THIN-FILM RECHARGEABLE LITHIUM BATTERIES

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Abstract

Rechargeable thin-film batteries with lithium metal anodes, an amorphous inorganic electrolyte, and cathodes of lithium intercalation compounds have been fabricated and characterized. The cathodes include TiS_2, the ω phase of V_2O_5, and the cubic spinel $Li_xMn_2O_4$ with open circuit voltages at full charge of about 2.5 V, 3.7 V, and 4.2 V, respectively. The development of these robust cells, which can be cycled thousands of times, was possible because of the stability of the amorphous lithium electrolyte, lithium phosphorus oxynitride. This material has a typical composition of $Li_{2.9}PO_{3.3}N_{0.46}$ and a conductivity at 25°C of 2 μS/cm. Thin-film cells have been cycled at 100% depth of discharge using current densities of 2 to 100 μA/cm^2. The polarization resistance of the cells is due to the slow insertion rate of Li^+ ions into the cathode. Chemical diffusion coefficients for Li^+ ions in the three types of cathodes have been estimated from the analysis of ac impedance measurements.

Introduction

The fabrication of a rechargeable thin-film lithium battery was first reported in 1983 by Kanehori and co-workers [1]. The cells, consisting of a lithium anode, an amorphous $Li_{3.6}Si_{0.6}P_{0.4}O_4$ electrolyte, and a TiS_2 cathode, were cycled several thousand times at current densities up to 16 μA/cm^2. Levasseur and colleagues [2] fabricated rechargeable thin-film lithium cells using a titanium oxysulfide cathode, a Li_2O-B_2O_3-Li_2SO_4 electrolyte, and a lithium anode [3]. Up to 50 cycles were reported at current densities as high as 62 μA/cm^2. At about the same time, Creus et al. described [4] the fabrication of thin-film lithium batteries using amorphous V_2O_5-TeO_2 cathodes, amorphous lithium silicon-phosphorus sulfide electrolytes, and lithium anodes. The initial poor performance of the cells due to reaction of Li with