

rate to make a spinel (LiMn_2O_4) with predetermined stoichiometry. X-ray diffraction cannot readily distinguish the different phases of lithium manganese oxide. The manganese and lithium analyses carried out by ICPAES in duplicate are in good agreement. It was observed that the oxygen contents of spinel samples fall with increasing temperature and also the particle size results are in good agreement for the sieving technique and for the laser diffraction method. Furthermore, spinels prepared at 850°C appear to be in good agreement with the values on the J.C.P.D.S. card.

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Development of a lithium-ion polymer battery for space power applications

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Introduction

In recent years lithium-ion batteries [1] have emerged as the leading advanced power source for a range of applications. Driven by the demands of the portable consumer market, small lithium ion cells are now available commercially and have demonstrated excellent cycle life and safety characteristics.

Here we report results from a project aimed at developing a lithium-ion polymer battery (LiPB) into a power source for GEO satellites. The LiPB technology combines the cycle life and safety benefits of the lithium-ion chemistry with those of flexible cell geometry afforded by the use of a solid polymer electrolyte. The concept of the all solid state battery is very appealing. Solid state batteries are intrinsically spill proof and rugged, have long shelf-life, and are capable of being engineered into any geometry. LiPB is a laminate structure based on LiNiO_2 as the active cathode material [2] and graphite as the active anode material. The average cell voltage during discharge is about 3.5 V.

Experimental

The composite anode, polymer electrolyte and composite cathode components of LiPB can be easily prepared using a range of coating techniques. Fabrication of LiPB laminate is achieved using a combination of heat and pressure.

Electrochemical evaluations under GEO space power duty cycle were performed on 56 cm^2 LiPB cells using Sycopel charge/discharge equipment.

Results and discussion

LiPB technology demonstrates significantly improved performance compared to our previously reported lithium metal anode polymer system [3]. Over 500 cycles have been obtained to date at 60% depth of discharge under a GEO duty cycle. A comparison with state-of-the-art liquid electrolyte cell technology indicates that lithium-ion chemistry is capable of achieving in excess of 1000 GEO cycles at 80% depth of discharge.

References

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Parallel cell arrangements for reserve lithium/sulphuryl chloride batteries

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The aim of this work was to investigate the processes leading to failure of large capacity reserve oxyhalide batteries. Previous work in our laboratories has shown that smaller ($< 600\text{ Wh}$) systems, using thionyl or sulphuryl chloride cathodes, have good reliability and predictable behaviour. However, on scale up to larger sizes, premature failure has been observed. Among the factors most responsible are excessive heat generation, leakage currents and lithium dendrite formation.

We report a part of this work concerned with minimising overall leakage currents and heat output through use of parallel arrangements of cells. Where higher currents are required it has been typical practice to make use of parallel sets of series piles. However, if the cells are coupled in parallel before being placed in series, the overall leakage current and heat output can be reduced.

Batteries of five paralleled strings, each string containing four cells in series, were compared with batteries of twenty, series-connected cells. Results showed that the heat output was some 44% less for the parallel arrangement at 25 mA cm^{-2} . Some other important observations were that, in a set of five parallel cells, the cells discharged at different rates (up to 50 mA cm^{-2} and as low as 10 mA cm^{-2} initially). As the higher rate cells became exhausted their current output reduced and the current output from the other cells increased. This current balancing appears to be beneficial in terms of

reliability. It means that if one cell fails completely the others are able to increase their proportion of current and an entire stack can remain in operation. It was also observed for sulphuryl chloride electrolyte during open circuit phases that reverse currents were passing between cells (when diodes were not used). This did not appear to be detrimental, and no lithium dendrites were observed (we generally do not observe lithium dendrite formation with our electrolyte, a study of dendrite formation will be reported at a later date). Only sulphuryl chloride can tolerate this, recharging being theoretically possible.

In conclusion, it is considered that the ‘‘parallel before series’’ arrangement, whilst maintaining the simplicity of pile type construction, appears to have an advantage over ‘‘series before parallel’’, not only because of lower heat output, but also because the burden of poorly functioning cells may successfully be taken by other cells without the overall performance of an entire stack being compromised.

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Fuel cells for vehicular applications — hydrogen storage and simulation aspects

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This work has been carried out by an industrial and research laboratory consortium and is now supported by an EU contract. State-of-the-art solid polymer fuel cell (SPFC) technology shows two main difficulties with this power source: On-board hydrogen storage and taking into account all the parameters which affect the global efficiency.

For the first point the technologies of hydrogen storage are reviewed here, including gaseous, liquid, hydride, adsorption or glass microsphere systems. For each technology, advantages, disadvantages, efficiency are presented in term of optimal applications (ship, plane, automobile...). From this review, gaseous technology has been selected and we report about the most promising compromise (H_2 pressure to use, materials for tanks, manufacturing technology) for a short term development. A carbon composite/coiled wire tank has been designed for a 70 MPa pressure of use.

First tests show that the main problems are the liner and the end piping.

The second major problem in designing a fuel cell stack concerns the interaction between the current density, the cell's voltage, the output voltage, the heat transfer system, the management of water, the oxygen feed... Computing tools have been successfully developed to simulate the operation of an elementary cell and allow for instance a satisfactory

correlation between calculation and experimentation on Nafion[®] membrane.

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High performance membrane electrode assemblies for solid polymer fuel cells

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Solid polymer electrolyte fuel cell performance is restricted by factors associated with membrane, electrode and hardware components. We have extensively evaluated a number of Membrane Electrode Assemblies (MEAs) and applied the resulting data to optimise the overall power capabilities. We show how electrodes with a low platinum loading (0.35 mg cm^{-2}) can provide comparable performance with electrodes containing a much greater quantity of the electrocatalyst. The key factors governing this high platinum utilisation involve efficient employment of the three dimensional reaction zone, to avoid using superfluous material and to limit problems associated with mass transport.

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Activity and stability tests in phosphotungstic acid electrolyte fuel cell

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A 40 cm^2 cell based on phosphotungstic acid (PWA) electrolyte has been constructed and tested at the Institute CNR-TAE, Messina. The cell works at room temperature, fed with hydrogen and oxygen as reactant gases. A through-flow design has been used in order to avoid excessive dilution of the electrolyte with water produced in electrochemical reaction. The influence of the hydrophobic-hydrophilic characteristics of different electrodes on the activity and stability of the cell has been investigated. Pairs of gas diffusion electrodes (cathode and anode), each having the same composition of diffusional and catalytic layer, with $0.50 \text{ mg Pt cm}^{-2}$ have been prepared.

The pairs differed among themselves by the PTFE loading in the catalyst layer. Each pair of electrodes was tested in the monosell for at least 70 hours under cycling conditions and at current density of 400 mA cm^{-2} . The monosell tests were conducted with the reagent gases at atmospheric pressure and without external heating. The results of the experiments dem-