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Developments in Li-ion Microbatteries: Fabrication and Packaging

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Energy-dense micropower sources are critical to the development of autonomous microelectronic devices. Li-ion microbatteries are presently the best choice for power on the small scale because of their low heat signature, low noise, and attitude insensitivity. They also cause little disruption to microelectronic systems and can be directly integrated into electronic components.

This presentation will discuss a top down approach to fabrication and miniaturization of a Li-ion microbattery. Other researchers have made microbatteries by sputtering [1] and lithography techniques [2]. We are combining several fabrication techniques to make a fully packaged Li-ion microbattery. We have already demonstrated that a laser-direct method can make high-capacity Li-ion microbattery electrodes and microbatteries [3]. The cycling performance is shown in Fig. 1 for a 4 mm × 4 mm $LiCoO_2$/MCMB microbattery prepared on Al and Cu foils and packaged in a trilaminate polymer/metal/polymer "blue bag".

This paper will describe the development of a complete microbattery system, including fabrication and integration of current collectors, electrode materials, electrolyte, and packaging. Current collectors are best prepared by microlithography because it permits precision structures of high purity metals with micrometer resolution. Specifically, Al and Cu metallic layers, approximately 200-nm thick, can be deposited using a negative resist method.

Electrodes are prepared by the laser direct-write of $LiCoO_2$ and MCMB. Laser direct-write allows for 20-μm spot sizes and precision-line deposition on top of the metallic current collectors. The electrodes are formed from inks containing the active material ($LiCoO_2$ or MCMB), NMP, PVDF, and graphitic carbon blacks.

New packaging materials are critical to the success of all microbattery development. The trilaminate packaging material adds significant mass and volume to the small batteries and is not a long-term solution. Batteries packaged with the trilayer film can lose viability in the open atmosphere because the heat seals at the perimeter of the packaging are susceptible to permeation by gaseous bad actors such as oxygen, nitrogen and water.

Details will be discussed on the application of inorganic-organic hybrid glasses as packaging materials. A modified hybrid organic-inorganic tin fluorophosphate glass possesses insulating characteristics and has low permittivity of water [4]. The low T_g of these tin fluorophosphate glass allows the deposition of a gas-tight package that is lightweight.

Construction of a new compact microbattery with high specific energy can be achieved by integrating the advanced fabrication methods with the new packaging materials. The envisioned configuration of a typical prismatic sandwich is shown in Figure 2. There will be some discussion on how to integrate the microbatteries with solar cells to form a hybrid micropower system to provide energy harvesting as well as energy storage.

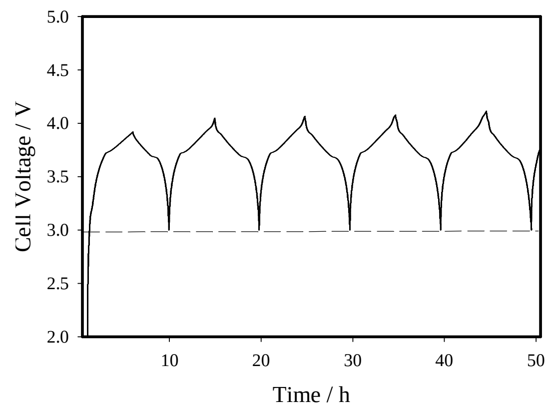

Figure 1. First 5 cycles of a packaged Li-ion microbattery cycled at a C/5 rate between 4.17 and 3 V (current is 44 μA or 275 μA/cm^2).

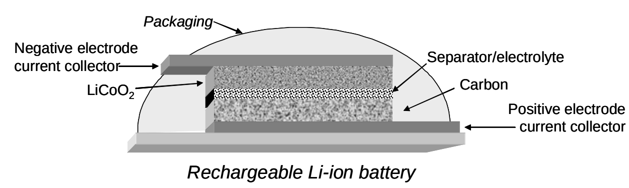

Figure 2. Schematic of a Li-ion microbattery packaged in a low-melting glass.

Acknowledgments

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