

ting 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 $\sim 5M$ 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

these batteries have been evaluated based on an electric utility load leveling mission. The lead/acid study also included a life-cycle environmental analysis.

Current work is being directed to the analysis of battery systems designed for use in electric vehicles. At present, an electric vehicle lead/acid battery and an electric vehicle nickel/zinc battery are being evaluated for their life-cycle energy use for the electric vehicle mission.

Future work will involve the analysis of all the major battery systems under development by DOE so that comparisons between the candidate batteries can easily be made.

Recent publications

- 1 Life-cycle energy analysis of the sodium-sulfur battery, Hittman Associates, Inc., Columbia, MD 21045, February, 1978.
- 2 Energy and environmental analysis of the lead/acid battery life cycle, *Hittman Associates, Inc., No. HIT-725*, Columbia, MD 21045, April, 1978.

DEVELOPMENT OF ELECTROCHEMICAL SYNTHESIS AND ENERGY STORAGE

Materials and Molecular Research Division, Lawrence Berkeley Laboratory, Berkeley, CA 94720 (U.S.A.)

The overall aim of this program is to improve the energy efficiency, lower the capital cost, and increase the materials yield of electrochemical cell processes used for the conversion of chemical to electrical energy in galvanic cells, and for the production of materials by electrolysis. These goals are pursued in several partially interdependent projects.

Surface morphology of metals in electrodeposition

The role of the electric field and the solution-side mass transport in the electrocrystallization of metals is being investigated in order to determine mechanisms of growth and propagation of surface imperfections. The morphology of copper deposited from acid solutions in a large flow channel is found to be similar at fixed fractions of the limiting current for $23\,000 < Re < 89\,000$. Zinc deposited from zinc halides shows grooved, striated profiles that follow the direction of electrolyte flow over the electrode surface. The model for electrodeposition of metals has been extended to include surface kinetics and it will be further developed to account for mass transfer boundary layers effects. Artificially induced secondary flows will be used to identify the mechanism responsible for the initiation and propagation of surface textures.