ELECTROCHEMICAL APPLICATIONS OF VGCFS

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Introduction

VGCF (vapor grown carbon fibers) generated in a different form than conventional carbon fibers, have been characterized in terms of the highly preferred orientation of their graphitic basal planes parallel to the fiber axis, with an annular ring texture in the cross section. This structure gives rise to excellent mechanical properties, very high electrical and thermal conductivity, and a high graphitizability of the fibers [1,2]. In terms of manufacturing process, exact control of growth factors make possible to obtain various carbon fibers from normal VGCFs (diameter=~10μm), Submicron VGCFs (diameter=~0.1μm) Nanofiber (diameter=20~50nm) to Carbon nanotube (diameter=~1nm). Therefore, many researchers have tried to reach the final target of "mass production" of these fibers at low cost. The development of the floating reactant method allows a three-dimensional dispersion of the hydrocarbon together with the catalytic particles, resulting in a high yield and a rather uniform diameter of the fibers. As a result, the success of mass production by using floating reactant method have spurred research for the application of these fibers in various fields. Combining effects in its excellent physical properties of these fibers and low production costs promise to enable production cost reductions for military and commercial applications, although at present the situation are immature.

High degree of graphitizability, high surface to volume ratio caused by small diameter make these fibers potentially useful for a number of applications, for example filler in CFRP (carbon fiber reinforced plastics) through injection molding and the electrode in electrochemical field, at relatively low cost.

In this study, electrochemical application such as the anode material itself or additive in lithium-ion battery system, and the electrode in double layer capacitor will be presented by exploiting their excellent properties of these fibers above mentioned, to interconnect the performance with nanostructure including size effects.

Experimental

The fibers used in this study were grown by the decomposition of benzene using ferrocene as the catalyst, and the detailed synthesis conditions are shown elsewhere [1]. Graphitization of the fibers was performed at 3000°C for 30 minutes, using a graphite-resistance furnace operated in a high-purity argon atmosphere. In this study of submicron VGCFs obtained by a floating reactant method, the basic properties and microstructural development as a function of heat treatment temperature (HTT), the physical properties of a single fiber and of the bulk states were evaluated for the purpose of applying this material as the filler for the Li-ion battery system and EDLC system.

Results and Discussion

Submicron VGCFs used in this study have a random orientation and sometimes aggregate into a few tens of fibers. The fibers have a semispherical tip and a homogeneous diameter, as do the thicker fibers. These kinds of morphology are very favorable when this fiber is applied as filler to improve electrical conductivity. The basic properties of carbonized and graphitized s-VGCFs are summarized in Table 1. The particular characteristics of interest are their high aspect ratio ($>10^2$) and extremely low volume density in the range 0.02 to 0.07 g/cm^3. These properties would be very favorable when using this material as the filler in an electrode. Furthermore, a very low content of ash, and a high oxidation resistance are also required. The cyclic efficiency of a synthetic graphite (HTT=2900) anode as a function of added weight percent of graphitized s-VGCFs is shown in Fig. 1. With increasing added weight percent of graphitized s-VGCFs, the cyclic efficiencies of the synthetic graphite anodes were increased continuously, and in particular when 10wt.% of the s-VGCFs was added, the cyclic efficiency was maintained at almost 100% up to 50 cycles.

At higher concentrations, the s-VGCF carbon fibers interconnect between graphite powder particles to form a continuous conductive network. The addition of graphitized s-VGCFs into anode materials improves the conductivity of the anode mixture, and also imparts other desirable properties that enhance the performance of Li-ion batteries, such as the ability to absorb and retain significant electrolyte and to provide resiliency and compressibility to the electrode structure. Furthermore, the relatively high capability of s-VGCFs for Li-ion intercalation when used as an anode filler would also be beneficial for battery performance as compared to that of conventional whiskers. When this fiber is applied as an additive in the electrode of double layer capacitor, improved capacity, especially, at higher current density (Fig. 2), indicates that resistance property of electrode has improved through network formation as compared with those of carbon black. This system will be very promising for EV (electric vehicle) and also for fuel cell EV.

Conclusions

In the near future, the application of s-VGCFs as a filler material in various electrochemical systems is expected to become widespread due to the excellent properties of the s-VGCFs, especially, for applications where improved conductivity is needed.

References

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Table 1. Basic properties of submicron VGCFs

I.D.	Carbonized s-VGCFs1)	Graphitized s-VGCFs2)	Unit
C_o	6.900	6.775	
Diameter	0.2	0.2	µm
Length	10-20	10-20	µm
Volume density	0.02-0.07	0.02-0.07	g/cm^3
Real density	1.9	2.1	g/cm^3
Surface area	37	15	m^2/g
Ash content	1.5	0.03	%
Oxidization temp.	550	650	

1) Carbonized s-VGCFs = HTT at 1200
2) Graphitized s-VGCFs = HTT at 2800 .

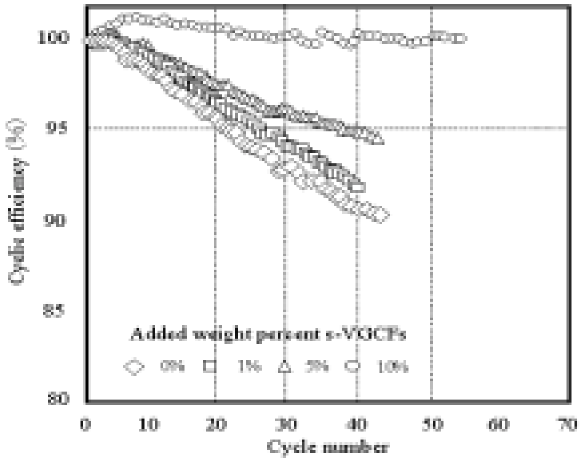

Figure 1. Cyclic efficiency of synthetic graphite (2800°C) as a function of added weight percent of graphitized s-VGCFs

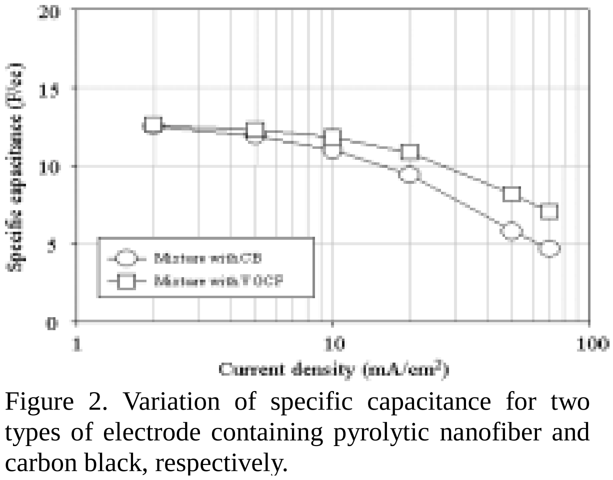

Figure 2. Variation of specific capacitance for two types of electrode containing pyrolytic nanofiber and carbon black, respectively.