Chapter 1

Introduction to the present work

1.1 Background

Solid state ionic solids are solids, which possess unusually high diffusion coefficients and conductance for specific ions. They have assumed considerable importance in recent years for battery research. The discovery of crystalline, glassy and polymeric materials with high alkali metal ion conductivity has inspired much research into the fundamental insertion electrolytes (Savadogo and Roberge, 1997). Due to safety reasons lithium metal is no longer the electrode used as the anode in lithium batteries. As a result lithium intercalation compounds have been made the cathode and carbon as the anode. An example of such intercalation solid, which acts as a cathode active material in lithium-ion batteries, is lithium cobalt oxide, $LiCoO_2$. It has a practically high discharge capacity of 140 $mAhg^{-1}$. It is safe to use in lithium batteries and is stable after many cycles of battery operation. It is already being used in commercial lithium-ion batteries and many manufacturers are currently improving the material. Other materials which are still being extensively researched on include $LiMn_2O_4$ which has a practical discharge capacity of 120 $mAhg^{-1}$, $LiNiO_2$, $LiNiCoO_2$ and in general $LiM_xM'_yM''_zO_2$ where M, M' and M'' are transition metals. Ideally these materials should have high ionic and electronic conductivities (Gabano, 1983).

The advent of these materials has greatly revolutionized lithium battery technology so as to meet the demands of the electronic age, the electric powers needs and the human mobility requirements. Apart from this the cost picture and the environment have also provided urgent reasons for changes in the existing technology of batteries (Bagotzky and Skundin, 1998).

1.2 Lithium transition metal oxides, properties and associated problems

Lithium-ion batteries have attracted much attention in recent years because of their high energy density and long cycle life. The current generation of lithium-ion batteries uses graphite or carbon as anodes and $LiCoO_2$ or $LiNiO_2$ as cathodes. However the high cost of $LiCoO_2$ and potential safety problems of $LiNiO_2$ in highly oxidized states have limited their commercialization power. Manganese, which is much cheaper and less toxic, has also been investigated extensively as the cathode material for lithium batteries.

In contrast to $LiCoO_2$ and $LiNiO_2$ systems, it is easy to synthesize a Mn-based cathode that contains more than one Li per formula unit (Qiu et al, 1997). The theoretical capacity of $LiCoO_2$ is 274 mAh/g (Koksbang et al, 1996) and its practical capacity is 140mAh/g (Koksbang et al, 1996) compared to $LiNiO_2$ which has a theoretical capacity of 275 mAh/g (Koksbang et al, 1996) and 200 mAh/g practical capacity (Koksbang et al,1996). Theoretical capacity for $LiMn_2O_4$ is 148 mAh/g and 134 mAh/g practical capacity (Xia et al, 1997).

1.3 Problems related to development of rechargeable lithium battery

A Canadian firm (Moli) produced the first version of a lithium battery in 1987. There was insufficient reliability of these batteries and isolated cases of ignition and explosion. The Japanese firm, Sony then replaced metallic lithium to carbon as the anode and $LiCoO_2$ as the cathode. Such a replacement resulted in a significantly enhanced reliability of the battery (Bogotsky and Skundin, 1998). Apart from environmental problems, battery industries are faced by the consumer needs of higher specific discharged capacity and good performance in the temperature range between -40^0C to 90^0C.

1.4 Objective of this research

The main objective of this research is to synthesize a lithiated intercalation cathode material using transition metals, which could give a specific discharge capacity greater than 120 $mAhg^{-1}$ by a soft chemistry method. The sol gel method is used to prepare the materials. The intercalation material prepared in this study will begin with $LiMn_2O_4$. Manganese will be substituted with copper. $LiCu_2O_2$, for example has a theoretical capacity of ~ 160 $mAhg^{-1}$ which if can be delivered 100% during battery operation will be the material that has the highest specific discharge capacity. The formation temperature of the cathode material will be known using thermogravimetry analysis (TGA) studies on the materials that are being synthesized. The composition of the material will be determined by the technique of energy dispersive analysis of X-Rays

(EDAX) and X-Ray diffraction (XRD). The ability of the lithium ions to intercalate and deintercalate the prepared materials and carbon will be examined by cyclic voltammetry. The prepared materials will also be characterized by infrared spectroscopy to verify that the acetates and other anions of the salts used are decomposed during preparation of the materials.