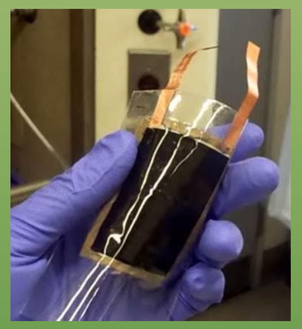
Development of Flexible, Conformal Batteries with Nanostructured Electrodes

Zhiqian Wang, Zheqiong Wu and Somenath Mitra

Department of Chemistry and Environmental Science, New Jersey Institute of Technology, Newark, NJ 07102

Introduction: The next revolution in electronics is expected to be in flexible electronics such as rollup displays, wearable devices, electronic identification tags, smart cards, and implanted medical devices. These require flexible and bendable energy storage devices that can be implemented for example on a small patch. Flexible battery developed in our laboratory can be light weight, conformal meaning can be in any shape, have the potential to provide easy transportability and integration into small electronics. Our battery is based on nanotechnology using carbon nanotubes (CNTs) along with printing methods that offers the potential for high throughput fabrication/manufacture of these devices.

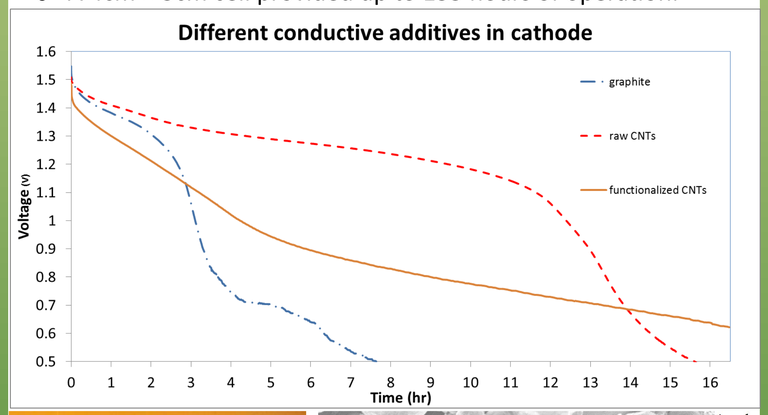


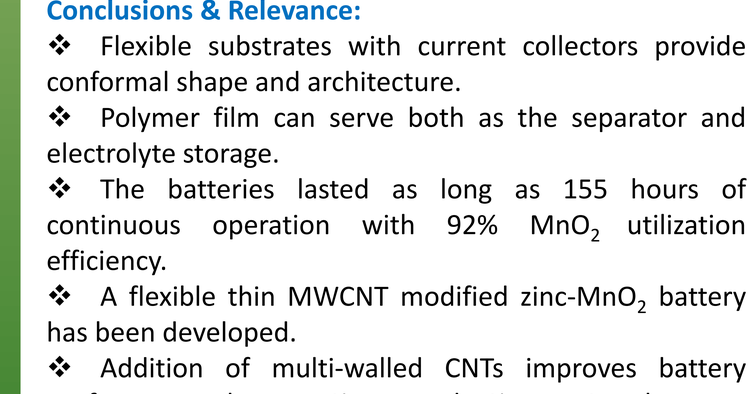
Characterization:

- Battery System: Zinc-Carbon; Alkaline
- Nominal voltage: 1.5 V – 1.3V
- Cut off voltage: 0.9V
- Typical Size: 40mm x 30mm x 1mm
- Typical Capacity: 70mAh

Results and Discussion:

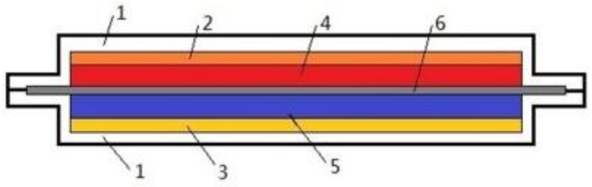
- Multi-walled carbon nanotubes (MWCNTs) led to higher conductivity and battery performance.
- Discharge efficiency increased with more efficient conductive network. Battery showed higher capacity and longer lifetime.
- Functionalization of CNTs caused decrease in performance due to the defects on CNT surface.
- A 4cm × 3cm cell provided up to 155 hours of operation.





Fabrication of flexible batteries:

- Developing formulation comprising of active materials, binder and conductive additives.
- Separator fabrication.
- Formation of homogeneous slurry.
- Electrode formation via coating.
- The battery assembly with separator and current collector.

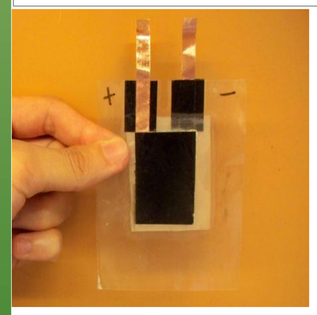


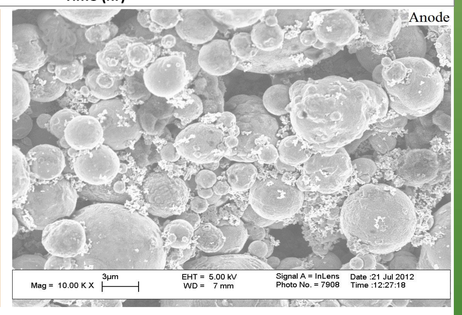
Cross sectional view of Flexible printed battery: 1. Laminated Substrate; 2.Cathode Current Collector; 3.Anode current collector; 4. Pasted Cathode; 5.Pasted Anode; 6.Separator.

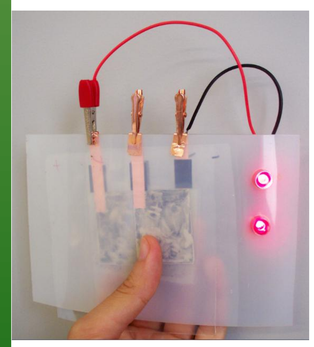
Reactions:

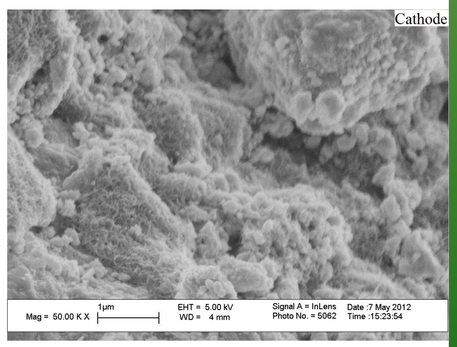
$$Zn(s) + 2\,MnO_2(s) + ZnCl_2 + 2\,H_2O(l) \longrightarrow 2\,MnO(OH)(s) + 2\,Zn(OH)Cl(aq)$$

$$Zn(s) + 2\,MnO_2(s) \xrightarrow{KOH} Mn_2O_3(s) + ZnO(s)$$









***Reference:**

Z. Wang, N. Bramnik, S. Roy, G. D. Benedetto, J. L. Zunino III, S. Mitra, J. Power Sources (2013), doi: 10.1016/j.jpowsour.2013.02.094

Conclusions & Relevance:

- ❖ Flexible substrates with current collectors provide conformal shape and architecture.
- ❖ Polymer film can serve both as the separator and electrolyte storage.
- ❖ The batteries lasted as long as 155 hours of continuous operation with 92% MnO_2 utilization efficiency.
- ❖ A flexible thin MWCNT modified zinc-MnO_2 battery has been developed.
- ❖ Addition of multi-walled CNTs improves battery performance by creating conductive network more efficiently comparing with graphite.
- ❖ Micron sized anode particles balanced among reactivity, stability and flexibility.
- ❖ MWCNTs, served as a more efficient conductive additive alternative to conventional graphite in MnO_2 cathode composite.

Acknowledgement:

- ❑ US Army is acknowledged for funding.