Supercapacitors, with long cycle lives and long-term efficiency, have potential to become an appealing alternative to traditional energy storage devices. However, the specific energy of supercapacitors lags well behind current state-of-the-art lithium-ion batteries. Nevertheless, numerous opportunities exist to optimize supercapacitors through the manipulation of the structure and morphology of novel materials. The implementation of hybrid supercapacitors, a device which combines a pseudo-capacitor with an electrical double layer capacitor, are of interest because material composites have greater charge storage capabilities than their components alone. The most effective hybrid capacitors for charge storage are ones possessing high specific capacitance (capacitance per unit mass). The optimization of a composite for high specific capacitance requires changes to intrinsic material properties, either by changing chemical or physical structures.

**Composite Synthesis**

A desired mass (range of 100-1000 mg) of NANOCYS MWCNTs were dissolved in 50 mL of ethyl alcohol and sonicated for 5 minutes in a beaker. 75 mL of deionized (DI) water was added into mixture and stirred using stir bar. 1.968g of KMnO₄ (from Alfa Aesar) was added after DI water and stirred for 1 hour at room temperature. The precipitate was washed with DI water, decanted, and dried in an oven at 70°C for 24 hr. Afterwards, the material was ground into a fine powder for subsequent characterization.

**Characterization Methods**

- X-ray Diffraction to study phase purity of composite
- Transmission Electron Microscopy (TEM) to study morphological features
- Charge-discharge test via three electrode setup to relate electrode discharge time to charge storage capability.
- 4.84%, 16.9% and 33.7% mass MWCNT were the samples chosen for charge-discharge testing

**Charge-discharge Characteristics**

<table>
<thead>
<tr>
<th>MWCNT 4.84%</th>
<th>MWCNT 16.9%</th>
<th>MWCNT 33.7%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Capacitance</td>
<td>4.84% MWCNT</td>
<td>16.9% MWCNT</td>
</tr>
<tr>
<td>Current Density</td>
<td>0.5 A/g</td>
<td>74.50</td>
</tr>
<tr>
<td></td>
<td>1.0 A/g</td>
<td>67.34</td>
</tr>
<tr>
<td></td>
<td>2.0 A/g</td>
<td>54.12</td>
</tr>
</tbody>
</table>

**X-ray Diffraction**

- α-MnO₂ (211) peak is present but broad, suggesting poor crystallinity of both the control and composites.
- Emergence of (002) peak in 33.7% MWCNT sample suggests widespread lack of MnO₂ coverage / bare MWCNT.

**Summary and Conclusions**

- 16.9% MWCNT had highest specific capacitance of samples in every current density tested
- Qualitatively, aggregation thickness decreases as MWCNT increases until MWCNT is in excess and agglomeration becomes favorable
- Potential relationship between average MnO₂ aggregation thickness and specific capacitance
- Further composite optimization is possible through changes in initial MWCNT concentration

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