1. V current collectors—dc magnetron sputtering of V in Ar

2. V_2O_5 cathode—dc magnetron sputtering of V in Ar + 14% O_2

3. Li electrolyte—rf magnetron sputtering of Li_3PO_4 in N_2

4. Li anode—evaporation of Li (10^{-6} Torr)

5. Protective coating

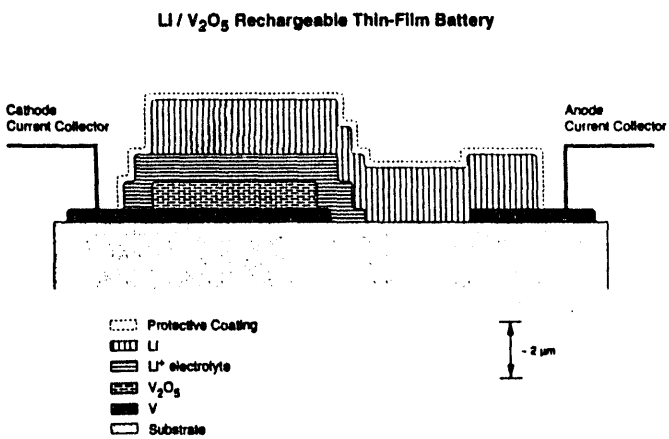

Fig. 1. Schematic cross section of a thin-film lithium battery.

Cells based on TiS_2 and $LiMn_2O_4$ were fabricated in a similar manner using cathodes prepared by the methods described in the literature [4,5,9]. The $LiMn_2O_4$ cell was fabricated in the discharged state. For the sputter depositions, two inch magnetrons (Torus) were used. The commercial V target had a specified purity of 99.97%; the Li_3PO_4 target was prepared by pressing Li_3PO_4 powder (Johnson Mathey, 99.9%) into a 2"-diameter × about 1/8"-thick disk and then sintering the disk in air at 900°C for 4 hrs. The substrate was located 5 cm above the targets, and the total pressure during sputtering was 20 mTorr. The slowest steps in the fabrication were the deposition of the cathode and electrolyte films at rates of about 0.1 µm/hr using a powers of about 30 W (dc) and about 35 W (rf) applied to the V and Li_3PO_4 targets, respectively. Typically the cathode and electrolyte films were each about 1-µm thick. A variety of techniques have been used to characterize the physical and chemical properties of individual cathode and electrolyte films [10,11]. These include Rutherford backscattering spectrometry (RBS), proton induced gamma ray emission spectrometry (PIGE), x-ray diffraction, scanning electron microscopy (SEM), x-ray microanalysis, x-ray photoelectron and Auger electron spectroscopies, and ac impedance.

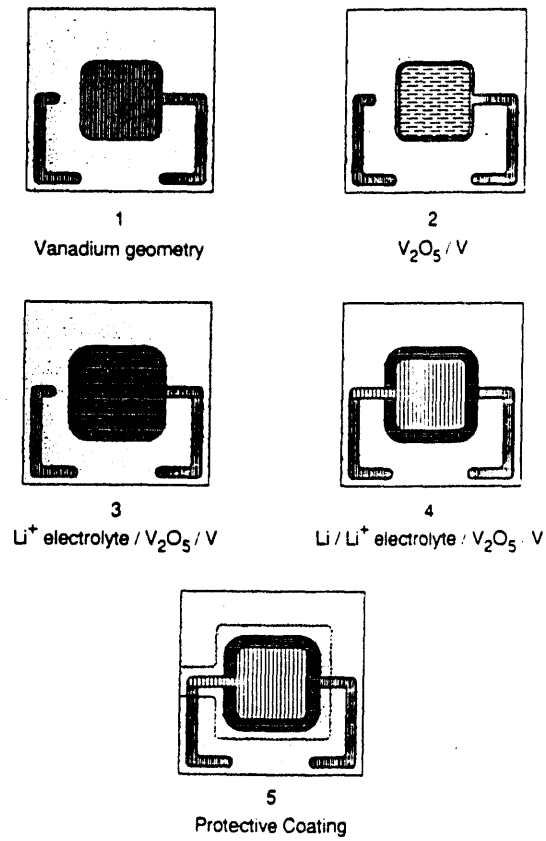

Fig. 2. Deposition sequence and typical geometry of a thin-film lithium battery.

The lithium films were deposited at a rate of about 10 µm/hr by evaporation of lithium metal contained in a Ti crucible. The substrate was located a few millimeters above a chimney placed on top of the crucible to minimize Li deposition on the chamber walls and fixtures. The Li films were typically 3- to 5-µm thick corresponding to three times to 10 times more lithium required for full discharge of the 1-µm thick cathode films. All of the operations with lithium were carried out in a recirculating glove box filled with Ar (99.999%) with the O_2 and H_2O content maintained at a few ppm. Prior to starting a series of lithium depositions, the box was purged with Ar to remove any residual N_2. After deposition of the lithium film, the cells were transferred in Ar to a another deposition system where the protective coating was applied. The main function of the coating is to protect the lithium anode from air and water vapor, but it also protects nearby electronic components from contact with lithium.