Materials Science and Engineering B 116 (2005) 327–340

MATERIALS SCIENCE & ENGINEERING B

www.elsevier.com/locate/mseb

$LiCoO_2$ and SnO_2 thin film electrodes for lithium-ion battery applications

J.P. Maranchi[a], A.F. Hepp[b], P.N. Kumta[a,*]

[a] *Department of Materials Science and Engineering, Carnegie Mellon University, 4309 Wean Hall, Pittsburgh, PA 15213, USA*
[b] *Photovoltaic and Space Environments Branch, NASA Glenn Research Center, Cleveland, OH 44135, USA*

Received 1 March 2004; received in revised form 1 May 2004; accepted 14 May 2004

Abstract

There is an increasing need for small-dimension, ultra-lightweight, portable power supplies due to the miniaturization of consumer electronic devices. Rechargeable thin film lithium-ion batteries have the potential to fulfill the growing demands for micro-energy storage devices. However, rechargeable battery technology and fabrication processes have not kept pace with the advances made in device technology. Economical fabrication methods lending excellent microstructural and compositional control in the thin film battery electrodes have yet to be fully developed. In this study, spin coating has been used to demonstrate the flexibility of the approach to produce both anode (SnO_2) and cathode ($LiCoO_2$) thin films. Results on the microstructure, crystal structure, and electrochemical properties of the thin film electrodes are described and discussed.

Keywords: $LiCoO_2$; SnO_2; Spin coating; Microstructure; Thin film battery; Economical

1. Introduction

Thin film batteries have become desirable energy storage devices for the diverse group of consumer portable devices and space-related government applications. Sputtering, chemical vapor deposition (CVD) and evaporation have often been used to fabricate the various components of thin film batteries. Kanehori et al. [1] used all three to develop a prototype thin film battery in the early 1980s. In the 1990s, sputtering and evaporation were used to produce commercially feasible thin film lithium batteries of type Li metal|solid electrolyte|(TiS_2 or $LiMn_2O_4$) [2]. Thin film lithium and lithium-ion batteries incorporating thin film $LiCoO_2$ cathodes were also produced by sputtering and evaporation [3–7]. Although the performance of the thin film batteries recently fabricated by physical vapor deposition (PVD) methods has been satisfactory, economical and versatile processing techniques are desirable to reduce the cost and improve microstructural and compositional control of the thin film electrodes.

Spin coating is a viable technique that is easy and relatively economical due to the reduced real estate and instrumentation. It can be used to produce a wide variety of electrochemically active cathode thin films. V_2O_5 thin films fabricated by spin coating on Ni/Si substrates were found to reversibly cycle greater than three equivalents of Li^+ per unit of V_2O_5 [8]. The spin coating approach was also used to prepare thin films of $LiMn_2O_4$ for use as a cathode material in thin film batteries [9]. Other lithium-containing transition metal oxide compounds such as $LiMn_xNi_{1-x}O_2$, $LiMn_{2-x}Co_xO_4$, and $LiNi_{1-x}Co_xO_2$ were also synthesized by a spin coating method, but were not evaluated electrochemically [10]. Similarly, Kushida et al. used sol–gel science and spin coating to produce $LiCoO_2$ thin films on Si substrates, but they did not investigate the electrochemical properties of the films [11]. Electrical resistivity and cyclic voltammetry analyses of spin-coated $LiCoO_2$ thin films on glass and aluminium foil substrates were conducted by Ehrlich and Schleich [12] A variety of precursor formulations designed to enhance

* Corresponding author. Tel.: +1 412 268 8739; fax: +1 412 268 7596.
E-mail address: kumta@cmu.edu (P.N. Kumta).

0921-5107/$ – see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.mseb.2004.05.041

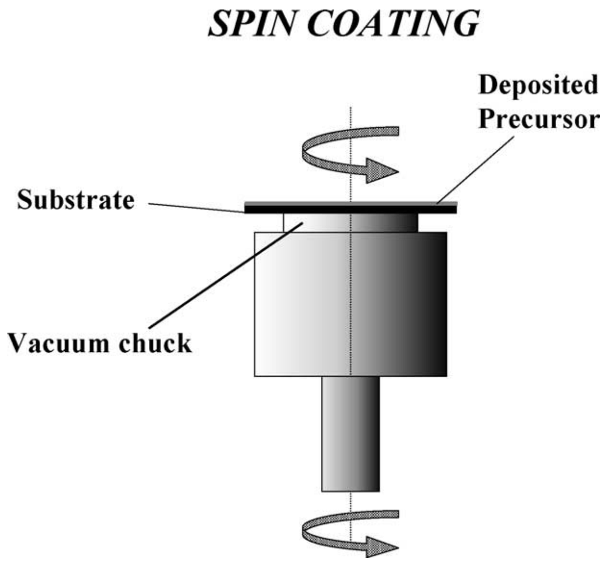

Fig. 1. Schematic depicting the spin coating process.

wetting during spin coating were used to produce $LiCoO_2$ films on Pt/Ti-coated Si substrates. The sol–gel produced films showed larger grain size and better electrochemical properties with increasing final anneal temperature [13]. A sol–gel spin coating process incorporating a crack-preventing component, poly(vinylpyrrolidone) in the precursor solution was used to produce $LiCoO_2$ thin films on Au and quartz substrates, which showed good electrochemical properties [14].

Spin coating has not been widely used to produce anode thin films for lithium-ion batteries. However, low-pressure CVD has been used to produce thin films of SnO_2 which cycled well out to ∼120 cycles [15,16]. The electrochemical properties of sputter-deposited SnO_2 anode thin films were investigated by Nam et al. [17] Electron beam evaporation has also been used to fabricate thin film SnO_2 and Si-doped SnO_2 anodes [18].

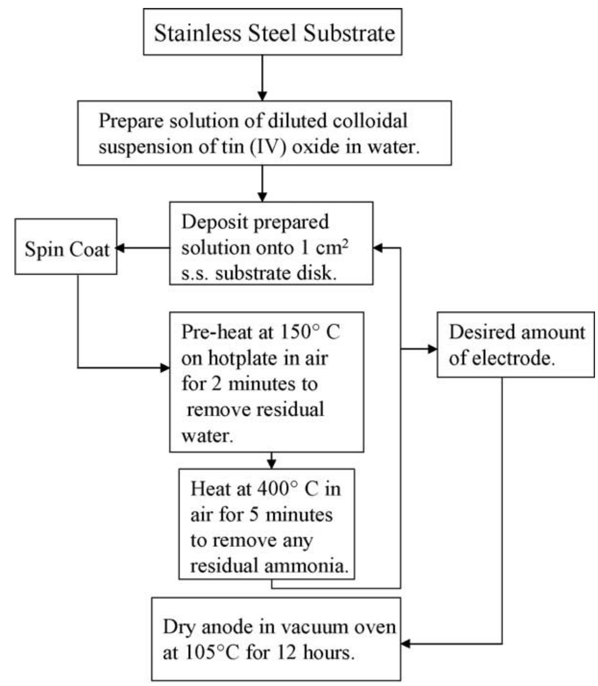

Fig. 3. Flowchart outlining the synthesis of thin film SnO_2 anodes on rigid substrates.

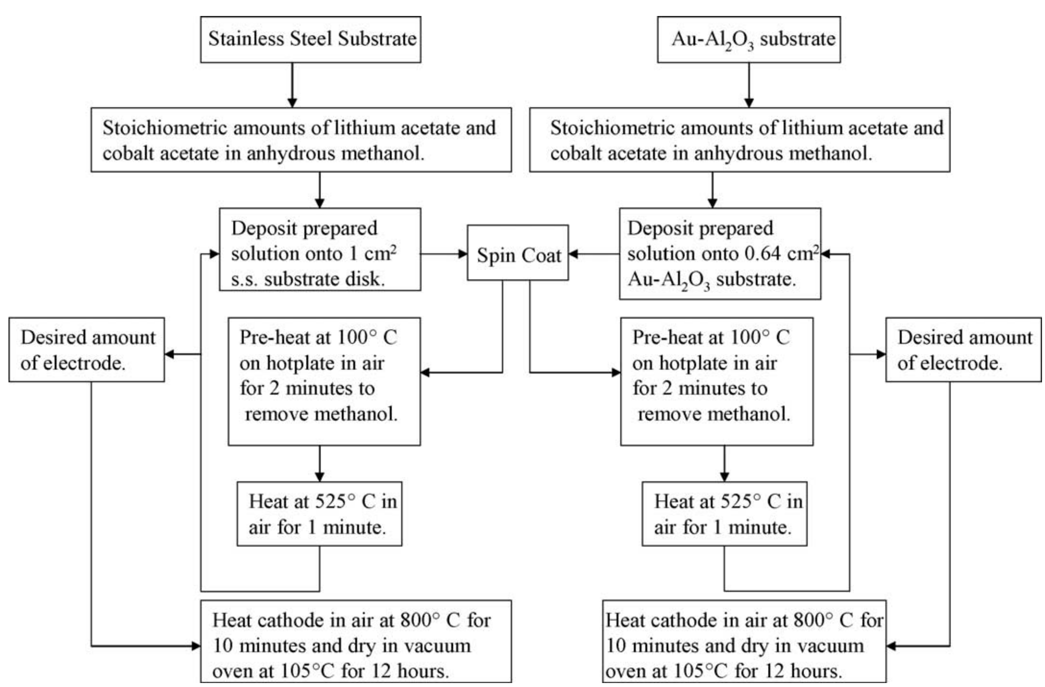

Fig. 2. Flowchart showing the synthesis of thin film $LiCoO_2$ cathodes on rigid substrates.