

A Study on Super Capacitor with a Reference of Carbon Nanotubes

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Abstract – Supercapacitor finds desirable applications in consumer electronic goods and alternate power sources as an electrical energy storage system due to its higher energy capacity, rapid discharge / charge cycle, low heating cost, reliability, long-term operational stability and no removable pieces. This thesis examines the latest supercapacitor advances focused on carbon nanotubes (CNTs) and their composites. The aim is to provide a thorough overview of the advantages and drawbacks of supercapacitor materials associated with carbon nanotubes, and to find ways to increase supercapacitor efficiency. We first explored the impact of pure carbon nanotubes on supercapacity of physical and chemical properties like height, strength, defect, form, functionalization and annealing. The composites, including CNTs / oxide and CNTs / polymer, were further explored in order to maximize supercapacity and preserve supercapacitor reliability by optimally designing the structure, particle size and distribution.

Keywords: Carbon nanotubes, Supercapacitor, Oxide/nanotube composite, Polymer/nanotube composite

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INTRODUCTION

In certain applications involving central storage or central electric power production, renewable energy storage is needed. A storage system to accommodate a specific application must satisfy both energy density (Wh) and maximum power (W) specifications as well as height, weight, initial cost and life, etc. Supercapacitors bridge the void between batteries and traditional condensers, spanning many orders of magnitude of both strength and energy densities. They are an appealing option for applications for energy storage in portable or remote systems where batteries and traditional capacitors have to be overdimensioned due to unfavorable power-to-energy ratios.

Supercapacitors can act as a short-term energy storage system with high power potential in diesel, hybrid diesel and fuel cell automobiles and enable the energy to be recovered from regenerative braking. -- devices like cellular phones and personal performance instruments often exist in telecommunications.

An ultracapacitor or supercapacitor may be defined as two non-reactive porous surfaces, or electrodes, submerged in an electrolyte with a propensity for voltage spread to the collectors. A transparent dielectric separator between the two electrodes stops the current between the two electrodes from traveling.

Super capacitors are normally divided into two types: a pseudo capacitor and a double-layer condenser. The electrical charge may be built up in the pseudo capacitor by an electron transfer that causes the changes in the chemical or oxidation state in the electro active materials according to Faraday's electrode-potential rules, i.e. Faradaic charge transfer is the basis for energy conservation in the pseudo capacitor. The charging mechanism in the electrical-double-layer capacitor (EDLC) is non-Faradaic, i.e. preferably there is no electron transport through the electrode interface and electrical charging and energy storage is electrostatic[1] .. However, owing to the electrochemically active redox functionalities, the EDLC with different high-area carbon electrodes often exhibits a slight yet substantial pseudo capacity.

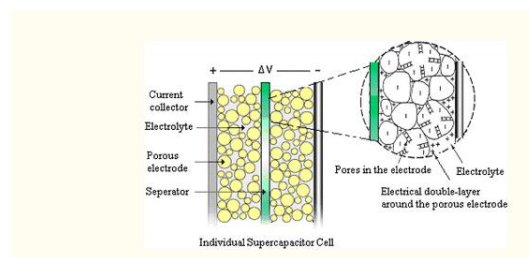


Figure 1 : A presentation of super capacitor

The electrical energy (E) accumulated in a supercapacitor is related to the capacitance (C) or the stored charges (Q) and voltage (V) by following formula:

$$E = \frac{CV^2}{2} = \frac{QV}{2}.$$

The capacitance and the stored charge rely in turn on the material used for the electrode, while the operating voltage is calculated by the electrolyte's stability window. A crucial consideration for increasing the energy efficiency is the usage of high-capacity materials. The super capacitor will typically have higher strength than other batteries, as a significant number of charges (Q) can be contained in the double layers. But due to the series resistance the power density, as shown in the following theorem, is reasonably poor.

$$P = \frac{V^2}{4R_s}$$

Where R_s describes the corresponding resistance of the two electrodes in sequence (ERS). Improving efficiency and power density involves the production of high-capacity, low-resistance materials, as shown in Eqs. 1 & 2.

A number of materials can be used as the supercapacitor electrodes, including rubber, silicone, cement, and their composites. Pseudocapacitor uses conductive polymers (such as polyacetylene, polypyrrole, and polyaniline), metal oxides (such as RuO_2 and Co_3O_4), or hybrid polymer oxide as electrode products.

Changes in chemical or oxidation condition in the electrodes induced in the pseudocapacitive activity by the Faradiac charge transfer which affect the cycling stability and restrict their application due to high resistance and low stability, although the basic capacitance of $\text{RuO}_2 \cdot 0.5\text{H}_2\text{O}$ can be as large as 900 F/g.

EDLC is usually formed utilizing porous carbon materials (such as activated carbon) as an electrode, and electrostatically collecting the electrical charge at the electrode / electrolyte interface.

These supercapacitors are commonly used in carbon aerogel (CA) or other forms of carbon products, such as carbon black or carbon cloths. In general, high surface area in carbon materials is characteristic of a highly established microporous structure, which, however, is unfavorable for electrolyte wetting and rapid ionic motions, especially at high current loads. Combining high surface carbon aerogel with high specific oxide or polymer capability can result in high strength and pressure density, and durability by using both metal oxide or polymer faradaic flexibility and carbon double-layer performance.

Since its development in 1991, carbon nanotubes (CNTs) have been extensively researched and gained considerable interest owing to their interesting and theoretically valuable structural, electrical and mechanical properties. CNTs are formed when a graphite layer, like single-walled CNT (SWCNT) and multi-walled CNT (MWCNT), is rolled into cylinders.

CNTs have a novel shape, small nanometer scale distribution, easily open surface region, low resistivity and strong stability]. These characteristics indicate that CNTs are the materials ideal for polarizable electrodes. Because of their peculiar properties both SWCNTs and MWCNTs were tested for electrochemical super capacitor electrodes.

In the other side, composites containing a nanotubular framework protected by an active layer with pseudo-capacitive properties, such as CNT / oxide composite, are an significant advance in the creation of a new generation of super capacitors focused in three fundamental reasons : (1) the percolation of active particles with annotates is more effective than with typical carbon materials; The first two properties are necessary to lower the resistance (R_s) of the corresponding sequence and thus increase the density of the strength. In this study, we will concentrate on recent developments on super capacitors centered on CNT and analyze the impact of CNTs and related composites on super capacitors output, and potential approaches and enhance efficiency.

The analysis is divided into five parts. In "Reference" the short introduction to the super capacitor is provided "CNT super capacitor" focuses on pure super capacitors focused on the CNTs. CNT / oxide composite super capacitor is discussed in the segment named "CNT and Oxide composite super capacitor." CNT / polymer composite super capacitor is explored in the segment "CNT and polymer composite super capacitor." Finally some concluding remarks are issued in "List."

SUPERCAPACITORS FROM CNTS

Niu et al. initially proposed in 1997 that CNTs could be used in supercapacitors. The MWCNTs were functionalized in nitric acid with the inclusion of functional groups on the surface. These functionalized MWCNTs had a maximum region of 430 m² / g, a gravimetric capacitance of 102 F / g, and an energy density of 0.5 W•h / kg obtained on a single-cell unit at 1 Hz, utilizing 38 wt percent electrolyte sulfuric acid. Over the elimination of 90 percent of the catalyst residue, the residual catalyst in the MWCNTs (mainly inside the inner tubes) will affect the supercapacitor output. The functional groups and the remaining catalyst could induce pseudocapacitance. Hence both the Faradiac and non-Faradiac processes have been used in the supercapacitor depending on the CNTs. The redox reaction observed on the SWCNT-based electrodes' cyclic voltammetric (CV) plot also suggested that the

pseudocapacitance was probably occurring to the CNT-based capacitor because of the functional groups and impurities.

However, the efficiency of distilled SWCNT, where the catalyst (Fe) was eliminated by thermal oxidation followed by immersion in HCl, was not as good as predicted due to the development of amorphous carbon by thermal oxidation, was shown to be. It is impossible to detach the catalyst entirely from the CNTs supported by the catalyst and maintain the graphitisation at the same time, and so the catalyst's influence is still there. To simplify the debate, we concentrate first on the structural properties of CNTs, such as diameter, weight, and pore size, which play an important role in the EDLC, and then address the effects of the catalysts and functional groups.

The sum of electric charge produced in EDLC due to electrostatic attraction depends on the region of the electrode / electrolyte interface where the charging carriers will reach. If the charging carriers can completely reach the field, the higher surface area of the electrode material may contribute to higher capacitance. The higher surface region, however, does not necessarily result in higher performance, as ability often depends on pore size, size distribution, and conductivity.

Higher potential can be reached by the optimization of all the relevant variables. For example, the vertically oriented CNTs with a diameter of about 25 nm and a specific region of 69.5 m² / g had a typical capacitance of 14.1 F / g and displayed excellent rate capabilities, which were better than those of enclosed CNTs due to the greater pore capacity, more normal pore structure and more conductive routes.

Frackowiak et al extensively studied the impact of CNT shapes and diameters, and the micro texture and elemental composition of the components on capacitance.

Table 1 indicates capacitance rises as the real surface area grows. The smallest value is obtained in CNTs with closed tips and graphised carbon layers, where in this content the mesopore capacity for ion diffusion and the active surface for the electrical double layer formation are very low. The most powerful for capturing charges are the annotates with multiple edge planes, either due to herringbone morphology (A900Co / Si) or due to amorphous carbon coating (A700Co / Si). Although a reasonably high specific surface area, reasonably reasonable output is provided by straight and rigid large diameter annotates (P800Al). However, it is very high in contrast with the scale of the solved ions, taking into consideration the depth of the central channel. In the other side, as indicated by the extremely limited amount of oxygen content, this specific behaviour may also be attributed to a very hydrophobic nature of these channels.

Table 1

BET specific surface area, mesopore volume, percentage of oxygen, and capacitance of the analyzed nanotubes

Type of nanotubes	A700Co/Si	A900Co/Si	A600Co/NaY	P800/Al
V_{meso} (cm ³ STP/g)	435	381	269	643
SBET (m ² /g)	411	396	128	311
Oxygen (mass%)	10.8	4.6	0.8	<0.3
Capacitance (F/g)	80	62	4	36

Heating is one of the main strategies to enhance CNT graphitisation and eliminate amorphous material. The capacitance effects of heating depend on the heating temperature and the nature of the as-grown CNTs. The capacitance of as-received SWCNTs (Rice) was around 40 F / g and presumably decreased to 18 F / g after heating treatment at 1,650 ° C due to the tubes becoming more precisely graphised. Li et al., nevertheless, noticed that oxidization improved the basic capacitance up to 650 ° C owing to enhanced target surface area and dispersity.

But the capacitance decreased due to reduced surface area with a further rise in temperature. At the same time, the heat treatment contributed to a decrease in the resistance of the corresponding series, resulting in a rise in power efficiency due to the graphitisation change.

CNT design engineering may also increase capability and power consumption considerably. The high-densely packed and balanced SWCNTs displayed higher capacitance, less capacitance decrease in high-power activity and improved efficiency for thick electrodes as contrasted with activated carbon cells.

Cyclic voltammograms of solid sheet and forest cells is quite close, which implies the two products had about the same capacitance per weight. The SWCNT strong EDLC's capacitance was greater than that of the forest unit. The measured energy density was 69.4Wh h / kg. Diffusiveness of ions plays a vital role in producing lightweight super capacitors with large energy capacity and high power efficiency. Since the electrolyte ions must migrate inside the SWCNT packaging system through the pores of interstitial regions, mobility of the ions is restricted in the internal area of the solids at the required time scale. Owing to the quick and simple diffusivity of ions, superior electrochemical properties of SWCNT solid cells derive from

coupled porous structures relative to activated carbon.

The composites with different SWCNT loads displayed outstanding cycling capacities, also at a high current of 2 A / g, with the MnO₂ and 20 wt percent SWCNT composite exhibiting the highest combination of 75 percent performance and 110 F / g basic capacitance after 750 cycles. The initial basic capacitance of the MnO₂ / CNTs nanocomposite (CNTs coated with standardized birnessite-type MnO₂) in an organic electrolyte with a broad current density of 1 A / g was 250 F / g, suggesting an outstanding electrochemical usage of the MnO₂ as the inclusion of CNTs as a conducting agent greatly increased the nanocomposite's high-rate capability.

CONCLUSION

Even, high capacitance may be accomplished by combining the CNTs with rubber, silicone, or both as the electrode. The hybrid supercapacitor allows the oxide nanoparticles to be chemically bound to the CNT walls, otherwise the polymer with correctly regulated thickness should be evenly covered by the CNTs. And the ratio of oxide / polymer to CNTs is crucial to capacitance enhancement. There is currently no general solution to the literature ratio since the starting materials, CNTs, oxide, and polymer, and methods of processing are variable from literature to literature. Systematic inquiries are needed to address this question. Yet the hybrid super capacitor's reliability is also uncertain.

REFERENCES

1. Conway B.E. (1999). Electrochemical Supercapacitors: Scientific Fundamentals and Technological Applications. Kluwer Academic/Plenum, New York.
2. <http://en.wikipedia.org/wiki/Supercapacitor> Website.
3. Lota K, Khomenko V, Frackowiak EJ. J. Phys. Chem. Solids (2004). p. 295. COI number [1:CAS:528:DC%2BD2cXmsFOjtg%3D%3D]; Bibcode number [2004JPCS...65..295L]
4. Ryu SK, Wu X, Lee YG, Chang SH. J. (2003). p. 1300. COI number [1:CAS:528:DC%2BD3sXks1Khtrk%3D]
5. Patra S, Munichandraiah N. J. (2007). p. 1160. COI number [1:CAS:528:DC%2BD2sXpsVOnsrg%3D]
6. Marchioni F, Yang J, Walker W, Wudl F. J. Phys. Chem. B. 2006. p. 22202. COI number [1:CAS:528:DC%2BD28XhtVKiur%2FP]
7. Ryu KS, Lee YG, Hong YS, Park YJ, Wu XL, Kim KM, Kang MG, Park NG, Chang SH.

Electrochim. Acta. 2004. p. 843. COI number [1:CAS:528:DC%2BD2cXptlymtL8%3D]

8. Ingram MD, Staesche H, Ryder KS. Solid State Ionics. 2004. p. 51. COI number [1:CAS:528:DC%2BD2cXksF2rsL8%3D]
9. Prasad KR, Munichandraiah N. Electrochem. 2002. p. A271. COI number [1:CAS:528:DC%2BD38XnvFOjsrw%3D]
10. Kim JY, Chung IJ. J. 2002. p. A1376.

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