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Title
Printing Energy Storage On-Chip

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Publication Date
2008

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Printing Energy Storage On-Chip

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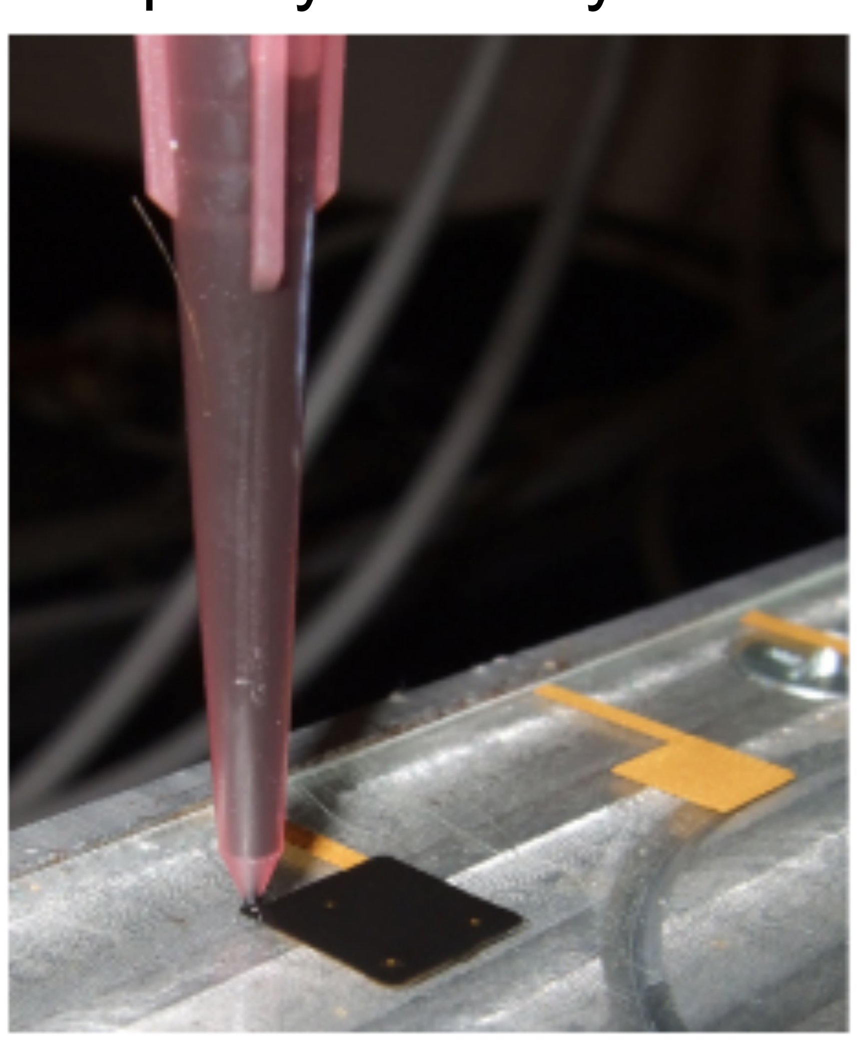
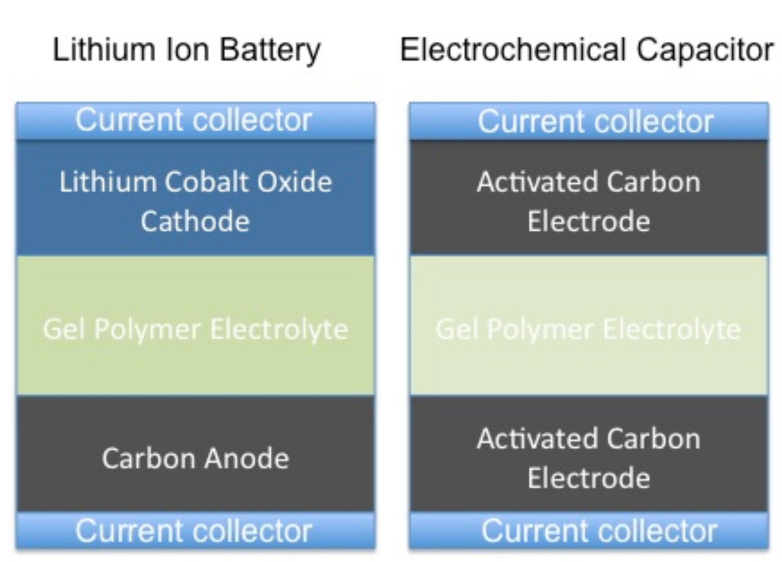
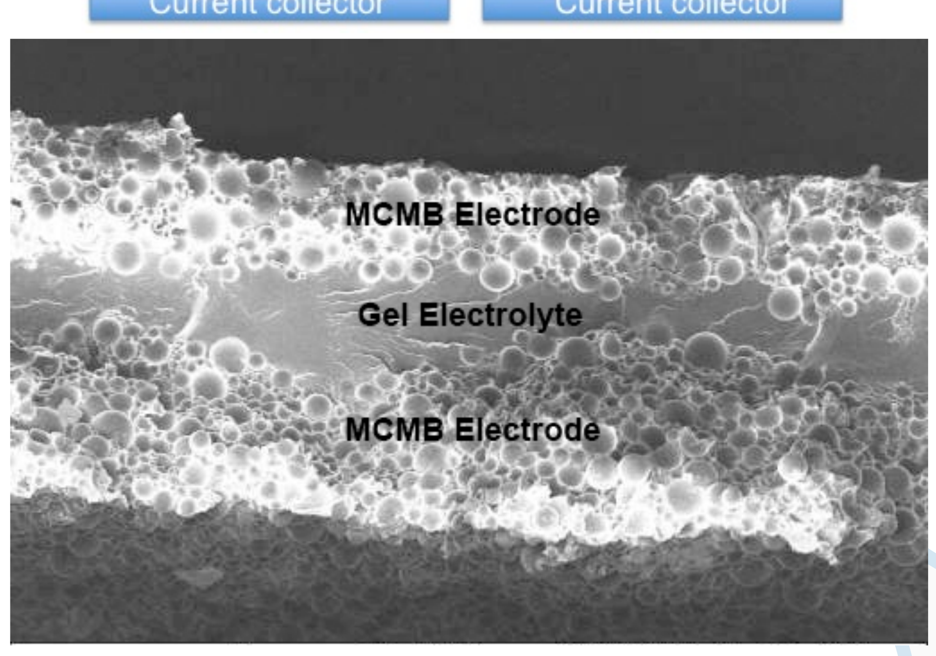
Vision

We are using a direct write dispenser printing method for integrating both lithium ion batteries and electrochemical capacitors directly on a substrate. Direct write tools are environmentally economical and require less processing steps than standard fabrication since materials are deposited additively without waste generation, and require no masking or etching. For electronic devices with a total monolithic volume of ≤$1cm^3$, our dispenser printer is a more viable fabrication method for making energy storage devices as opposed to typical casting processes, which require the battery or capacitor components to be assembled and packaged separate from the device, as well as thin-film microfabrication approaches, which use deposition tools that are unable to deposit sufficient amounts of electrode material, therefore limiting the capacity of the system.



Dispenser Printer



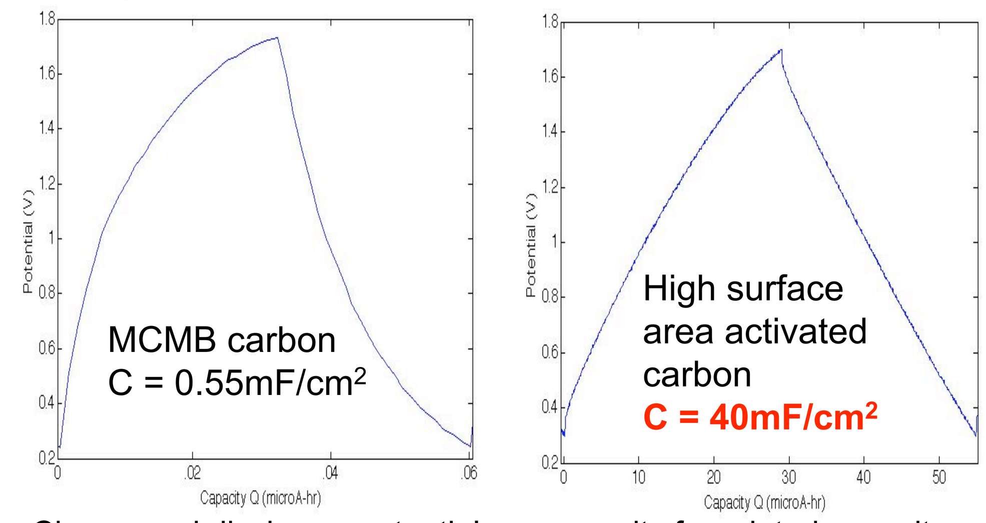


SEM micrograph of capacitor cross section

Methods

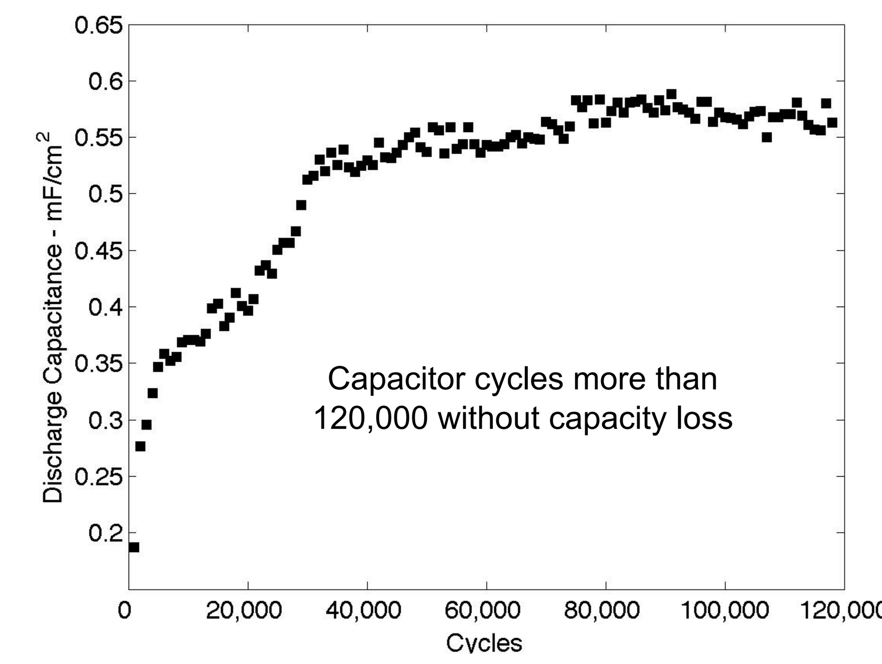
Our printer is able to deposit films with thicknesses ranging from <1µm to 100 µm per pass, and this flexibility enables the fabrication of thick film electrodes and thin film electrolytes. Furthermore, the dispenser printer is able to deposit a range of materials such as slurries, suspensions, and sol-gels, all of which can be printed at room temperature in ambient conditions. The system is also indiscriminate to the substrates (silicon wafers, printed circuit boards, glass, plastic) it can deposit on, and is able to maximize any open space around neighboring components on a substrate and utilize it for storage capacity.

Improved Capacitor Performance Using Higher Surface Area Carbon

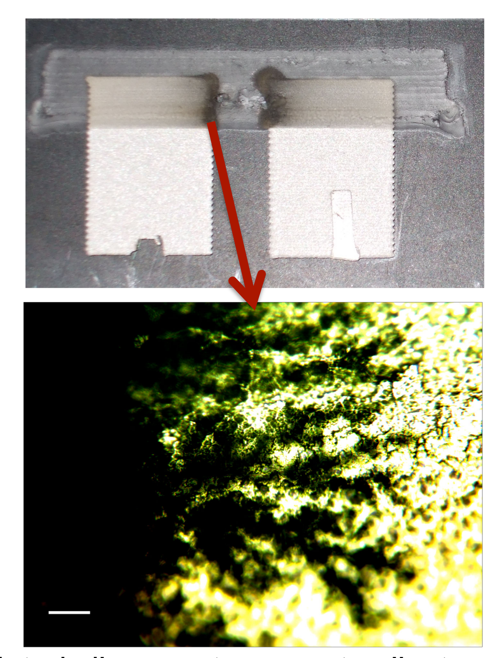


Charge and discharge potentials vs capacity for printed capacitors with (left) mesocarbon microbeads electrodes and (right) high surface area activated carbon electrodes.

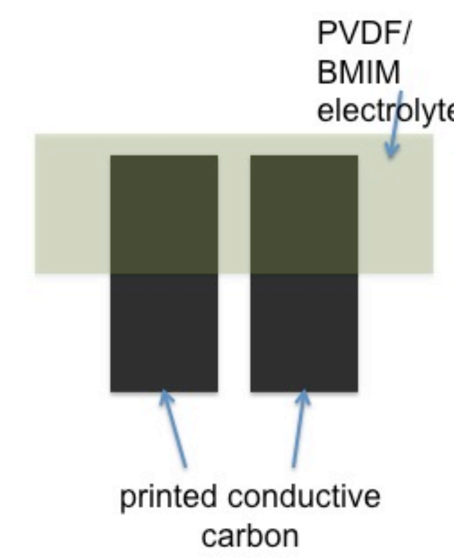
Cycle Life of Printed Capacitor

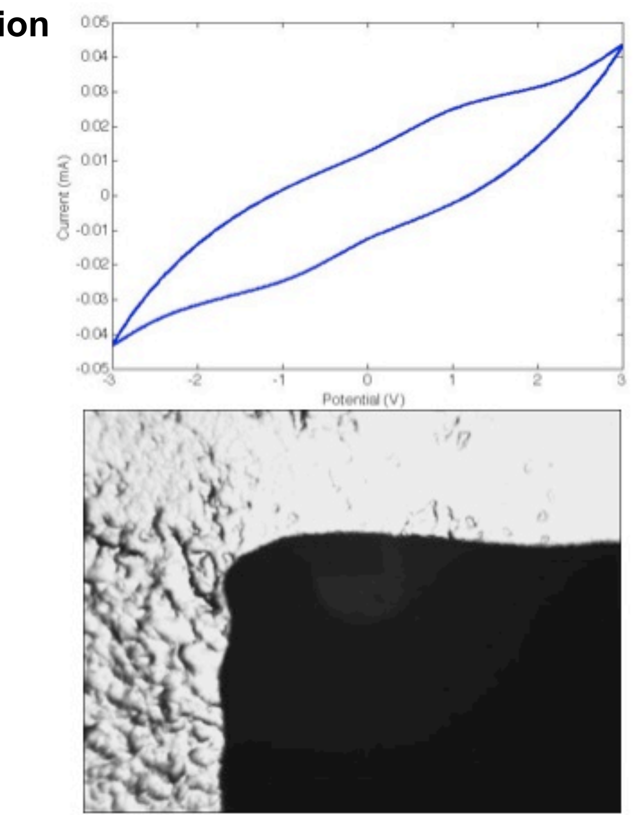


Printed Current Collector Materials – Avoiding Dendrite Formation



Printed silver paste current collectors form dendrites upon cycling





Using a printed conductive carbon as the current collector instead, the device cycles without showing signs of breakdown during cyclic voltammetry (top). No dendrites are visible in the micrograph (bottom)

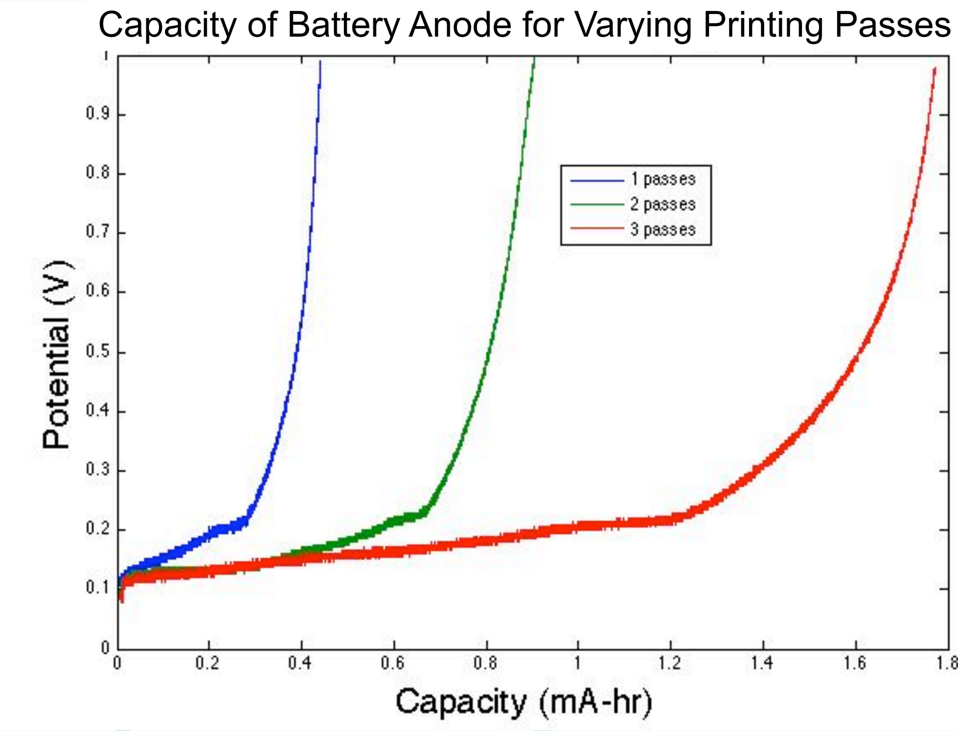
Research Questions

•What materials will provide maximum energy storage and power performance at small dimensions?
•How can a material's properties be tailored so that it can be printed using dispenser processing?
•What geometries can be patterned using the dispenser printer and how will they optimize the electrochemical performance of the energy storage device?

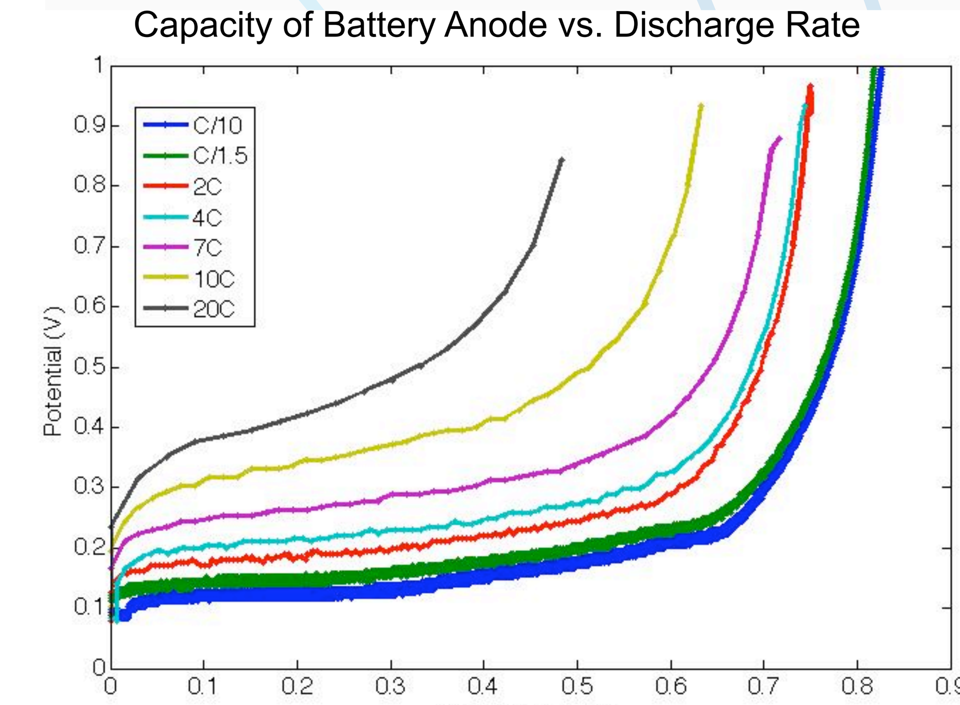
Findings

Printed electrochemical capacitors showed excellent cycling behavior (>120,000 cycles). Improved capacitance (by two orders of magnitude) have been measured when higher surface area carbons are used as electrode materials.
Lithium ion battery electrode materials have been tested in half cell configuration against lithium foil. The electrode thickness can be easily tailored by the printer for required energy and power performance.

Capacity of Battery Anode for Varying Printing Passes



Capacity of Battery Anode vs. Discharge Rate



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