Title
Printed Energy Storage Devices

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Printed Energy Storage Devices

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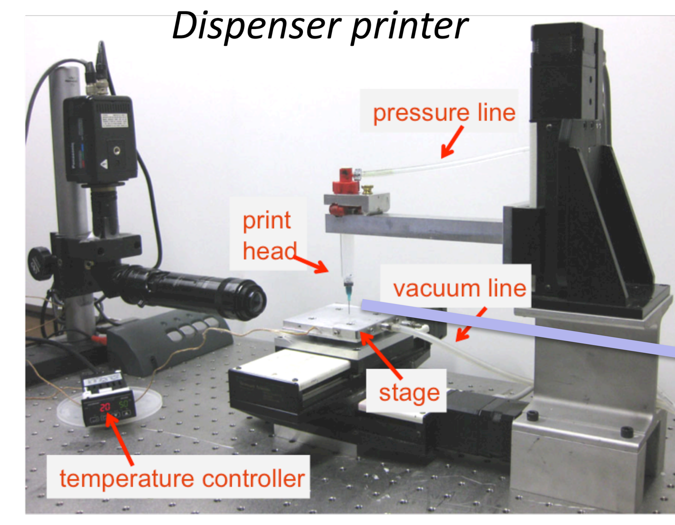
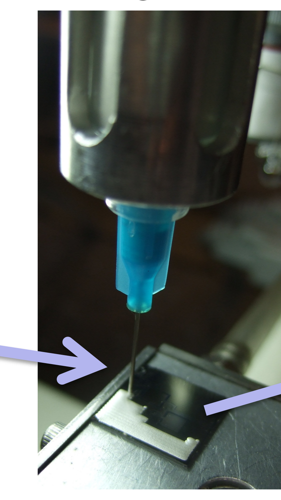
Vision

We are exploring direct write printing methods for integrating both batteries and electrochemical capacitors directly onto 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 able to pattern energy storage devices with lateral and vertical control within a few microns, resulting in the precise tailoring of energy storage for a microdevice.

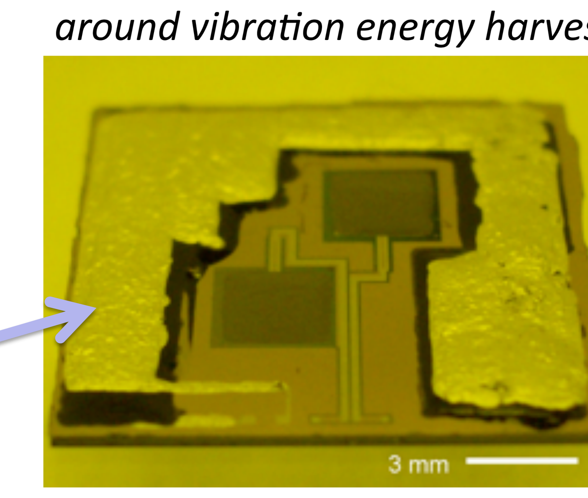
Dispenser printer



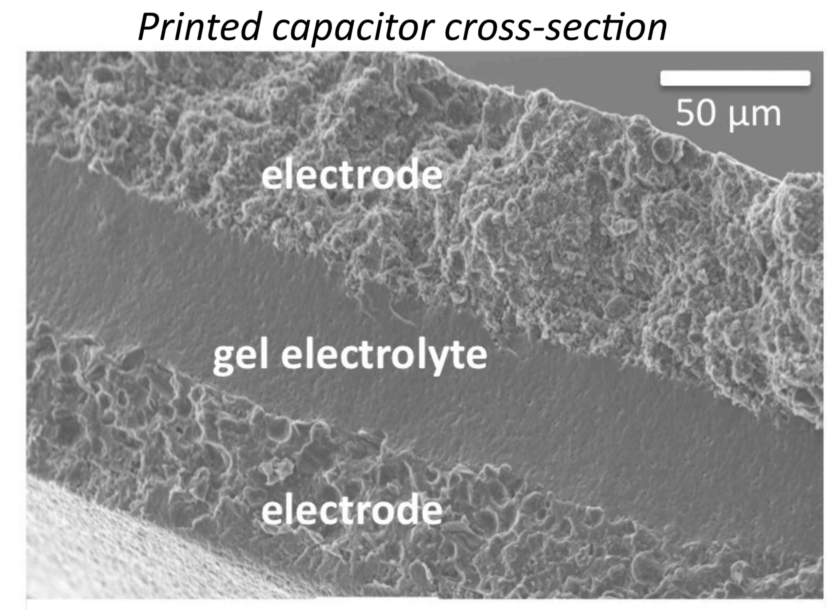
Integration



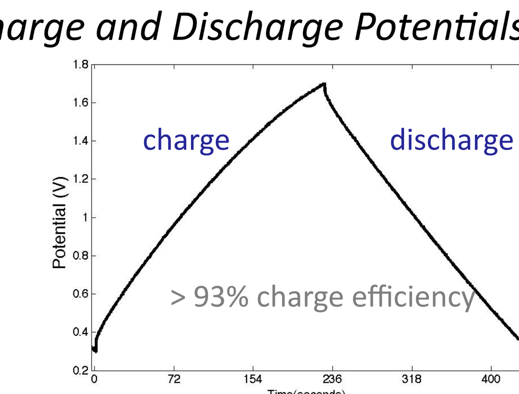
Hybrid power supply with capacitor printed around vibration energy harvester



Printed capacitor cross-section

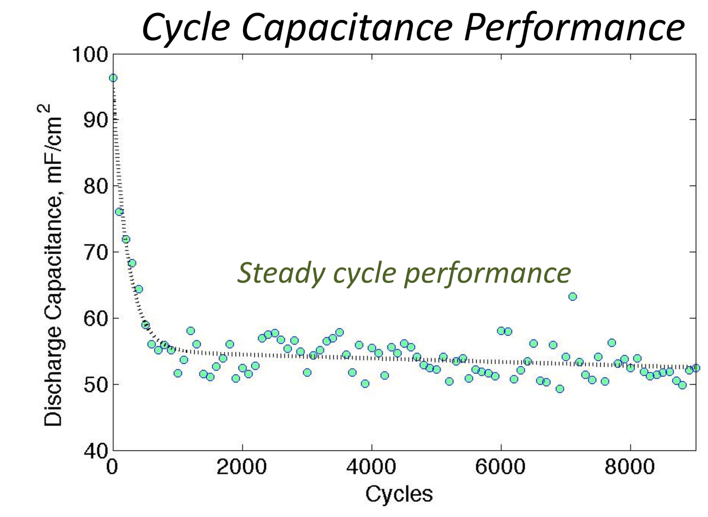


Charge and Discharge Potentials for 1 mA



Capacitor current performance
Capacitance: 100 mF/cm^2
Max. Power : 600 µW/cm^2 (60 mW/cm^3, 50 W/kg)
Energy Density: 10 µW-hr/cm^2 (1 mW-hr/cm^3, 1 W-hr/kg)
ΔV : 2 V
More than 120,000 cycles

Cycle Capacitance Performance



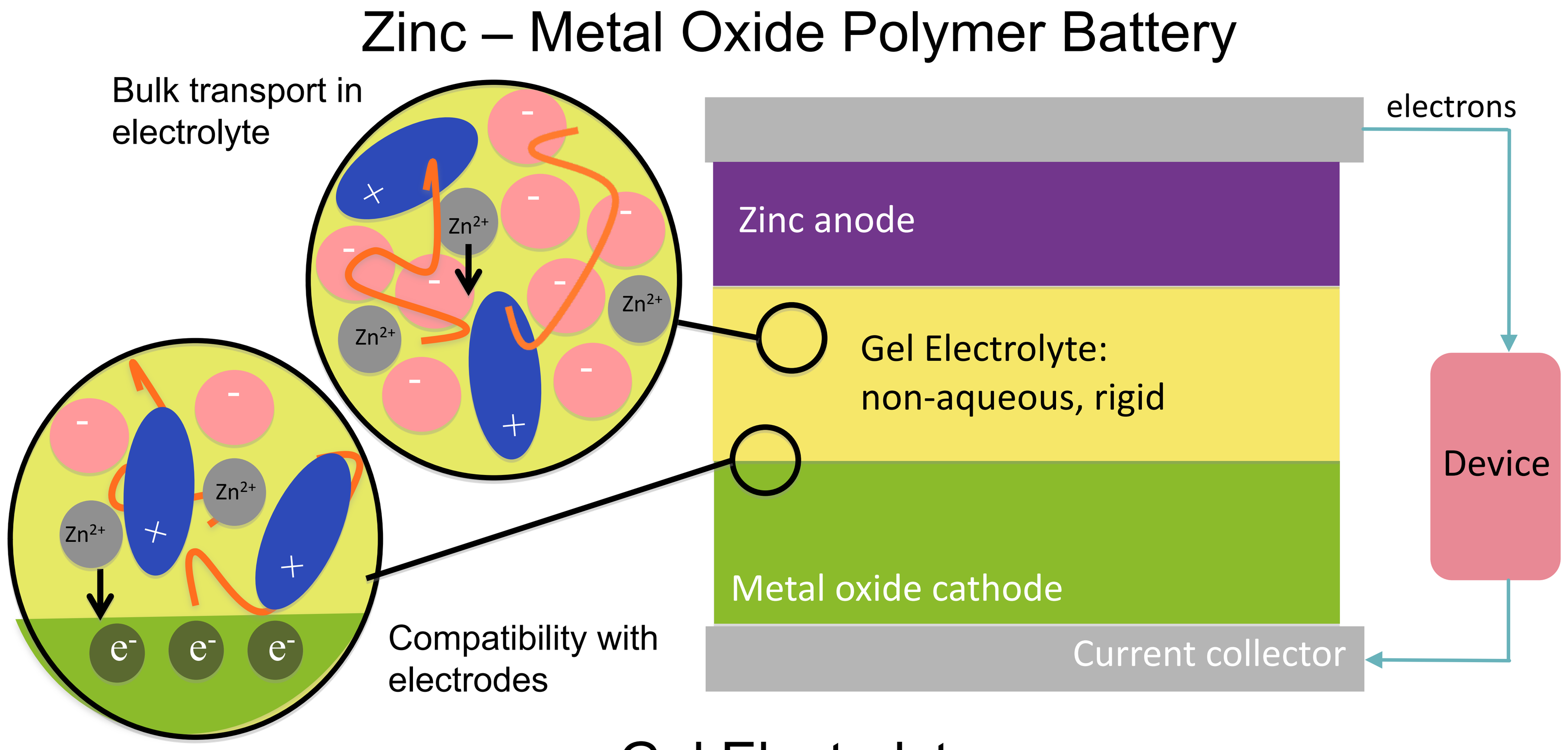
Zinc Polymer Battery

Zinc-metal oxide polymer batteries are especially attractive for applications requiring lower operating voltages (1-2 V nominal), lower cost, and higher safety (zinc is not as reactive as lithium metal; no liquid components are used). A gel electrolyte system utilizing non-aqueous ionic liquids swollen in a polymer (PVDF-HFP) binder was developed. Ionic liquids provide unique properties, including a negligible vapor pressure and are non-flammable. The resulting gel electrolytes have solid-like mechanical properties, but liquid like transport properties, therefore simplifying the fabrication process and packaging while outputting electrochemical performances similar to commercial zinc batteries.

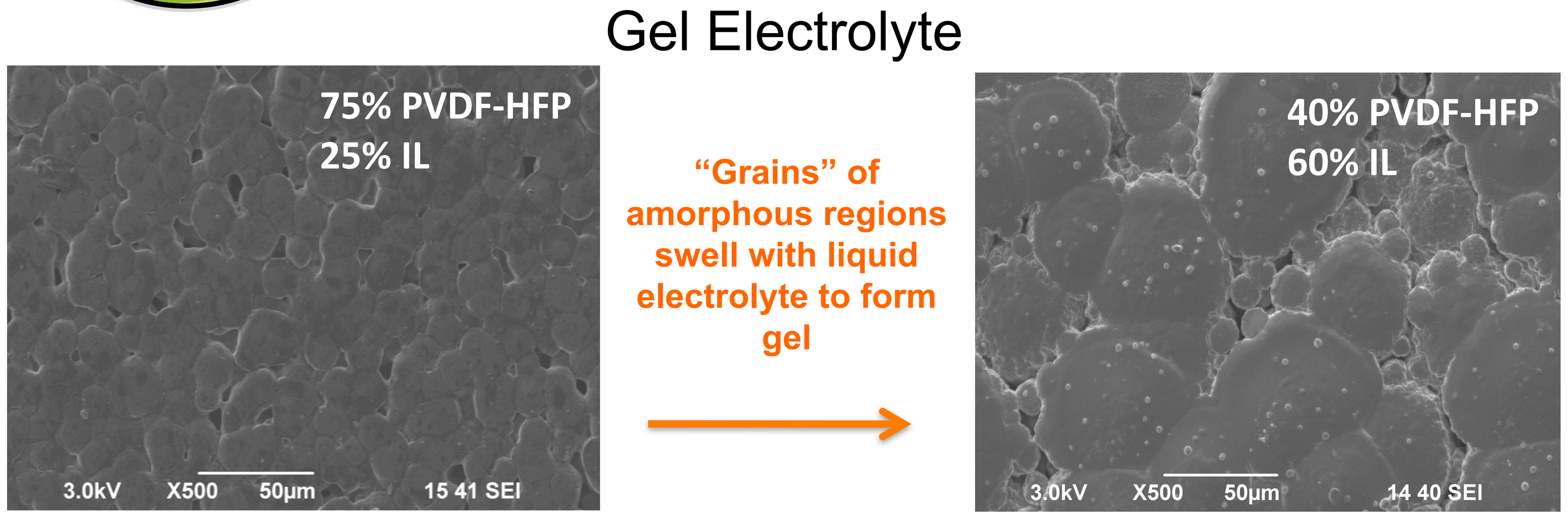
Electrochemical Capacitor

Electrochemical capacitors are fabricated via the successive printing of current collector, activated carbon electrode, and ionic liquid gel electrolyte films into a symmetric configuration. The capacitors show excellent cyclability (>120,000 cycles) without performance degradation. By utilizing carbon powder with higher surface area and microporosity, recent capacitors have shown power densities as high as 600 µW/cm^2 and 100 mF capacitance. The dispenser printer's ability to precisely pattern lateral and vertical dimensions of a film enables the integration of energy storage devices tailored for a given application. We have demonstrated the physical integration of a printed capacitor surrounding two vibration energy harvesting cantilever device and attempt to develop an integrated hybrid micropower supply for such applications as active RFID tags.

Zinc – Metal Oxide Polymer Battery

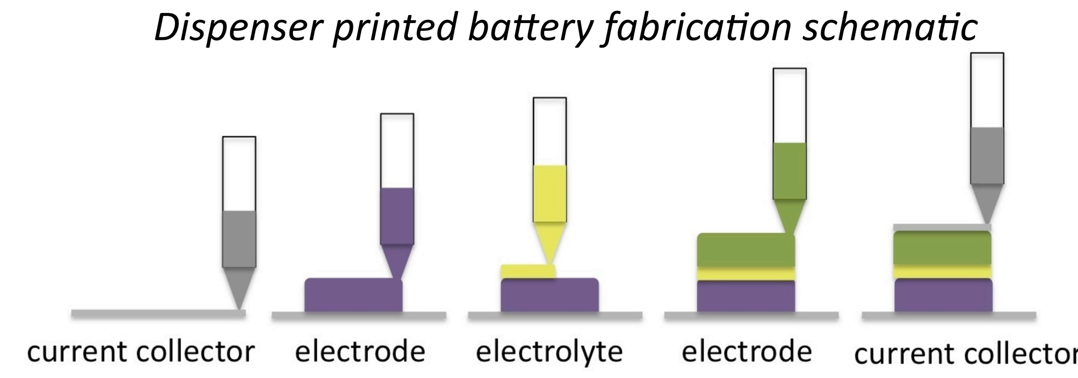


Gel Electrolyte



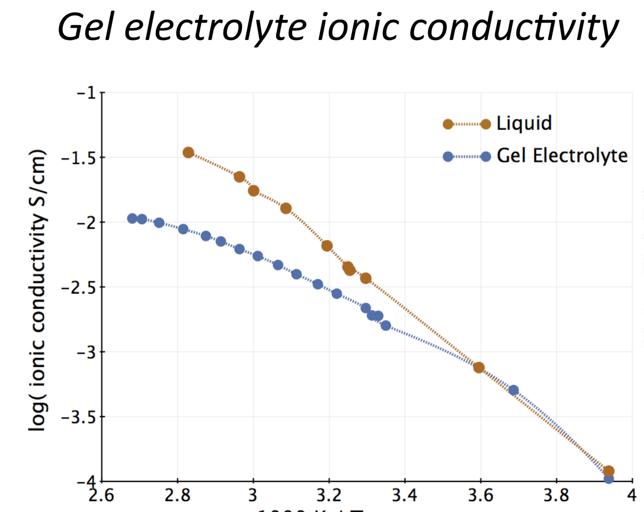
Zinc Polymer Battery Performance

Dispenser printed battery fabrication schematic

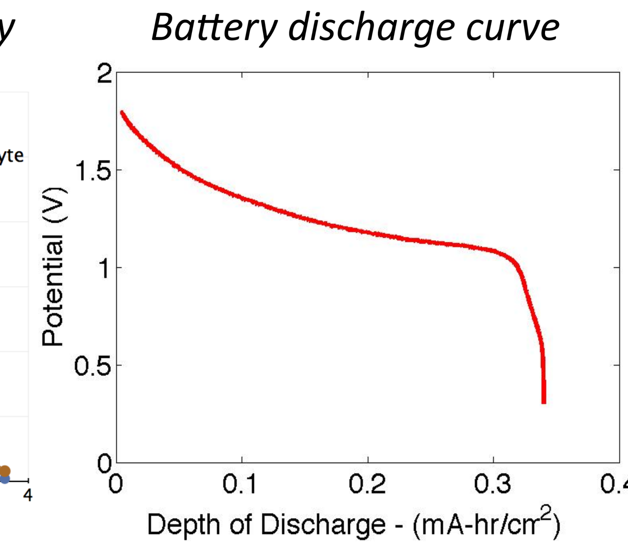


Battery current performance
Capacity: 1 mA-hr/cm^2
Energy Density: 1.5 mW-hr/cm^2 (150 mW-hr/cm^3, 130 W-hr/kg)
Operating Voltage : 1.2 - 1.5 V

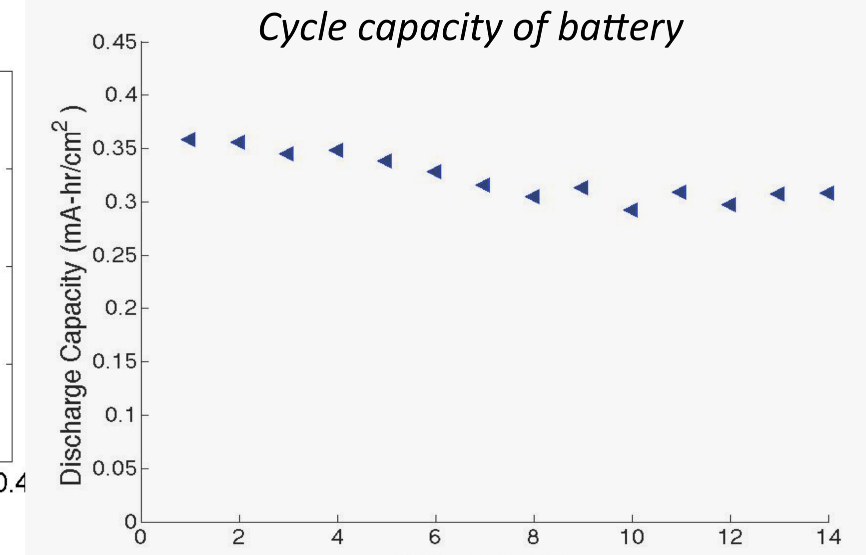
Gel electrolyte ionic conductivity



Battery discharge curve



Cycle capacity of battery



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