Mesoscale Priority Research Direction

Hierarchically Structured Porous Electrodes for Energy Storage

Opportunity

- Most batteries today consist of porous electrodes formed by simple random particle packing; such meso-structure remains unchanged for decades.
- Tailoring porous electrode architecture at the mesoscale is largely an unexplored research direction.
- With many examples in energy storage/conversion, mechanics and life science, design and fabrication of hierarchically structured porous electrodes could result in revolutionary energy storage systems.

Meso Challenge

- How to fabricate and characterize meso-structures in porous electrodes with flexibility, precision and efficiency?
- How to accurately model charge transport and degradation in electrodes containing multiscale (nano-, meso-,micro-) porous channels?

Approach

- Develop multi-resolution models to enable efficient and high fidelity simulations to inform electrode design at multiple length scales.
- Combine top-down (e.g. direct ink writing) and bottom-up (e.g., nano-particle self-assembly) methods to synthesize electrodes with desired hierarchical structural features.
- Apply advanced in-situ characterization techniques to interrogate meso-structure evolution upon battery cycling.

Impact

- Will accelerate advancement in energy storage systems and push the performance and lifetime limit by optimizing “degrees of freedom” at the mesoscale that have been rarely explored before.
- A great test ground for the further development of various mesoscale fabrication, characterization and modeling techniques and their integration.

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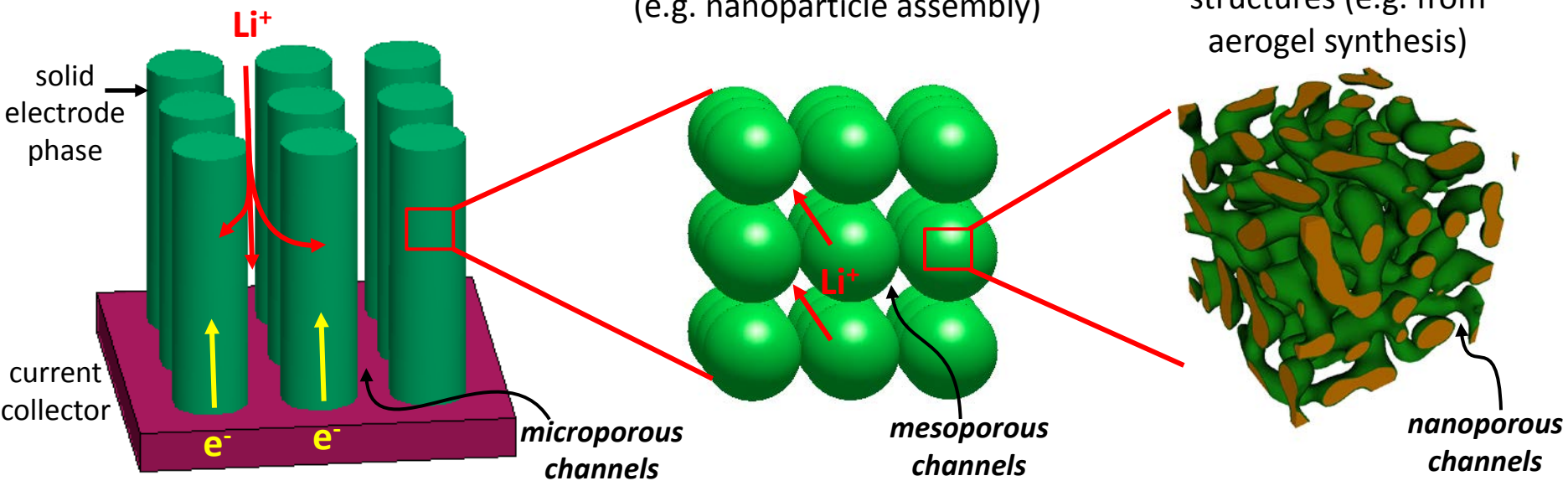
3D battery electrodes
(e.g. by direct ink writing)

Microscale building blocks
have meso-structures
(e.g. nanoparticle assembly)

Nanoparticles may also
contain internal porous
structures (e.g. from
aerogel synthesis)



Central question to address: How to organize porous channels at different length scales in electrodes to maximize charge transport efficiency and minimize chemical and mechanical degradation?

Modeling & Design
phase-field simulations[1], coarse-graining scheme, etc.

Fabrication
direct ink writing[2], nanoporous particle synthesis[3], etc.

Characterization
In-situ spectroscopy, tomography & scattering , etc.

References: 1. M. Tang et al., J. Phys. Chem. C (2011); 2. J.A. Lewis, Adv. Func. Mater. (2006); 3. J. Biener et al., Energy Environ. Sci. 2011.

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