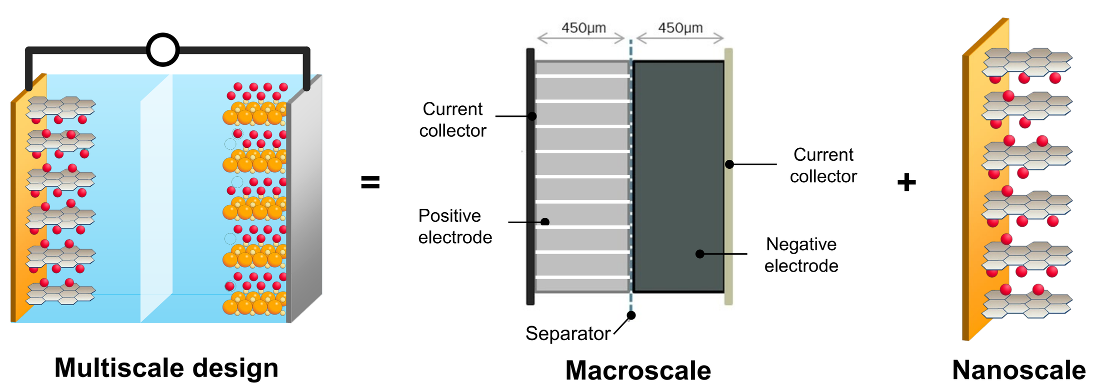
3D Printing for Structured Composite Electrodes of Li-ion Batteries

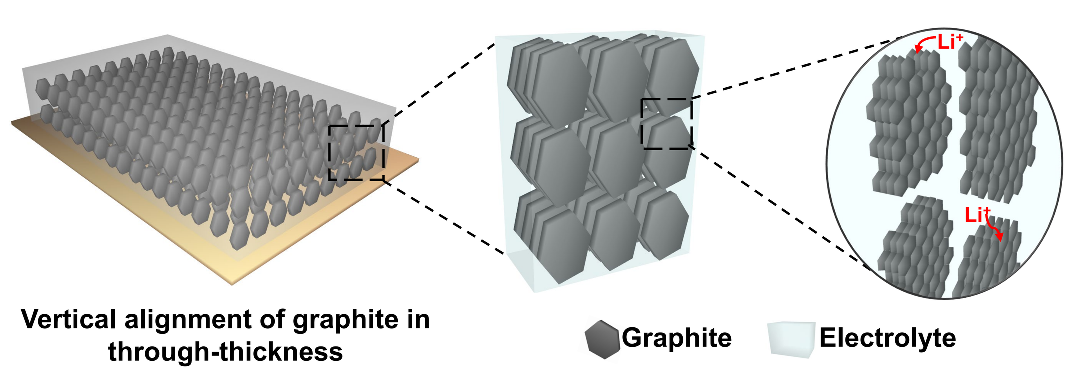
Soyeon Park (Ph.D.M.E.)[1], and Prof. Kun Fu [1,2]
University of Delaware | Department of Mechanical Engineering[1] | Center for Composite Materials[2]

Introduction

The through-thickness oriented graphite flakes reduce ion path for enhanced lithium-ion mobility within the electrode and increase the availability of preferential intercalation paths within graphite flakes, both promoting power-and-energy dual enhancement in thick electrodes.



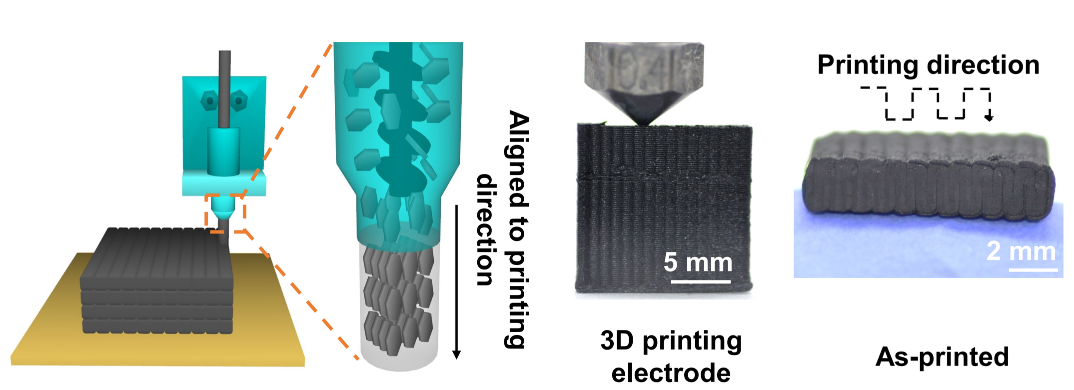
3D printing can rapidly fabricate structured electrodes with an out-of-plane aligned architecture with low tortuosity and mechanical robustness.



3D printing structured electrodes

The shear forces generated by passing a nozzle at high pressure can orient anisotropic materials along their length.

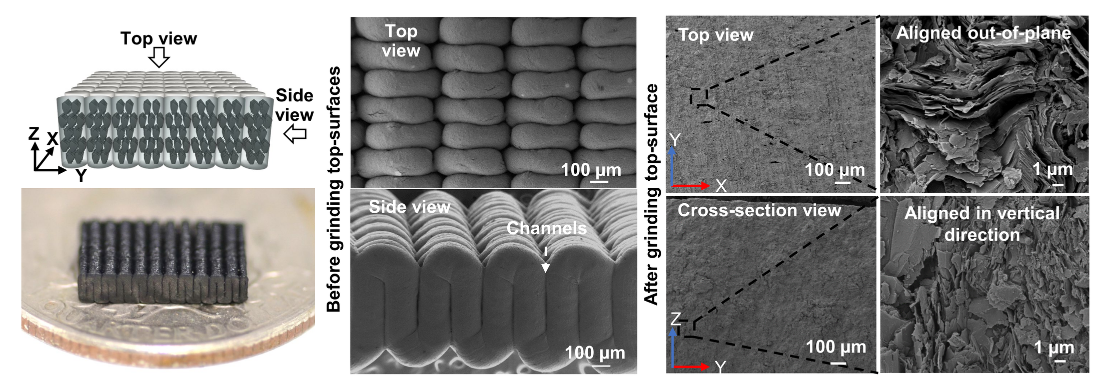
According to the designed printed pattern, the structured electrode has graphite aligned with out-of-plane and densely packed columns without defects.



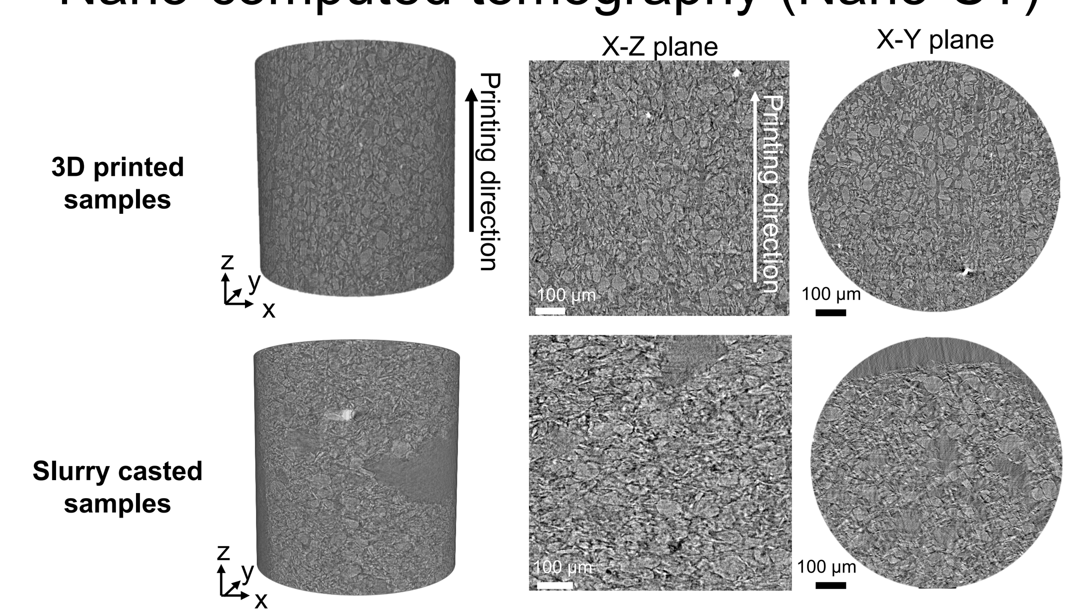
Morphological and physical properties of 3D printed structured electrodes

The orientation of graphite was confirmed by characterizing the internal structure of the printed electrode by non-destructive scanning (SEM, Nano CT, XRD).

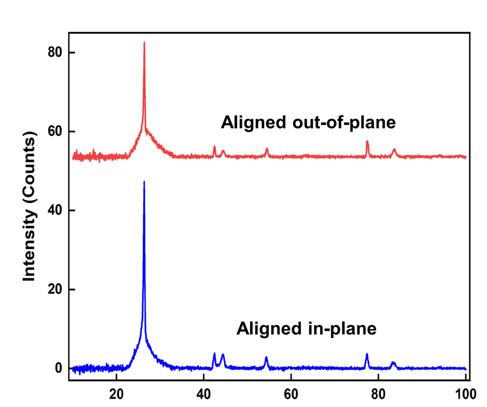
- Scanning electron microscope (SEM)



- Nano-computed tomography (Nano-CT)

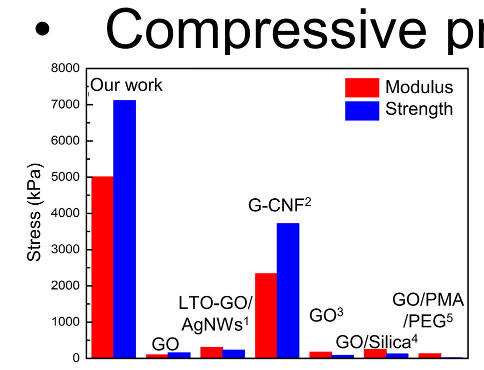


- X-ray diffraction (XRD)



Tracking the intensity of the (002) Bragg peak corresponding to the graphite basal plane reveals the out-of-plane-alignment of graphite.

- Compressive properties

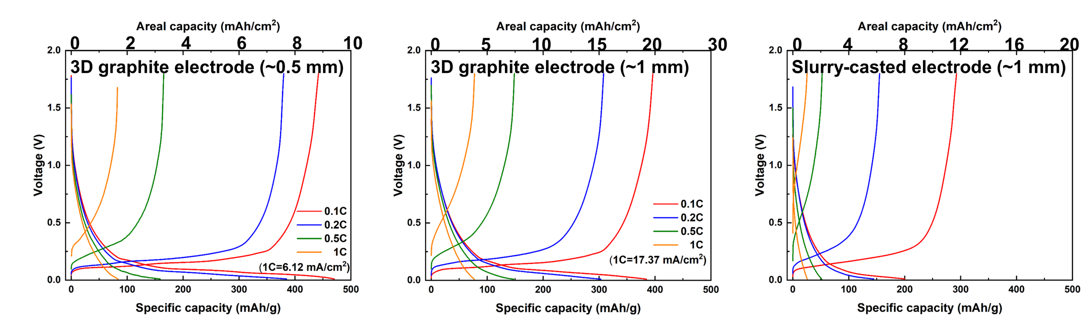


Reference
1) Sun et. al. (2020). Chem. Eng. J.
2) Liu et. al. (2021). Small Methods.
3) Zhang et. al. (2016). Small.
4) Zhu et. al. (2015). Nat. Commun.
5) García-T'On et. al. (2015). Adv. Mater.

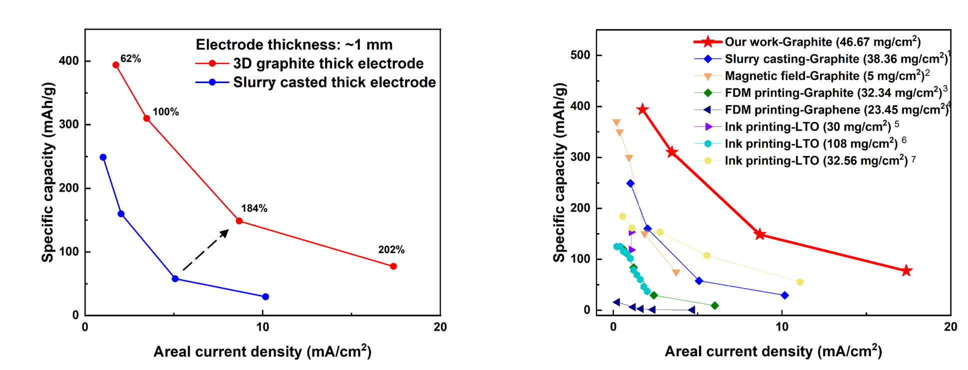
The structured electrode has higher compressive properties than the other reported 3D printed electrodes, showing good structural stability.

Electrochemical performances of the structured electrodes

- Rate cycling

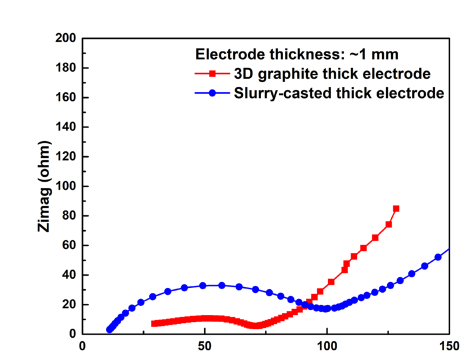


The 0.5mm thick structured electrode delivered the highest specific capacity of ~ 80 mAh/g at 1C. On the other hand, the slurry-casted electrode delivered a much lower capacity of ~ 25 mAh/g at 1C.



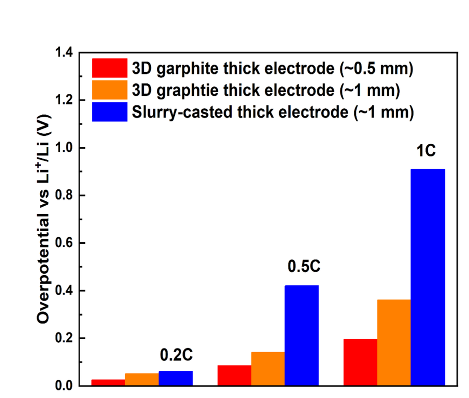
As the current density increases, the performance gap increases, more than doubling at 1C. Our 3D printed structured electrodes have high electrode material loadings and can achieve highest capacity due to the aligned graphite structure

- Electrochemical impedance spectroscopy (EIS)



The structured electrode showed a lower charge transfer resistance than the reference electrode.

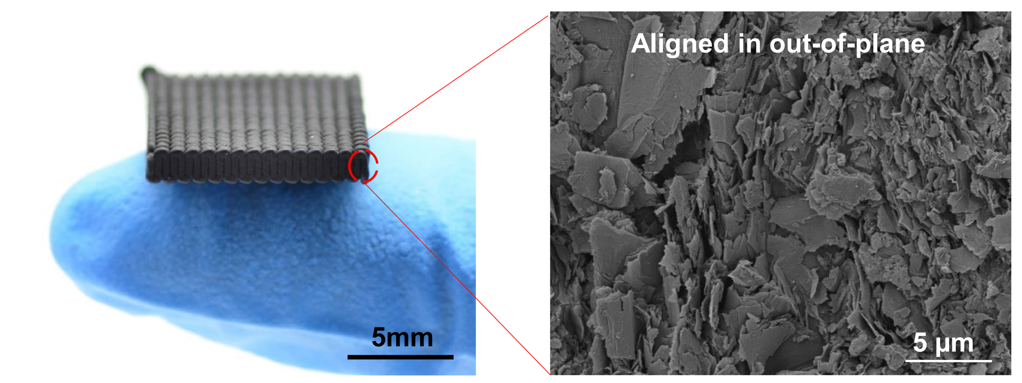
- Overpotential



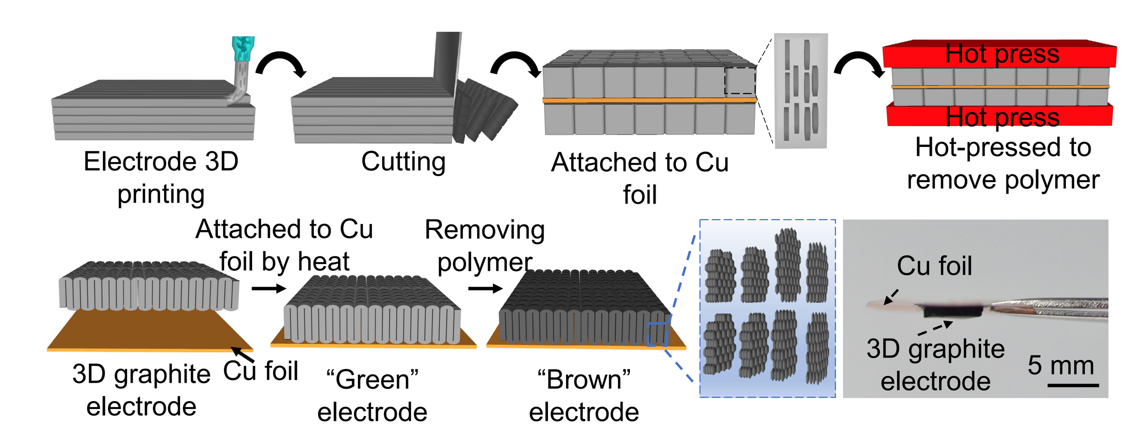
The gap between the overpotential of the structured and the reference electrode increases with a current.

Conclusions

We developed electrode fabrication process using 3D printing and produced structured electrode with out-of-plane aligned architecture, which delivered improved electrochemical performance and showed enhanced mechanical properties.



3D printing has the potential to fabricate structured electrodes on a large scale. As a laboratory-scale demonstration, single-sided electrodes were made by co-sintering electrodes/current collectors.



Acknowledgements

This work was funded by the University of Delaware startup.

We thank members of the Advanced Materials Characterization Lab (AMCL) for assisting characterization.