Hybrid supercapacitors including a $Li_4Ti_5O_{12}$/activated carbon composite negative electrode

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INTRODUCTION

Supercapacitors allow a reversible storage of electric energy. Contrary to secondary batteries, they show very high specific power density but low specific energy density, typically less than 10 Wh/kg. Hybrid systems are studied as candidates to enhance energy density. Hybrid supercapacitors are made of a standard activated carbon positive electrode facing a battery-type negative electrode. Lithium titanate $Li_4Ti_5O_{12}$ can be used as the negative material, notably because of its little volume expansion during Li^+ intercalation[1]. This work is focused on studying different systems, from symmetric conventional activated carbon / activated carbon (AC) supercapacitors to full hybrid systems based on $Li_4Ti_5O_{12}$ (LTO) negative electrode. New intermediate systems made of composite activated carbon/$Li_4Ti_5O_{12}$ (ACLTO) negative electrode were also investigated. Thus, the aim of this work is to analyze the performances of the different systems according to composition variation.

EXPERIMENTAL

A first objective was to ascertain one same protocol which could be followed to manufacture the different electrodes made of AC, LTO or composite ACLTO. Blade-coating was chosen as the most versatile methodology. In such a way, a slurry containing the active material is coated onto an etched aluminum foil, with typical thicknesses ranging from 30 to 110 µm. The advantage of this laboratory fabrication methodology deals with its easy scaling-up for large-scale production. The slurries are prepared following an eco-friendly formulation with water as solvent to avoid the use of reprotoxic solvents such as 1-methyl-2-pyrrolidinone. Disk electrodes were punched from the coatings and tested in coin cells. Electrochemical tests were performed with a VMP3 potentiostat driven by the EC-Lab software (BioLogic, France).

RESULTS AND DISCUSSION

Up to now four compositions have been studied for negative electrodes (Table 1). Two of them are composite; they are denoted as ACLTO5050 and ACLTO3070.

	AC	ACLTO 5050	ACLTO 3070	LTO
wt% of activated carbon (AC)	100	50	30	0
wt% of $Li_4Ti_5O_{12}$ (LTO)	0	50	70	100

Table 1: composition of negative electrodes

First, the electrodes were tested facing lithium metal to measure their capacity (Figure 1, dashed line). As expected, composite electrodes show intermediate capacities. Then, full systems including an activated carbon positive electrode and one of the four negative electrodes were tested at different discharge rates. Adding activated carbon may decrease the capacity of the negative electrode, but it allows the system to better respond to high-rate discharges up to 200D (Figure 1, solid lines). Hybrid supercapacitors deliver higher energy densities than the symmetric system, as shown on the Ragone plot (Figure 2). The latter diagram allows then to determine the optimal negative composition according to a target application that requires energy or power design. For example, the supercapacitor based on ACLTO3070 negative electrode exhibits the best energy/power densities for a 20s-discharge. To supply a device requiring an energy density of 10 Wh/kg, it seems that this AC / ACLTO3070 configuration will provide the highest power density. On the basis of these first results, we are currently studying a complete range of ACLTO compositions to better characterize the power *vs.* energy density relationship.

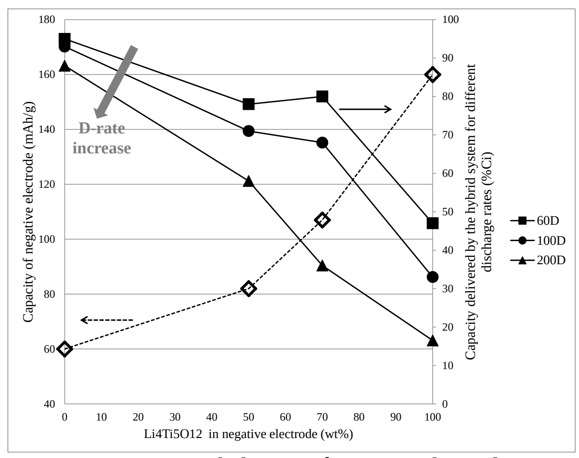

Fig. 1: capacity behavior of negative electrodes

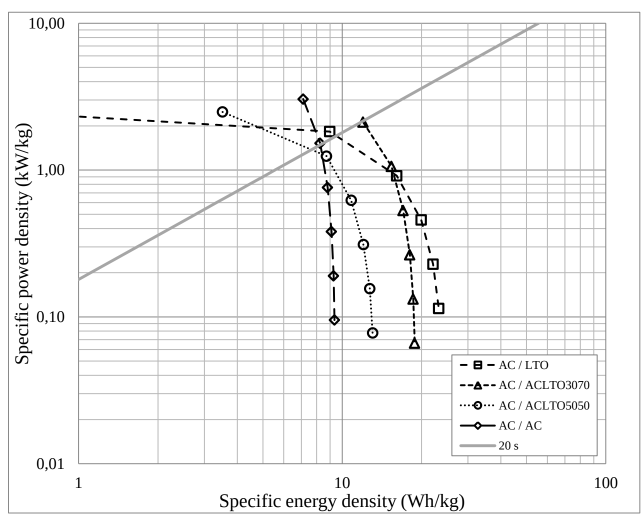

Fig. 2: Ragone plot

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REFERENCES

[1] G. Amatucci, F. Badway, A. Du Pasquier, T. Zheng, *J. Electrochem. Soc.*, **148**, A930 (2001)