"On recent work related to super and pseudo capacitors"

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Super capacitors (SC) are promising electrochemical energy storage devices, which fill the gap between electrostatic capacitors and batteries in terms of energy and power densities.
Generally, super capacitors can be divided into electrical double layer capacitors (EDLC) and pseudo capacitors (PsC).
We present herein, three different routes for the synthesis of large surface area carbon\CNT composite materials for EDLCs electrodes.
Using dispersion in dissolved polymers[1] (Figure 1a), VACNT\AC[2] (1b), and Micro-filtrated CNT\AC (1c) composite we were able to clearly demonstrate the positive influence of CNT dispersed in the activated carbon matrices on the mechanical and electrical stability of EDLCs electrodes upon many thousands of cycles. The crystallinity and the associated electromechanical properties of the CNT which are well maintained after the carbonization and activation of the composite active mass, enable the new composite materials to exhibit much higher stability compared to the conventional EDLC electrodes' materials produced from the activated carbonized polymers, and demonstrate much better electrochemical performances upon cycling.
The unique porous morphology of the electrodes, as reflected in the adsorption isotherms (Figure 2), enabled improvements in the electrochemical performances in various electrolyte solutions (>350, 250, 190, 130 Fg^{-1} in H_2SO_4, KOH, organic [3], and IL repectively).

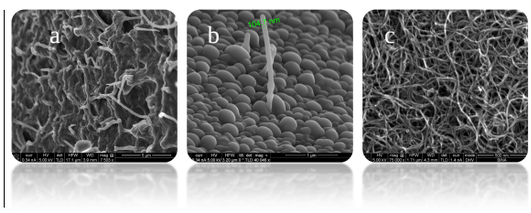

Figure 1: HRSEM images of composite materials. a)AC/CNT, b)AC\VACNT, c)AC\MF-CNT.

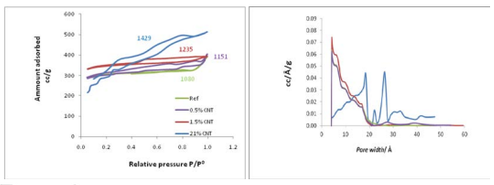

Figure 2: Adsorption isotherm measurments and the calculated pore size distribution of the AC/CNT composite with different CNT concentrations.

A key limitation to the EDLC technology is its relative low energy density, hence there is a good incentive to explore pseudo-capacitive materials where Faradaic mechanisms based on surface red-ox activity offer higher energy density than simple electrostatic interactions.
PsC, another family of SC, is based on materials which posses this kind of red-ox behavior.
Among the materials studied, one can find conductive polymers, red-ox functional groups and transition metals sulfides, nitrides, carbides and oxides.
Generally, the PsC are limited by the electrochemical stability of the active material, presenting behavior which is similar to batteries in terms of cycle life, thus prevents PsC from becoming as stable as EDLC.
MoO_3 is a transition metal oxide which has several options for redox activities with protons in aqueous solutions due to the multi-valence nature of molybdenum.
We report herein on pseudo-capacitor electrodes, composed of monolithic ,binder free, molybdenum trioxide/CNT/activated carbon - AC/CNT/MoO_3) demonstrating stable capacity up to 400 Fg^{-1}, within a potential window of 1V in acidic aqueous electrolyte (Figure 3) solution, during at least 10,000 cycles. They also exhibit high and stable capacity (250 Fg^{-1}) in alkaline solutions.

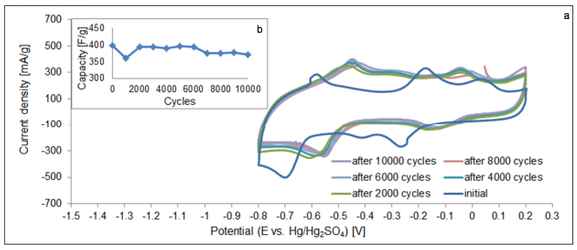

Figure 3: Cyclic Voltammetry response of AC/CNT/MoO_3 composite electrode in 1M H_2SO_4, Long term performances demonstration.

1. Noked, M., Okashy, S., Zimrin, T. and Aurbach, D. (2012), Composite Carbon Nanotube/Carbon Electrodes for Electrical Double-Layer Super Capacitors. Angew. Chem. Int. Ed., **2012**, 51: 1568–1571,.

2. Malachi Noked, Sivan Okashy, Tomer Zimrin & Doron Aurbach
Thick,Vertically Aligned Carbon Nanotubes / Carbon Composite Electrodes for Electrical Double-Layer Capacitors. CARBON, 58, **2013**, 134–138.

3. Arie Borenstien, Malachi Noked, Sivan Okashy, Tomer Zimrin & Doron Aurbach "Compatibility of Composite CNT/Activated Carbon Electrodes for Organic Electrolytes in EDL Super Capacitors",**2013**, in press

4. Sivan Okashy, Malachi Noked, Tomer Zimrin & Doron Aurbach* The study of Carbon/CNT/MoO3 electrode for aqueous Pseudo-Supercapacitors ,**2013**, in Press.