3D-Printing Hybrid Electrolyte Hierarchal Structure Designs for Dendrite Suppression

Barrett The Honors College
Arizona State University
*kenan.song@asu.edu

Nathan Fonseca, Kenan Song and A.M. Kannan**

Ira A. Fulton Schools of Engineering
Arizona State University
*amk@asu.edu

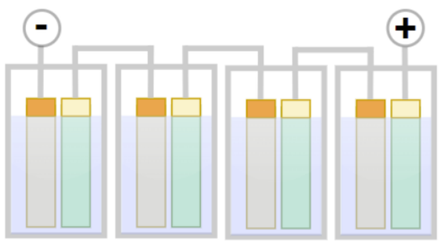
Ira A. Fulton Schools of Engineering, Arizona State University, The Polytechnic School, Mesa, AZ

Abstract

The current lab production of Solid-State Electrolyte (SSE) for Lithium-ion batteries is limited to planar geometries and random porosities. Although SSE has shown improvements, they still face dendrite propagation issues. Additive manufacturing known for its rapid prototyping allows the materials and structures to be modified and achieve a more stable battery. Moreover, different hierarchies (e.g., patternings) can be modified to block dendrite growth. Finding an ideal configuration is our ultimate goal, where safe, high-energy-density solid-state batteries can be a reality and pass the lab-scale production into the commercialization phase.

Motivation

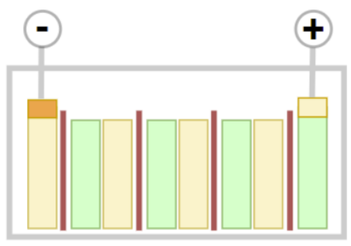
Lithium-Ion Battery



Problems with Conventional Methods:

- Limited to planar geometries and random porosities
- Restrained to lab production
- Dendrite propagation
- Unknown current, and future market environment

Solid-State Battery

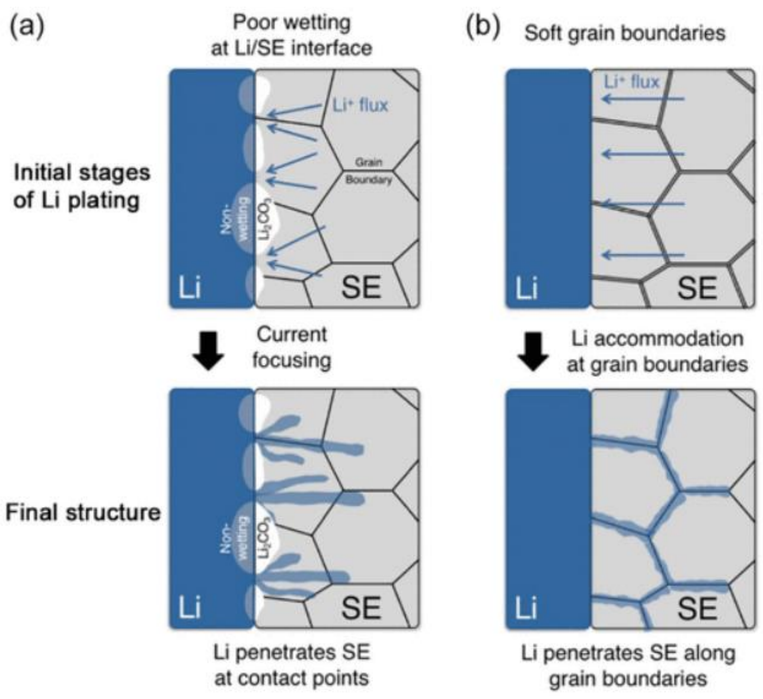


3D-Printing:

- Rapid prototyping
- Skips over conventional physical separation and re-ranging of solutions
- Consistent & standardizing procedures
- Commercialization

Dendrite Propagation

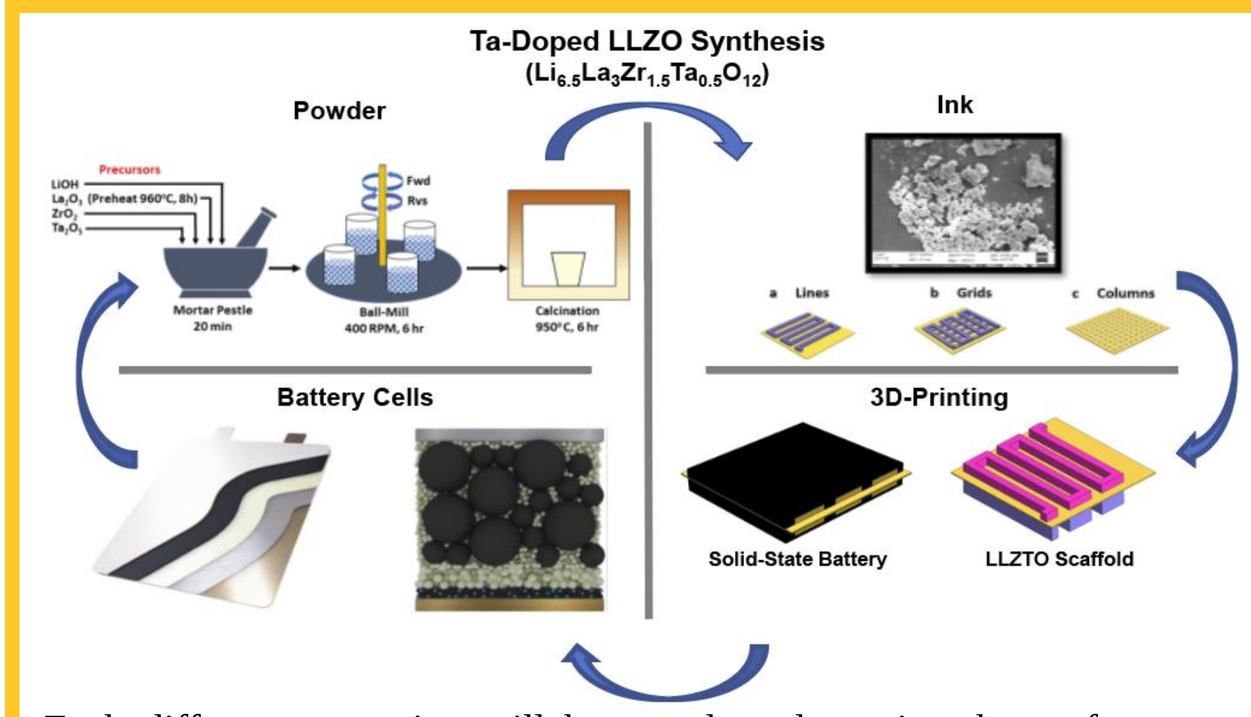
Tantalum-doped cubic garnets ($Li_{6.5}La_3Zr_{1.5}Ta_{0.5}O_{12}$, LLZTO) have been shown to decrease dendrite growth while creating a more stable battery against Li-metal, which has the highest negative redox [1].



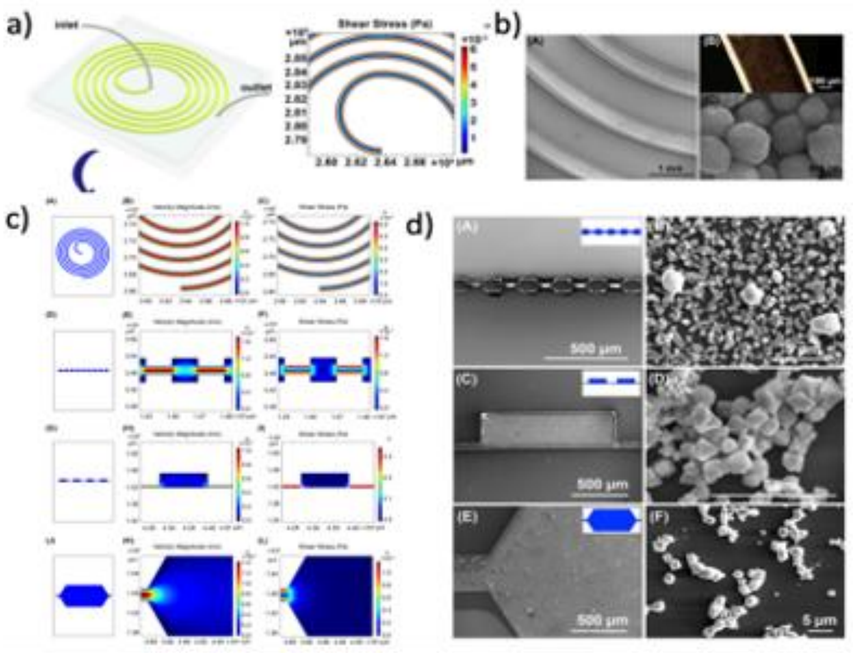
- Uniform contact area
- Wettability between electrode & electrolyte
- Penetration at contact points
- Penetration along grain boundaries

- *ACS Energy Letters* **2020** 5 (3), 833-843 DOI: 10.1021/acsenergylett.9b02660
- *C&EN Global Enterprise. 2019;97(48):10-10. doi:10.1021/CEN-09748-SCICON6*

Overview & Testing



Each different patterning will be tested to determine the performance behavior of our SSE batteries. We hypothesize the ionic conductivity may increase based on uniform shear stress from the patterns [4]. Also, different patterns may be tailored for blocking dendrite propagation which will create stability and have higher energy density.



- Spiral
- Contraction & Expansion
- Side Chamber
- Hexagonal

Testing:

- PEIS (Potentio Electrochemical Impedance Spectroscopy)
- GCPL (Galvanostatic Cycling with Potential Limitation)

Acknowledgements

Website:
https://sites.google.com/site/kenansonglab/home?authuser=0

Ira A. Fulton Schools of Engineering Arizona State University
ASU Global Sport Institute Arizona State University
ASU Rob and Melani Walton Sustainability Solutions Initiatives Arizona State University
City of Phoenix Public Works Department
ASU ASURE
KEEN Engineering Unleashed
ASU Biodesign Institute Arizona State University
Fusion A Scientific Retreat

References

[1] Pavan Pramod Badami, "Facile Synthesis Approaches for High Lithium Ion Conducting Garnet Structures ," Mesa, 2021.
[2] D. W. McOwen et al., "3D-Printing Electrolytes for Solid-State Batteries," Advanced Materials, vol. 30, no. 18, May 2018, doi: 10.1002/adma.201707132.
[3] C. Wang et al., "Garnet-Type Solid-State Electrolytes: Materials, Interfaces, and Batteries," Chemical Reviews, vol. 120, no. 10. American Chemical Society, pp. 4257–4300, May 27, 2020. doi: 10.1021/acs.chemrev.9b00427.
[4] Y. Nie, C. Jin, and J. X. J. Zhang, "MicrofluidicIn SituPatterning of Silver Nanoparticles for Surface-Enhanced Raman Spectroscopic Sensing of Biomolecules," ACS Sensors, vol. 6, no. 7, 2021, doi: 10.1021/acssensors.1c00117.
[5] M. R. Manfredo and C. J. Shultz, "Risk, Trade, Recovery, and the Consideration of Real Options: The Imperative Coordination of Policy, Marketing, and Finance in the Wake of Catastrophe," vol. 26, no. 1, pp. 1547–7207, 2007.

FURI

Ira A. Fulton Schools of Engineering
Arizona State University