# The Effect of Single Walled Carbon Nanotubes on Lithium-Ion Batteries and Electric Double Layer Capacitors

C. Moran, Y. Abe, K. Sato, S. Umemoto, T. Yanagiura, M. Endo
Faculty of Engineering, Shinshu University, Nagano, Japan

## Introduction

We tested the effects of SWNTs on the overall performance of Li-ion batteries and EDLCs.

SWNTs were incorporated into the anode of the Lithium-ion Battery (LIB). A LIB using only graphite in the anode was the control.

SWNTs were mixed with activated carbon in the EDLC to act as conductors. An EDLC containing no SWNT was the control. Activated carbon is used because of its high surface area.

### Better than Other Secondary Batteries:

Lithium-ion Batteries

•Higher energy density than other secondary batteries

•High voltage (3.6 V)

•No memory effect

Image courtesy of Y. Abe and T. Yanagiura

weight


Application: cell phone, camera and laptop batteries

EDLCs

•High power density

•High charge/discharge efficiency (>90%)

•Short charge/ discharge time

•No pollution

### How it works:

Li-ion Battery

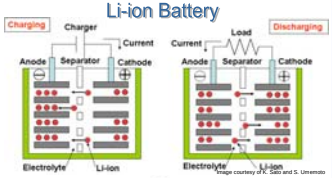


Image courtesy of K. Sato and S. Umemoto

EDLC

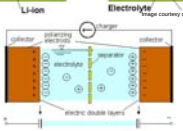


Image courtesy of Y. Abe and T. Yanagiura

## Experiment

### Li-ion Battery

ANODE: HiPco SWNT + PVdF binder pressed into zinc mesh

DEVICE: assembled with Lithium metal cathode

Image courtesy of K. Sato and S. Umemoto

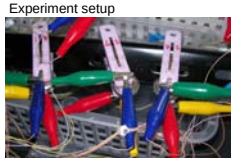
Order of assembly of Li-Battery

Current Rate: 30mA/g
Electrolyte: EC+DEC
Supporting electrolyte : LiClO4(1mol)

Run 20 cycles to test capacity of charge/discharge

(1 cycle = charge and discharge of LIB)

Experiment setup



### EDLC

ELECTRODES: HiPco SWNT + PTFE binder + activated carbon

DEVICE: assembled with glassy carbon as current collector

Order of assembly of super capacitor

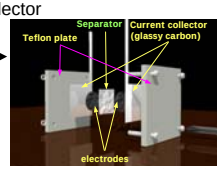
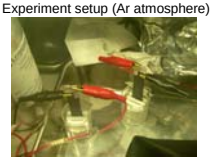


Image courtesy of Y. Abe and T. Yanagiura

Electrolyte:
1M, $Et_4NBF_4$/PC

Experiment setup (Ar atmosphere)



Potential/Galvanostat Method:

For each of three voltages – 2V, 2.5V and 3V – six discharge currents were tested – 1mA, 5mA, 10mA, 20mA, 40mA and 60mA.

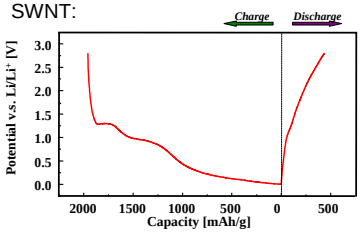
$$C = I \times \frac{t_2 - t_1}{V_1 - V_2} \quad [F]$$

Capacitance calculated using voltage and time at 60% and 40% of regulation voltage

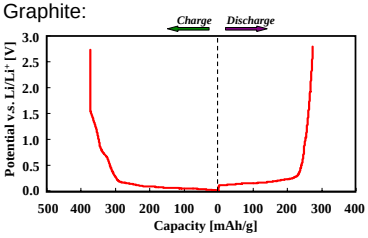
## Results

### Li-ion Battery

SWNT:

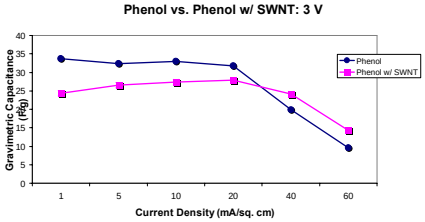



Graphite:

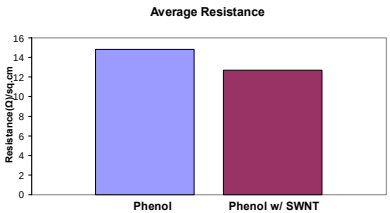



The LIB with SWNT reached a much higher capacity (close to 500 mAh/g) than graphite alone (close to 300 mAh/g).

### EDLC




Electrodes with SWNT only perform better at high current density (>30 mA/cm$^2$)




Electrodes with SWNT had a much lower resistance than plain activated carbon.

## Conclusions

### Li-ion Battery

•Using SWNT increased the capacity of the battery

•However, the battery was unable to hold a constant voltage.

•The graphite anode had a lower capacity, but was able to hold a voltage constant for an extended period of time.

### EDLC

•Adding SWNT improved the capacitance at high current densities.

•Resistance decreased with addition of SWNT

## Acknowledgements

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