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EXAMINATION OF DESIGN OPTIONS FOR 35 A h AMBIENT TEMPERATURE Li–TiS_2 CELLS

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Summary

Some of the design options for a rechargeable 35 A h Li–TiS_2 cell have been examined A specific energy of 80 - 100 W h kg^{-1} at the 2 h rate is feasible using advanced hardware materials. Development of an engineering database for utilization of lithium and TiS_2 electrodes is needed to verify their design and make further improvements.

The Jet Propulsion Laboratory is actively engaged in the development of ambient temperature rechargeable lithium cells for future NASA Geosynchronous Earth Orbit (GEO) missions. The Program goals are given in Table 1.

TABLE 1

NASA secondary lithium battery program goals

- Demonstrate feasibility of ambient temperature secondary lithium cells for GEO applications by FY'89
- Targets
  - $\geqslant$100 W h kg^{-1}
  - 10 year life
  - 1000 cycles
  - Safe

To achieve these ambitious goals, we have examined Li–TiS_2, Li–MoS_3 and Li–V_6O_{13} systems in detail. Of these three, the Li–TiS_2 system has shown the longest life cycle and highest rate capability. Experimental Li–TiS_2 batteries (10.5 V, 0.4 A h) developed in-house have completed eight simulated and accelerated GEO seasons successfully. Evaluation of these batteries is being carried out at Rockwell International and some of these results were reported by Otzinger [1]. In view of these encouraging results, we have examined the design options for a scaled-up Li–TiS_2 cell. It is hoped that the results of these studies will provide priority guidelines for the research efforts and the selection of optimized materials. In our present study, we have examined designs for 35 A h Li–TiS_2 cells because present day geo-

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synchronous satellites are powered by batteries of 35 A h capacity. We have developed a computer program to evaluate the influence of various design parameters on the specific energy and the rate capability of the cells.

Table 2 summarizes the important design parameters that have been considered in the present study. Some of the issues that have not been considered are: thermal design parameters, utilization of the lithium electrode, and the degradation of the electrolyte We have also restricted ourselves to the prismatic cell configuration.

TABLE 2

Design parameters

Cathode	Anode	Electrolyte	Separator	Grid	Can
● Current density	● Negative to positive ratio	● Composition	● Material	● Material	● Material
● Thichness	● Number	● Density	● Porosity	● Type	● Thickness
● Width	● Li foil thickness	● Quantity	● Inter-electrode spacing		● Seal
● Height to width ratio			● Thickness		● Overhead space
● Number			● Weight		
● Porosity					
● Weight					
● Capacity					

The program details are summarized in Table 3. To date, no engineering database exists in the literature for the utilization of TiS_2 cathodes of different thicknesses and porosities at various current densities We have created a database for the execution of the program, based on the limited published and in-house experimental results. Since the cells are required to operate at the *C*/2 rate, we considered cathodes in the thickness range 20 - 40 mil. An anode to cathode capacity ratio of 6 1 has been used in the present studies, as excess of lithium has minimum influence on cell energy density. The various materials that have been considered for the cell case and cover are stainless steel (SS), titanium (Ti), carbon composite (C) and polypropylene (PP). A thickness of 30 mil is considered for stainless steel, titanium, and carbon composite and 120 mil is considered for polypropylene.

Figure 1 shows the dependence of specific energy on the cathode thickness. Cathodes of 25 mil thickness provide the highest energy density for cells that are required to operate at the *C*/2 rate. All further analysis is based on cathodes of 25 mil thickness.

Figure 2 gives the number of cathodes required for different *R* ratios (*R* represents the height to width ratio of the electrode). As can be seen, the

TABLE 3

Program details

Inputs	Constants/variables	Data base		Output
● Capacity	● Anode to cathode capacity ratio 6 1	Current density (mA cm^{-2})	Utilization*	● Design capacity
● Over rating	● No of anode = no of cathode +1	1	0 85	● Energy density
● Discharge current	● Plate width 7 - 14 cm	2	0.85	● Cathode no and dimension
	● Height to width ratio 0 8 - 2	3	0 76	● Anode no and dimension
	● Cathode thickness 20 - 40 mil	4	0 53	● Grid details
	● Grid material Ni, Al	*		● Electrolyte quantity
	● Case material S S , Ti, C, PP			● Separator details
	● Seal Ceramic/Zigler			● Can dimensions
				● Components weight budget

*For 25 mil cathode thickness

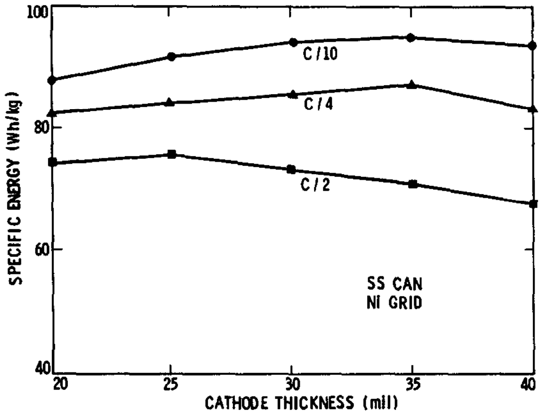

Fig 1 Dependence of specific energy on cathode thickness of an Li–TiS$_2$ cell for various discharge rates

number of cathodes required increases with decreasing plate width and *R* ratio. Current distribution, heat management and ease of fabrication are key issues in selecting the plate width, height-to-width ratio, and the plate number. One needs to make a judicious choice of these parameters, keeping in view the performance requirements and fabrication limitations. For our further analysis, we have chosen a cathode width of 12 cm and height-to-width ratio of 1.5.

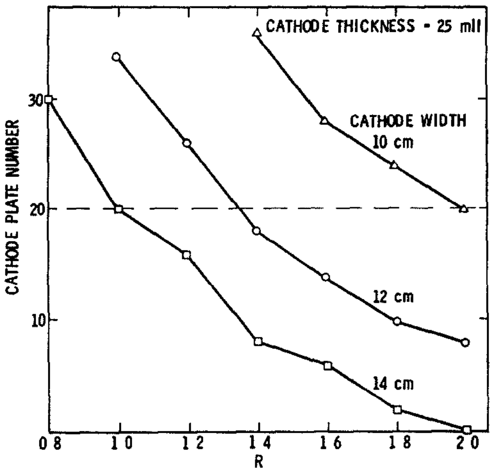

Fig 2 Dependence of cathode plate number on cathode height to width ratio, R

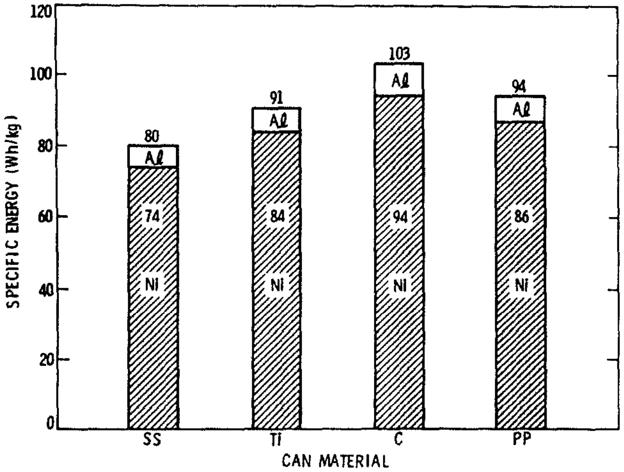

Fig 3. Dependence of specific energy on hardware materials for a 35 A h Li–TiS_2 cell

Figure 3 gives the specific energies that can be achieved with different can and grid materials. Aluminum grids are also considered for cathode current collectors but not for anodes because of the reactivity of Al with Li. Ti/Al, C/Al, and PP/Al materials all look promising in terms of energy density. While Ti cans are lighter than S.S, they are more expensive. Also, C cases are strong and lightweight, but their chemical and electrochemical stability in respect of the active components needs to be determined. Polypropylene cans are cheap, but in view of their poor mechanical properties thicknesses of greater than 100 mil are needed. In view of their poor thermal characteristics, it may not be the material of choice for space applications.

The details of the cell weight budget (cells with stainless steel can) are given in Fig. 4. The can contributes the dominant fraction to the weight

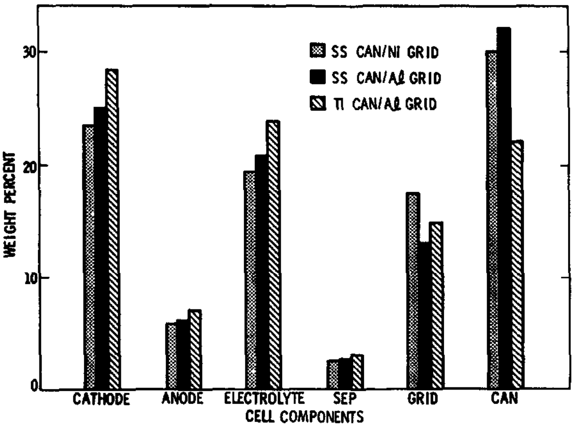

Fig 4 Li–TiS_2 cell weight budget

budget. Of the active materials, the contribution of the anode active material is the lowest. The grid contribution is more than the lithium itself (with respect to weight).

In summary, a specific energy of 80 - 100 W h kg^{-1} at $C/2$ for 35 A h Li–TiS_2 cells is feasible. This calls for the use of advanced hardware materials. Cathode widths greater than 10 cm at 25 mil thickness are needed for 35 A h cells operating at $C/2$. Development of an engineering database for the utilization of lithium and TiS_2 electrodes is needed to verify, and make further improvements in, cell design. Other cell configurations and active materials will be considered in the future.

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