made in that over 50 discharge/charge cycles have been realized before the cathode utilization drops below 20%. Coulombic efficiency is close to 100%.

Studies have also been carried out on the $LiI(Al_2O_3)$ solid electrolyte. These have been successful in that the factors contributing to the high conductivity and stability of the electrolyte are now better understood. Material of the quality necessary to meet the requirements of the cycling experiments carried out thus far can be made routinely.

Preliminary efforts to make larger diameter cells by the usual punch-and-die pressing techniques have also been carried out. Some problems with weakly bonded interfaces have been considerably alleviated by annealing.

The objectives during the remainder of the present program include: (1) the continued evaluation of the cycling characteristics of different cathode mixes; (2) the testing of the most promising cathode mix in a larger area cell; (3) the preliminary testing of cells having higher stoichiometric capacities per unit area; (4) the design, building, and testing of reusable, hermetically sealed cans for cell cycling.

We have found no problems thus far that would seem to be intractable or to prevent the full development of a high rate, solid state system. The problems that should be addressed in the follow-on programs are both scientific and engineering in nature, that is, they should involve both basic studies and the investigation of scale-up problems. They include: (1) a study of the ionic and electronic conductivity of cathode materials after partial discharge and after repeated cycling; (2) an investigation of the magnitude of the interface impedances after partial discharge and after repeated cycling; (3) the development of fabrication methods to make improved higher area and higher capacity cells; (4) an investigation of problems that may be encountered when several cells are stacked in series or parallel; (5) the continued development of appropriate testing equipment (hermetic cell and battery containers, etc.); (6) a comprehensive scientific and engineering study of the $LiI(Al_2O_3)$ solid electrolyte.

Recent publications

1 C. C. Liang, A. V. Joshi and N. E. Hamilton, Solid state storage batteries, *J. Appl. Electrochem.*, *8* (1978) 445.

LOW TEMPERATURE ALKALI METAL–SULFUR BATTERIES

EIC Corporation, 55 Chapel Street, Newton, MA 02158 (U.S.A.)

The aim of this program is the development of a practical ambient temperature Li/S secondary battery. The cell has a liquid electrolyte containing the dissolved cathode as Li_2S_n. Due to the formation of a protective passivating film on the Li electrode, we have found that the Li can be recharged with high efficiency, despite its direct contact with the reducing environment, which is ~5M in sulfur. Of major importance is the demonstration of >100 full cycles for such a system.

During 1978, primary emphasis was placed on determining and alleviating the principal failure mode on cycling. It was discovered that in failed cells, all of the sulfur had become isolated on the Li electrode as Li_2S. Several approaches are being investigated to resolubilize the Li_2S, so that it may be transported to the carbon cathode current collector and oxidized. These are: (1) solubilization of Li_2S with Lewis acids, such as $B(OAc)_3$; (2) adding an internal scavenger to the electrolyte which would be generated on overcharge (*e.g.*, $2I^- \rightarrow I_2 + 2e^-$) and subsequently oxidize the Li_2S; (3) using solvents where the Li_2S_n is only partially soluble, thus reducing the self-discharge rate (and, hence, Li_2S isolation). Each approach has provided moderate success in laboratory cells.

A further aspect of this program has been to test the reversibility of a variety of simple sulfides, *e.g.*, Bi_2S_3, As_2S_3, NiS, SiS_2 and CuS. X-ray analysis has been employed to determine Bi_2S_3 and CuS. Bi_2S_3 itself was shown to accept up to $6e^-$/mole, the first three of which appear to be reversible.

Recent publications

1 K. M. Abraham, R. D. Rauh and S. B. Brummer, A low temperature Na–S battery incorporating a soluble S cathode, *Electrochim. Acta*, *23* (1978) 501.
2 R. D. Rauh, K. M. Abraham, G. F. Pearson, J. M. Buzby and S. B. Brummer, Rechargeability of a Li/dissolved Li_2S_n secondary battery, *Abstract No. 62, Fall Meeting Electrochem. Soc., Pittsburgh, PA, 1978.*
3 R. D. Rauh, K. M. Abraham, G. F. Pearson, J. K. Surprenant and S. B. Brummer, A lithium/dissolved sulfur secondary battery with an organic electrolyte, *J. Electrochem. Soc.*, *126* (1979) 523.

INPUT/OUTPUT (LIFE-CYCLE ANALYSIS OF TWO ADVANCED BATTERY SYSTEMS)

Hittman Associates, Inc., 9190 Red Branch Road, Columbia, MD 21045 (U.S.A.)

The objective of this project is to analyse the energy requirement of batteries over their entire life cycle, from the mining of raw materials to battery use and disposal. This analysis of the life cycle requirements of the battery insures that excessive front-end energy requirements do not result in an unfavorable net energy balance for any battery system.

To date, analyses of two battery systems have been completed, the lead/acid battery and the sodium/sulfur (glass electrolyte) battery. Both of