SOLID STATE BATTERIES: SCIENCE & TECHNOLOGY

NEWS: Cause of pesky failure mode in solid state Li-ion batteries found

WHAT'S IN THE NEWS?

A recent study found that mechanical fatigue of the lithium metal anode, not just current density, is the primary cause of dendrite formation and failure in Solid-State Batteries (SSBs). This insight is critical for advancing SSBs, which offer higher energy density and safety over traditional lithium-ion batteries.

1. What are Solid-State Batteries (SSBs)?

- Solid-State Batteries are next-generation batteries that replace the liquid or gel-based electrolyte used in conventional lithium-ion batteries with a solid electrolyte.
- They promise significant improvements in energy density, safety, and performance over traditional battery technology.

2. Working Mechanism of SSBs

- During Charging: Lithium ions (Li^+) move from the cathode to the anode through the solid electrolyte, storing energy.
- During Discharging: These ions reverse direction—from the anode to the cathode—and release energy in the form of electric current.

3. Key Differences Between Traditional Li-ion Batteries and SSBs

Feature	Traditional Li-ion Battery	Solid-State Battery
Electrolyte	Liquid (flammable)	Solid (non-flammable)
Energy Density	Moderate	Higher (up to 2x)
Safety	Risk of fire/leakage	Much safer, thermally stable
Charging Speed	Moderate	Potential for faster charging
Thermal Stability	Lower	Higher, reducing fire risk

4. Mechanical Fatigue as a Major Challenge in SSBs

- A recent study reveals that the cyclic mechanical fatigue of the lithium metal anode, not merely high current density, is a primary cause of failure in solid-state batteries.
- This fatigue leads to the growth of lithium dendrites, which compromise the battery's structural integrity and safety.

5. What Are Lithium Dendrites?

- Dendrites are needle-like or hair-like structures of lithium metal that form on the anode during charging.
- These structures occur when lithium ions deposit unevenly over multiple cycles.
- Impact of dendrites:
    - They can pierce the solid electrolyte.
    - Reach the cathode and cause internal short circuits.
    - Lead to battery failure or safety hazards, even at low current densities.

6. Scientific Principle Involved:

- The Coffin-Manson Law, a principle in materials science dealing with low-cycle fatigue, has been found relevant to lithium metal degradation in SSBs.
- Repeated expansion and contraction of the lithium metal during charging and discharging cycles causes microcracks, which evolve into dendrites over time.

7. Applications of Solid-State Batteries

- Electric Vehicles (EVs): Automotive giants like Toyota and BMW are integrating SSBs into next-gen EVs for extended driving ranges and faster charging.
- Consumer Electronics: Companies such as Apple and Samsung are investing in SSB technology for safer and longer-lasting smartphones, laptops, and wearables.
- Grid Energy Storage: Firms like Tesla are researching SSBs for renewable energy storage systems, which require high energy density and long life cycles.

8. Current Status and Future Potential

- While promising, SSBs face technical and commercialisation hurdles, especially around manufacturing costs, material stability, and scaling production.
- However, with ongoing R&D, SSBs are expected to play a key role in clean energy transitions, EV adoption, and next-gen electronics.

Source: https://www.thehindu.com/sci-tech/science/cause-of-pesky-failure-mode-in-solid-state-li-ion-batteries-found/article69563675.ece