Abstract #1047, 224th ECS Meeting, © 2013 The Electrochemical Society

Bicontinuous carbon electrode structures fabricated from high internal phase emulsion polymer (polyHIPE®) templates and their use for 3D microbattery applications

Habtom D. Asfaw, Matthew Roberts, Leif Nyholm and Kristina Edström, Department of Chemistry - Ångström, The Ångström Laboratory, Uppsala University, Box 538, SE-751 21 Uppsala, Sweden

The rapid growth in microbattery research is stimulated by the need for miniature power sources for use in autonomous sensing, wireless communications, medical implants and so forth. Currently either thin film or thick film microbatteries are in common use. However, 2D electrode geometries suffer from severe limitations and are unable to meet the demands for both high power and high energy densities. Hence, a shift to 3D configuration has been identified as a feasible solution to alleviate the drawbacks of the 2D approach. With this end in view, a variety of 3D electrode designs and fabrication techniques are being explored[1–3].

Of all the techniques studied so far, synthesis of electrode structures via templates is the most commonly applied. Electrodeposition of nano-pillars using porous alumina[4] and synthesis of bicontinuous and interconnected electrode structures making use of self-organized polymer nanoparticles are shining examples in this regard. Three dimensional ordered macroporous (3-DOM) electrodes have been synthesized mainly using polystyrene and polymethyl methacrylate nanospheres and are widely investigated for microbattery applications[5]. Other methods include sol-gel synthesis of aerogels and template synthesis of carbon foams from high internal phase emulsion (HIPE) polymer precursors. HIPE consists chiefly of a continuous organic phase and an aqueous internal phase. Radical polymerization of the continuous phase gives rise to a highly porous and networked polymer which subsequently is pyrolyzed to prepare a carbon foam (Figure 1)[6]. Porous and interconnected electrodes based on carbon foams, 3-DOM structures and aerogels offer the combined benefits of large specific surface area, high porosity and buffering against volume change during cycling[3]. Even though they provide plenty of room for depositing the active materials, the electrolyte and the current collector(s), they are unfortunately associated with low volumetric energy densities and high ohmic losses. Success with porous electrode designs, therefore, hinges on the ability to prepare materials with optimum porosity, less tortuous channels and acceptable conductivity[5].

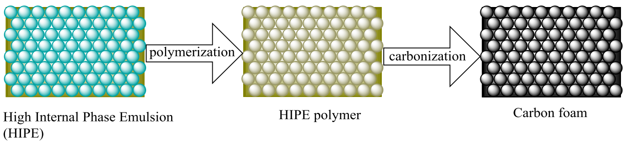

Figure 1: Schematic synopsis for the preparation of bicontinuous carbon foams

In this work, we demonstrate the use of emulsion-templated porous polymers as precursors for the manufacturing of bicontinuous carbon structures (foams). The obtained carbon foams were coated with $LiFePO_4$ using the Pechini sol-gel method[7]. Several techniques (SEM-EDX, TEM, XRD, gas sorption analysis and Raman) are used to characterize the carbon foams and the composites prior to electrochemical testing.

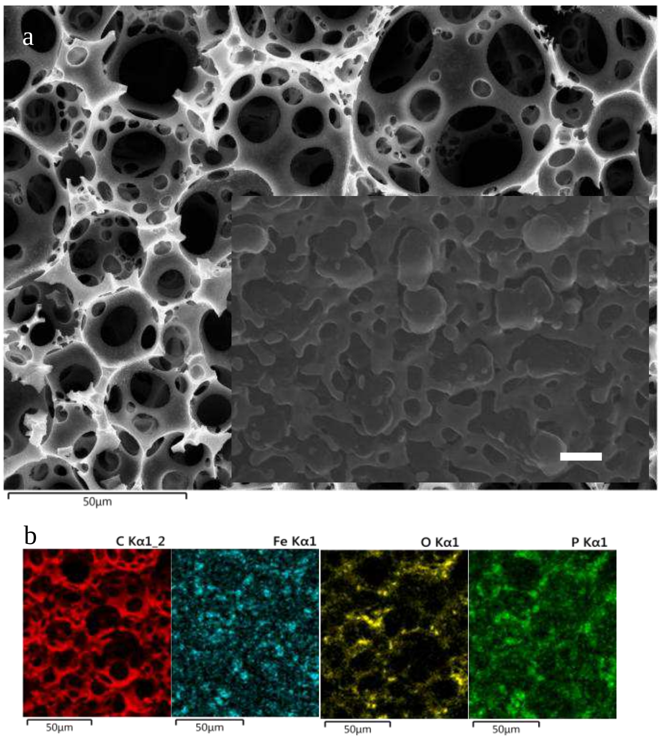

Figure 2: (a) Scanning electron micrograph of polyHIPE-derived carbon foam-coated with $LiFePO_4$ Inset: coating shown at a higher magnification, scale bar = 200 nm
(b) EDX-maps of the $LiFePO_4$ coating on the carbon foam

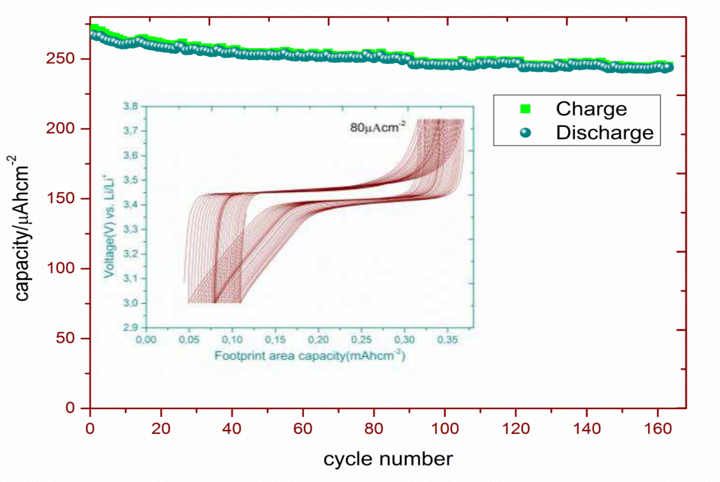

Figure 3: Galvanostatic cycling of $LiFePO_4$@ carbon foam at 80 µAcm^{-2} Inset: charge-discharge profiles

References:

1. J. W. Long et al., Chem.Rev., **104**, 4463–92 (2004).

2. M. Roberts et al., J. Mater. Chem., **21**, 9876–9890 (2011).

3. J. F. M. Oudenhoven et al., Adv. Energy Mater., **1**, 10–33 (2011).

4. E. Perre et al., Electrochem. Commun., **10**, 1467–1470 (2008).

5. J. S. Sakamoto et al., J. Mater. Chem., **12**, 2859–2861 (2002)

6. D. Wang et al., Polym. Int., **54**, 297–303 (2005).

7. M. Gaberscek et al., Solid State Ionics, **176**, 1801–1805 (2005)