

ELECTIVE REPLACEMENT INDICATOR FOR IMPLANTABLE LITHIUM CELLS

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Summary

A reliable sensor has been developed for the accurate determination of the elective replacement or End of Life (EOL) indicator. The sensor is imbedded into the lithium anode and indicates a voltage change upon depletion of the lithium in contact with the sensor. The technique is applicable to most lithium-based chemistries and has been demonstrated in Li/CuS and Li/SOCl₂ with $\pm 2\%$ accuracy.

Introduction

One of the prime requirements for a power source used in implantable systems is a reliable elective replacement or End of Life (EOL) indicator, and various methods have been utilized to develop an effective unit. Changes in physical properties of the cells, such as impedance, or the electrochemical reaction, either at the anode or cathode, have been utilized. In the Li/I₂ system, the internal impedance of the cell increases as a function of drain; hence, the voltage decreases and EOL is signalled when the voltage reaches a certain value [1]. For the Li/CuS system, the stoichiometry of the active elements is adjusted so that a two-step voltage *vs.* discharge relationship is produced [3]. Additionally, multicomponent anodes and/or cathodes have been fabricated to change the primary electrochemical reaction (*i.e.*, voltage) to yield a two voltage plateau system [3].

The rapid development of pacer technology into areas such as physiological (two-chamber) pacing, real time telemetry of internal EKG data, etc., has made additional demands on the power source necessitating the use of higher energy density systems such as Li/SOCl₂. One of the problems with these inherently low impedance and constant voltage systems is the lack of a reliable EOL indicator. Recently, Cordis has developed a new sensor [4] which can be used in any cell with a monolithic lithium anode to provide a distinct signal when the cell has been drained to a predetermined level of reserve capacity.

The basic principle of the sensor is similar to that of a liquid level gauge in a conducting fluid. A small electrode is imbedded in the lithium anode at

an appropriate depth. The electrode, which may be in the form of a wire or a thin strip, is conductively bonded to the lithium above (in the direction of the cathode) and insulated from the lithium below. This electrode is attached to a separate feedthrough to bring the EOL signal to the "outside world". The circuit is completed by attaching the sensor output to the cathode side of the cell through some means of voltage sensing. As long as the sensor is in ohmic contact with the lithium anode, the voltage between the sensor and the cathode will be equal to the main anode voltage. When electrochemical action has reduced the thickness of the anode to the point where the sensor is no longer covered with lithium and conductive contact has been lost, the voltage in the sensor circuit will fall rapidly to a low value.

Experimental

Figure 1 shows a typical arrangement for the sensor in a dual-cathode, planar-type cell. In this case, the sensor consists of a strip of 304L stainless steel, 0.050 in. wide by 0.002 in. thick, insulated using a fluoropolymer film except for a small window at the end of the sensor where contact is made with the lithium overlay.

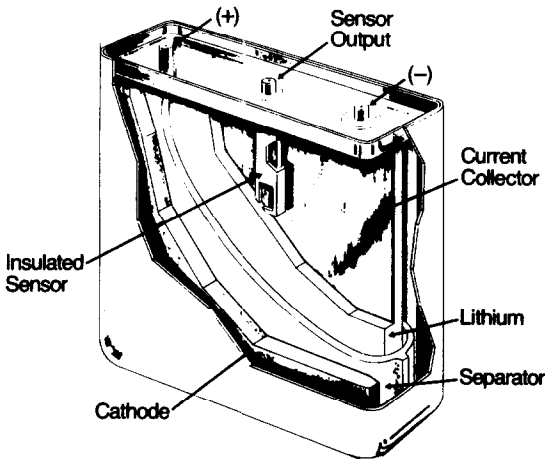


Fig. 1. EOL sensor construction.

Since a typical thickness for a lithium anode is about 0.050 in., it is necessary to imbed the sensor with considerable accuracy. Initial trials were made by placing the sensor between two wafers of lithium which were then pressure bonded to the anode current collector (a thin plate of stainless steel). Widely varying trip points were obtained by this method; destructive analysis revealed that in the bonding process, the sensor could be forced above or below the actual interface of the wafers, leading to large trip point errors. The preferred method is to mount the sensor on a "pedestal" attached to the current collector. This pedestal is a slender shim of stainless

steel of appropriate thickness for the desired trip point. When the lithium anode is pressed onto the assembly, the sensor will be supported at an accurate level above the current collector.

To insure reproducible operation of the sensor, it is essential that an intimate bond be established with the lithium. Prerequisites for achieving a good bond are clean surfaces on both the lithium and the exposed portion of the sensor. The sensor is cleaned by exposure to an oxygen plasma and the lithium is brushed with a stainless steel brush just prior to bonding to expose native lithium.

Results

The sensor has been evaluated in planar-type lithium cells of both the organic electrolyte type (Li/CuS) and the liquid depolarizer type (Li/SOCl₂) with equally good results. Figure 2 shows a representative discharge curve for an Li/SOCl₂ cell showing both the cell and the sensor voltages. Tests to date indicate that reproducibilities of $\pm 2\%$ in the trip point of the sensor can be obtained for Li/CuS cells, as shown in Table 1.

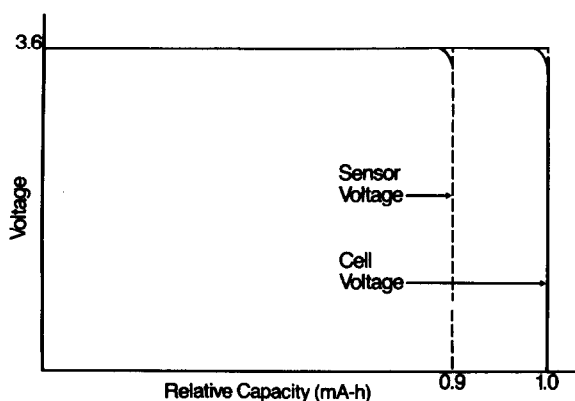


Fig. 2. Discharge curve for Li-SOCl₂ with EOL indicator.

TABLE 1

Li/CuS cell

0.005 in. Pedestal, 1 k Ω load

Cell no.	Weight of Li (g)	Total capacity (mA h)	Capacity at EOL (mA h)	Capacity available at EOL (%)
1	0.2501	1855	1738.7	6.3
2	0.2442	1811	1625.6	10.2
5	0.2462	1826	1659.3	9.1
6	0.2429	1801	1672.2	7.2

Conclusion

The sensor offers many advantages as an EOL indicator. With the operation dependent on the oxidation/depletion of the lithium, any unexpected discharge, such as accidental shorting or excessive self discharge, will not affect the performance of the sensor. The EOL sensor voltage level is independent of the cell voltage such that even after the EOL sensor has decreased to zero volts, the cell voltage remains at the level of the primary electrochemical reaction. In addition, simple detection circuits in the application electronics can easily recognize the digital type change in the sensor voltage.

References

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