

creased actual surface area and an evenly distributed network of permanent nucleation sites for Zn deposition.

Full-scale cell tests of some of these anode materials have shown them to form substantially more stable anodes than pure ZnO alone. Performance decay with the repetitive oxidation and reduction of secondary battery cycling has been shown to be minimal.

SUPPORTED LIQUID MEMBRANE BATTERY SEPARATORS

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The purpose of this research program is to develop supported liquid membrane battery separator technology as it applies to the nickel/zinc battery, in particular, to provide a separator that will prevent zinc dendrite growth from shorting out the cell and alleviate capacity loss due to zinc shape changes.

Supported liquid membranes use a highly specific organic transport reagent contained in a microporous membrane support to transport hydroxyl ions while rejecting zincate ions. Five organic reagent-solvent-support systems that meet these criteria have been tested for hydroxyl ion transport using d.c. resistance measurements. Separator resistances are in the range of 15 to 80 ohm cm². These membranes exhibit hydroxyl ion transport and resistance levels adequate for testing in nickel/zinc cells when used as a separator. The five supported liquid membranes when tested for zincate transport in KOH solutions show very low zincate transport rates and are therefore highly specific for hydroxyl ions.

Recent tests using higher concentrations of transport agents indicated the possibility of lowering separator resistance and a value of 7 ohm cm² was measured with one combination.

A number of membrane materials have been tested for use as supports of liquid membranes. Loaded membranes were tested for chemical compatibility with both organic components and KOH solutions and resistivity. Polyvinyl chloride (PVC), PVC copolymer, and nylon membranes all undergo slight chemical attack or swelling when used as a support. Nonwoven polypropylene supports have low resistivity but are not hydrophobic and may gradually allow displacement of organic by KOH solution. Thus far, Celgard 2500 works well, but tests indicate that a similar material with larger pores could improve supported liquid membrane performance. Use of Teflon membranes may be feasible if organic wetting can be improved.

All five combinations of transport reagent-solvent-supports have been tested as separators in nickel/zinc tests cells. The cells used sintered nickel electrodes and polymer bound zinc oxide electrodes in a flooded configura-

tion. Cells were conditioned with three formation cycles of 3.2-mA/cm²-20 h charges and 10-mA/cm² discharges. Cycling tests were then run at C/3 discharge and C/5 charge rates. With all the supported liquid membrane separators, the cells cycle at normal current densities, although slightly higher internal cell resistances were noted. Cells with one layer of separator have been cycled from 50 to 100 cycles without dendrite shorting problems. In comparison, cells with one layer of Celgard alone formed dendrite shorts after three cycles.

The accelerated tests run thus far favor dendrite growth on the zinc electrode. The supported liquid membrane outperforms one layer of Celgard 3501 under these conditions. Tests are currently being run on multiple layers of Celgard 3501 for further comparison. An accelerated test, closer to commercial tests, is being developed to maximize dendrite growth and shape change failure modes. This will better be able to demonstrate any positive effects of the supported liquid membrane separator.

The following are planned as part of the continuing research effort during 1983 on supported liquid membranes:

- Optimization of nickel/zinc test cells for direct comparison with state-of-the-art technology;
- Continued fundamental transport studies of the five candidate supported liquid membrane systems including the effect of concentration changes on transport, measurement of transference number for the OH⁻ ion, and spectroscopic measurements to help understand bonding mechanisms within the organic; and
- Long-term chemical and electrochemical stability tests on new combinations.

TEMPERATURE LIMITATIONS OF PRIMARY AND SECONDARY ALKALINE BATTERY ELECTRODES

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The objectives of this research program are to determine the mechanisms of increased irreversibility of Ni associated with deep discharge at elevated temperatures, quantify the extent of Fe(II) and Fe(III) dissolution at elevated temperatures, and quantify dissolution and conduct further studies of passivation and current oscillation phenomena at Zn electrodes.

SRI has sought to apply 'high information' electrochemical techniques to nickel oxide, iron, and zinc electrodes in an attempt to understand kinetic limitations, or mechanisms leading to increased irreversibility, that may impair iron/nickel oxide and zinc/nickel oxide alkaline batteries. The most