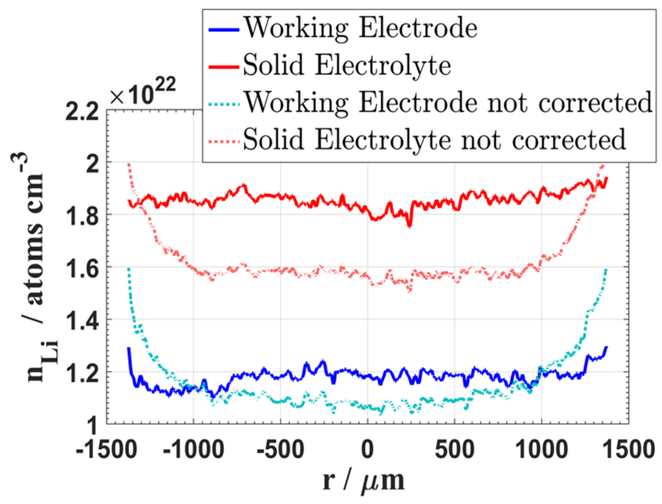
But **polychromatic** beam: $\sigma \propto n \cdot \delta = \sigma_{eff} \neq cst$



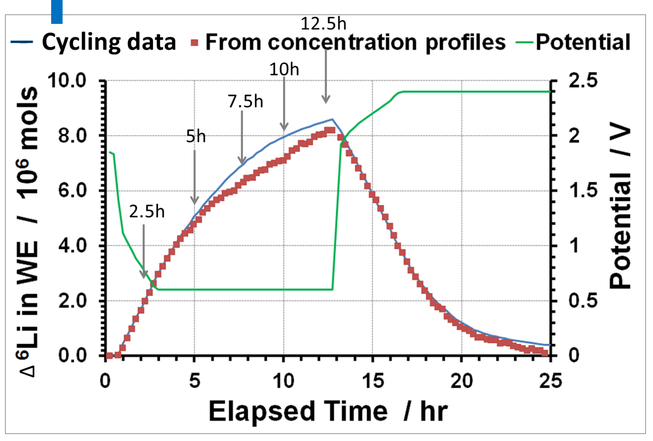


Beam hardening effect

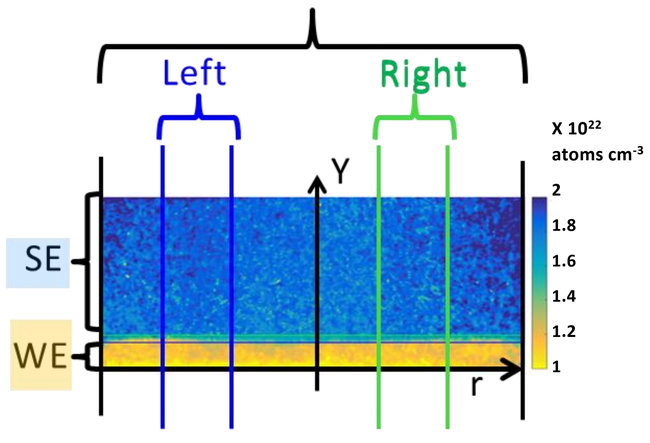


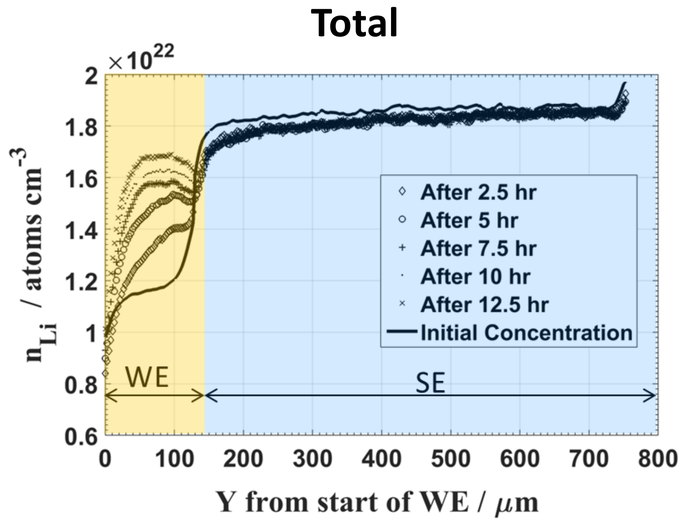


Faraday's law



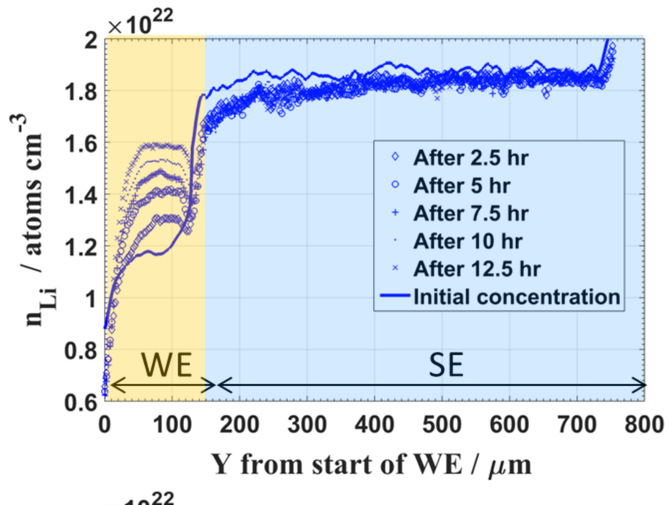
^{6}Li Concentration Profiles to Diagnose Li^+ Transport Limitations



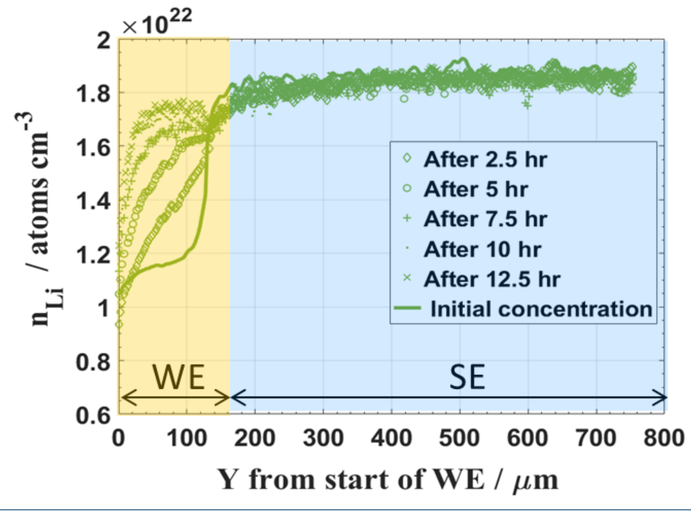


Homogeneous Li^+ distribution in WE?

Left



Right



High-resolution neutron imaging for solid-state batteries:

- Track **Li^+ transport** hindrance & inhomogeneous (de-)lithiation

Causes for hindrance of Li^+ transport:

- High **tortuosity** of composite electrode
- **Delamination** of **SE** and **active materials** and/or **cracks** in SE due to **volume changes**