surface into the substrate. Such diffusional losses and coating defects can be compensated for by introducing iron borides (Fe_2B and FeB) into the positive active material where they will be available for diffusion to the initially boronized material.

The objective of this program was to give a preliminary demonstration of the basic concept. High corrosion stabilities were found for low-carbon ferrous materials boronized by the IGT pack boronization technique. Boride migration from iron boride-containing positive active material has been demonstrated, which, under long-term battery cycling, is expected to enhance the practical lifetime of the initial coating. Reproducible pack boronization techniques have been developed which allow for the rapid boronization of lithium–metal sulfide components and are readily amenable to commercial scale-up. No cell assembly difficulties were identified as a result of this technique.

Recent publications

1 M. R. St. John and A. F. Sammells, Development of *in situ* boronization protection of positive electrode current collectors, Final Report, June 1979.

INSULATION DEVELOPMENT FOR HIGH-TEMPERATURE BATTERY FOR ELECTRIC VEHICLE APPLICATION

Union Carbide Corporation, Linde Division, Tonawanda, New York, NY 14150 (U.S.A.)

The objective of this contract is to develop and demonstrate a high-performance vacuum insulation which is capable of withstanding 0.1 MPa (15 psi) plus battery loading with low compression, operating in the 350 - 450 °C range. The developed insulation would allow construction of rectangular, lightweight and low-cost, vacuum-insulated enclosures for electric vehicles using Na/S or Li/MS batteries. The goals of the program are to develop a vacuum insulation with the following properties: thermal conductivity 0.0024 - 0.0035 W/m K (140×10^{-5} - 200×10^{-5} BTU/h ft °F); density 288 kg/m^3 (18 lb/ft^3); compression 10% from 0 to 0.103 MPa (15 psi) load.

A new milestone in high-temperature, load-bearing, preformed insulation has been achieved through Linde's efforts on this program. Prior to this program, the best load-bearing commercial vacuum insulation system had a thermal conductivity six times higher than the goal.

It should be noted that two insulation systems demonstrated to date have exceeded the goals of the program. The Pegged Multi-Foil system has a measured conductivity of 0.0017 W/m K (100 × 10^{-5} BTU/h ft °F) between 450 °C (840 °F) and 24 °C (75 °F), a density of 177 kg/m^3 (11 lb/ft^3), and a compression of 10%. The second system which exceeded the goals of the program is a Linde Multi-Foil insulation with discrete load-carrying support areas. It had a measured thermal conductivity of 203 × 10^{-5} W/m K (117 × 10^{-5} BTU/h ft °F), a density of 192 kg/m^3 (12 lb/ft^3) and a compression of 9%. A third promising insulation is a continuous support, load-bearing board system, but to-date, the thermal conductivity and density are slightly above the goal of the program. The best load-bearing board insulation system developed to-date has a conductivity of 388 × 10^{-5} W/m K (224 × 10^{-5} BTU/h ft °F), a density of 352 kg/m^3 (22 lb/ft^3) and a compression of 9%.

It is believed that the new insulation systems need further development in order fully to qualify for the above application. Questions that remain to be answered include long-term stability, handleability, and cost-effective manufacturing. The proposed follow-on program for 1980 is directed at: (1) advanced development of attractive insulation candidates; (2) evaluation of insulation and enclosure design through fabrication and testing of enclosure test units; (3) cost estimation of insulation and enclosure manufacturing.

Recent publications

1 Insulation development for high-temperature batteries for electric vehicles application, 1979 Annual Report.

CALCIUM/METAL SULFIDE BATTERY DEVELOPMENT

Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439 (U.S.A.)

The objective of this program is to develop inexpensive high-performance calcium alloy/iron disulfide secondary cells for electric-vehicle propulsion. This program was initiated in 1979, and is an outgrowth of an earlier program (Advanced Battery Research) in which various calcium alloys and transition metal sulfides were shown to be reversible toward calcium ions in molten-salt electrolytes. The ultimate goal of this program is to develop a calcium alloy/iron disulfide cell having the following characteristics: specific energy, 160 W h/kg; energy density, 525 W h/l; peak power, 200 W/kg; energy efficiency, 75%; lifetime, 1000 cycles; materials cost (1979 dollars) $15/kW h in mass production.