DESIGNING CARBONS FOR ELECTROCHEMICAL APPLICATIONS

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Introduction

Energy storage technologies play a crucial role in modern society because not only the daily requirements by so many electronic devices but also due to sustainable consideration of the energy sector in general. Electrochemical devices are therefore receiving a lot of interest in order to improve their capability according to the constant increasing demands. One of the main strategies, besides improvements of the device configuration and new electrolytes formulation, is the development of active materials that provide more energy and power density for supercapacitors, more energy density and durability for batteries and more cost-effective materials for fuel cells. Carbon xerogels are polymeric materials which properties may be designed, structurally and chemically, in order to fit the requirements for their final application. The composition of the precursor solution, the sol-gel process conditions or the type of post-treatment will determine their final properties[1]. Thus, they are candidates to be used as active materials in electrochemical devices as supercapacitors, batteries or fuel cells, although the required characteristics differ considerably from one device to another.

Materials and Methods

Carbon xerogels were obtained by polymerization of resorcinol and formaldehyde in a sol-gel process assisted by microwave heating[2]. During the sol preparation, graphene oxide may be added as a stable suspension. The polymers obtained were dried and submitted to different thermal treatments: (i) activation at 1000ºC with CO_2, or (ii) heated in inert atmosphere at 1000ºC for carbonization or up to 2800ºC for graphitization process or (iii) N-functionalization with melamine and Fe doping by incipient wetness impregnation. Samples were chemically and texturally characterized and their behavior tested in different electrochemical devices: supercapacitors, Li-ion batteries and in the oxygen reduction reactions involved in fuel cells.

Results and Discussion

Carbon xerogels may be obtained by a fast and cost-effective method, with no impurities, and with desired properties for the different electrochemical devices. In the case of the supercapacitors, it is necessary a good electrical conductivity, high micropore volume (i.e. high surface area) and the right feeder pores to promote the diffusion of the electrolyte. A carbon xerogel with narrow mesopores and ca. 1500 m^2/g containing graphene imbibed in the structure exhibited greater electrical conductivity, energy and power density than the commercial YP-50F as active material in supercapacitors with aqueous electrolyte (Figure 1). On the other hand, in the case of Li-ion batteries structural order in the carbon material is the main required feature for a high storage capacity due to the high insertion of Li-ions. In this case a carbon xerogel containing graphene, with wide macropores and relatively high ordering degree, displayed higher capacitance and stability than the commercial SLP50 (Figure 2). Finally, in the case of fuel cells, the main objective is to get a good performance in the oxygen reduction reaction without the use of platinum. The use of carbon xerogels with very different properties allowed studying the role of the microporosity, the electrical conductivity and surface chemistry in this type of reaction. Activated carbon xerogel with a good combination of microporosity and feeder pores seemed to be a good carbon support for nitrogen and iron, and thus a substitute to the expensive platinum as electrocatalyst in fuel cells.

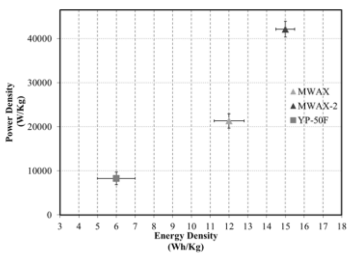

Figure 1. Ragone plot for a supercapacitor with carbon xerogel (values calculated at 16 A g^{-1} per electrode) and aqueous electrolyte vs the reference material YP-50F [3].

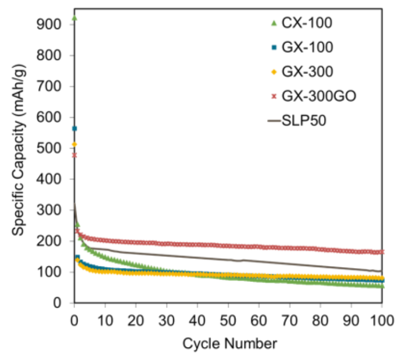

Figure 2. Cycling performance of carbon xerogels in a Li-ion battery vs the reference material SLP50 [4].

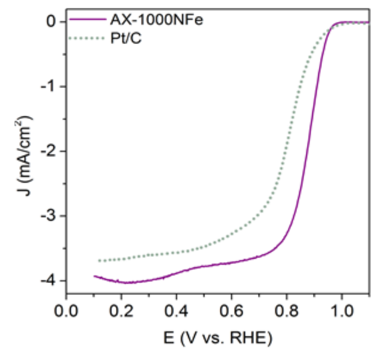

Figure 3. LSV at 1600 rpm for a carbon xerogel in the oxygen reduction reaction vs the reference material Pt/C [5].

Conclusions

Carbons xerogels can be easily obtained by a sol-gel process assisted by microwave heating, that combined with different post-treatments may produce completely different materials that may be adjusted to different electrochemical devices: (i) with high microporosity and the adequated feeder pores combined with high electrical conductivity for supercapacitors; (ii) with high electrical conductivity, adequated feeder pores and structural order for stable Li-ion batteries; and (iii) with high active sites (i.e. micropores and N/Fe sites) for a good performance in oxygen reduction reaction in fuel cells.

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