

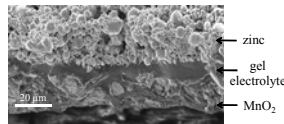
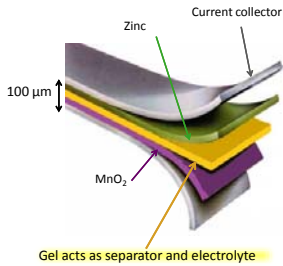
Printed Energy Storage Devices

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and Prof. Paul Wright

Printed Batteries

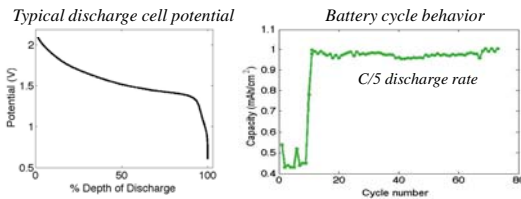
We have developed a dispenser printed battery composed of zinc and manganese dioxide electrodes sandwiching an ionic liquid gel electrolyte.

- Zinc battery chemistries:**
- High power and energy densities
 - Inherent safety & low toxicity
 - Ease in handling and processing
 - Low cost



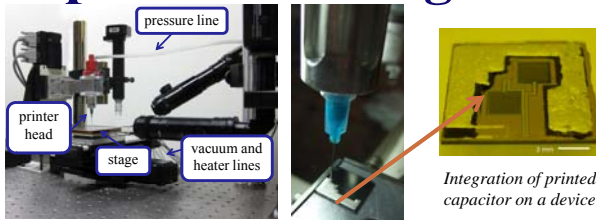
Microbattery cross-section

The ionic liquid gel has very unique properties: fast ion transport, mechanically robust even under compression, and it does not “sweat” or dry out over time.



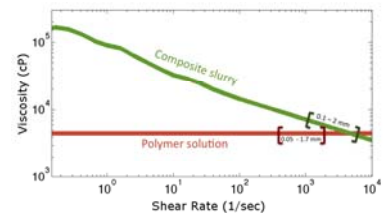
| Current microbattery performance | | |
|----------------------------------|---|-------------------|
| Capacity | Energy Density | Operating Voltage |
| 1 mAh/cm ² | 1.5 mWh/cm ² 150 mWh/cm ³ 130 Wh/kg | 1 - 2 V |

Dispenser Printing

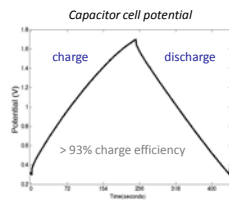
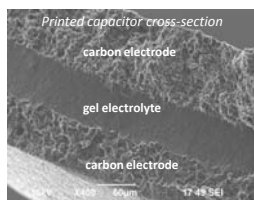


Custom dispenser printer

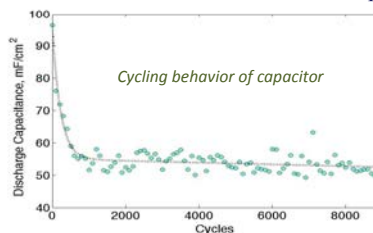
- Capable of 10-300 μm size factors
- Large viscosity range (100-10000 cP)
- Ambient, room temperature process
- Low waste
- Fast, scalable, economical



Carbon electrochemical capacitors, having similar materials constituents and geometric configuration, are being developed concurrently with the printed batteries.

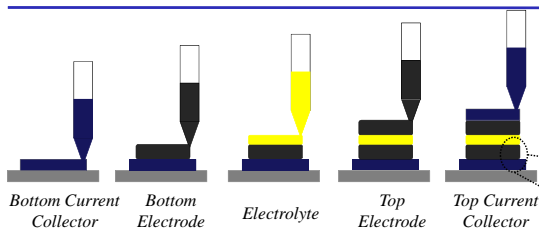


These are very stable and reversible devices; we have cycled a capacitor more than 120,000 times without performance degradation.

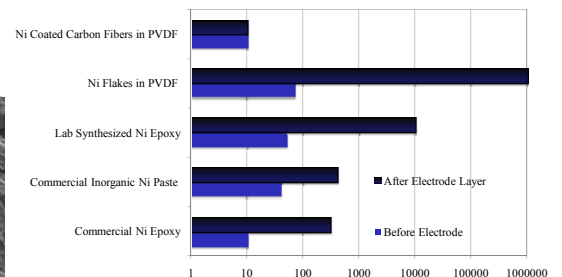
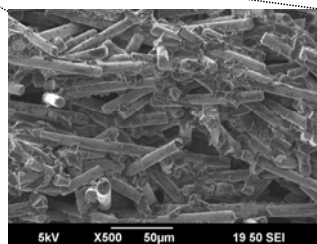


| Current electrochemical capacitor performance | | | |
|---|--|--|-------------------|
| Capacitance | Max. Power | Energy Density | Operating Voltage |
| 100 mF/cm ² | 600 μW/cm ² 60 mW/cm ³ 60 W/kg | 10 μW-hr/cm ² 1 mW-hr/cm ³ 1 W-hr/kg | 0 - 2 V |

Printed Current Collectors



Since we want our devices to be fully printable, we have recently made advancements in a printable current collector made up of nickel coated carbon fibers in a polymer matrix.



Current Collector Sheet Resistance (Ohms)