Electrodeposition of Nanostructured Electrode Materials for 3D- Li-ion Microbatteries

Leif Nyholm, Gabriel Oltean, David Rehnlund, Mario Valvo, Solveig Böhme, Habtom D. Asfaw, Wei Wei, Kristina Edström

Department of Chemistry – Ångström Laboratory, Uppsala University, Uppsala, Sweden
Box 538, SE-75121 Uppsala, Sweden

Contemporary rechargeable lithium-ion (Li-ion) batteries exhibit good performance regarding energy and power density which has made them the primary choice for application in consumer electronics. The rapid development of the fields of microelectronics and microelectromechanical systems has, however, generated an increased demand for miniaturized rechargeable energy storage devices which is difficult to meet with the battery technology available at present. This has generated a demand for the development of new battery concepts with higher energy and power densities per footprint area. The three-dimensional (3-D) microbattery approach [1] is presently the most promising concept addressing these requirements. By expanding the batteries in the third dimension an increased electrode area can be obtained while preserving the same areal footprint as well as high power capabilities [1-3]. The realization of 3-D microbatteries, however, requires the development of techniques that allow straightforward and inexpensive manufacturing of 3-D current collectors coated with thin layers of active materials and suitable electrolytes, e.g. polymers or solid electrolytes.

In this quest, electrodeposition has emerged as a particularly promising technique [2,3]. Whereas several groups have demonstrated electrodeposition of nanostructured anode materials, there is still a need for a corresponding development of suitable approaches for 3-D cathodes and electrolytes [2,3]. As cathode materials mainly include intercalation compounds which require well defined lattice planes to enable reversible lithium ion transport within the structures, electrodeposition of cathode materials is generally more challenging than its anode counterpart [2]. More attention also needs to be paid to the electrodeposition of thin active films on metals such as copper and aluminum, as well as the possibility to electrochemically develop free-standing nanotube based electrodes with larger surface areas.

This presentation will focus on our recent work aiming at the development of electrochemical approaches for the manufacturing of electrode materials for 3-D microbatteries. It will be shown that electrodeposition can be used for the manufacturing of 3-D copper [2,3] and aluminum [4,5] current collectors as well as the coating of these with thin layers of anode or cathode materials. This work is exemplified in Figure 1 and 2 which show SEM micrographs of copper nanorods coated with a 15 nm thick layer of Cu$_2$O and a thin layer of vanadium oxide deposited on an aluminum rod current collector, respectively. Electrodeposition of materials such as Sb, Sb$_2$O$_3$, Cu$_2$Sb, Sn, SnO$_2$, Al$_2$O$_3$ and MnO$_x$ will also be discussed as well as the manufacturing of electrodes composed of free-standing TiO$_2$ nanotubes [6]. A novel strategy facilitating electrodeposition of cathode materials on nanostructured Al current collectors will likewise be described.

**References**