7 Lithium solid-state batteries represents a new concept in battery technology. Solid-state means that the liquids and pastes present in ordinary battery systems such as lithium-ion batteries are replaced by a solid plastic film.

Solid-state batteries are broadly classified into two types: bulk solid-state batteries, and thin film solid-state batteries. The large capacity bulk solid-state batteries can store a lot of energy. While the capacity of thin film solid-state batteries is less than that of bulk solid-state batteries, they have advantages of long cycle life and the ease of manufacturing.

In a lithium solid-state battery, the plastic film separates a lithium metal anode (positive electrode) from a composite electrode (negative electrode) which is in contact with aluminium foil as shown in Fig. 7.1. The resultant cell can be constructed so that it has a large electrode area but is less than 0.2 mm thick. It is in many ways similar to a sheet of paper and can be cut and formed into almost any shape. Lithium solid-state cell is rechargeable.

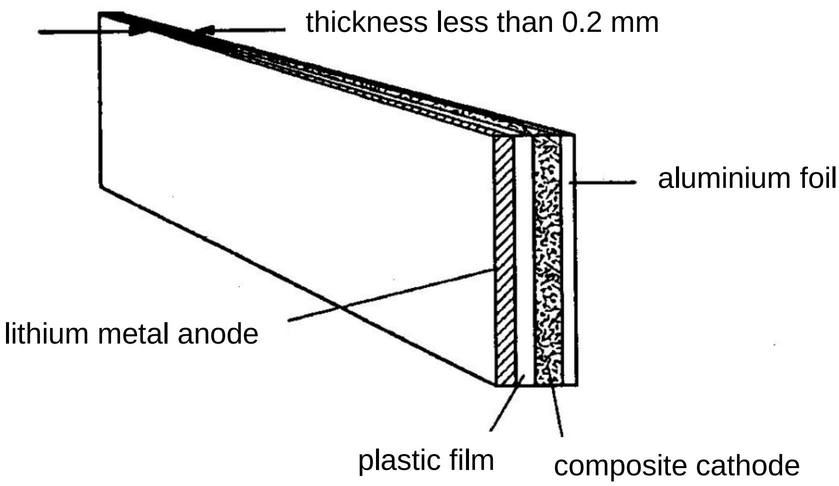

Fig. 7.1

The initial electromotive force (e.m.f). of the cell at full charge is 3.4 V but it rapidly falls to about 2.8 V on load and thereafter falls as shown in Fig. 7.2. The cell needs to be recharged when the e.m.f. reaches 2.0 V. In practice, its average e.m.f. is 2.5 V.

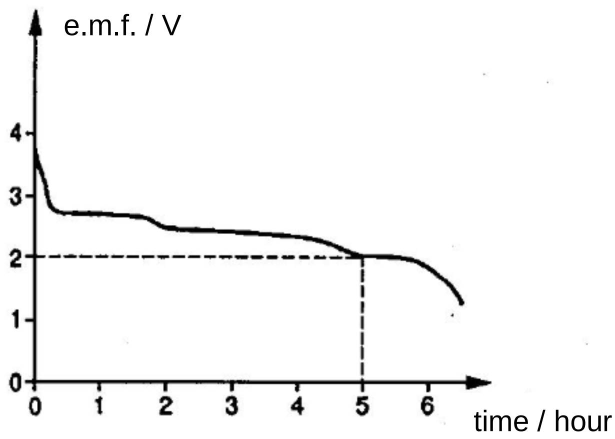

Fig. 7.2

The current density, energy density and charge capacity all have to be considered for a particular application.

The recommended maximum value of discharge current density is 0.15 milliampere per square centimetre of electrode area, the charge capacity is 3.6 coulombs per square centimetre of the electrode area, and the energy density is 120 watt-hours per kilogram of cell mass.

Charging one of these cells should be carried out with a constant applied voltage of 3.4 V and with a current density limited to 2.5 milliampere per square centimetre. A typical charging current against time graph is shown in Fig. 7.3 for a cell of electrode area 50 cm^2.

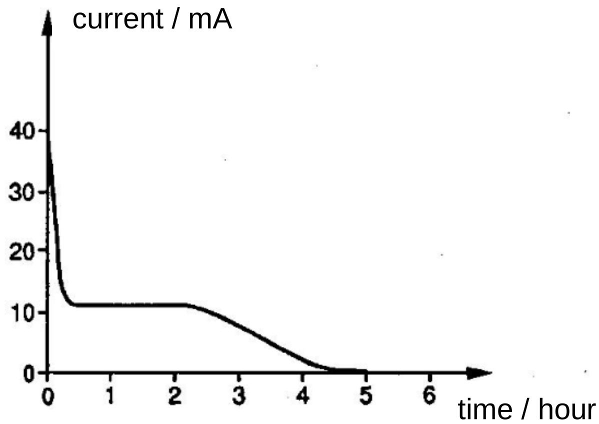

Fig. 7.3

(a) (i) Apart from having higher energy density, state one advantage of solid-state batteries over lithium-ion batteries.

.... [1]

(ii) Suggest one application of each of the following as a power source:

1. bulk solid-state battery,

....[1]

2. thin film solid-state battery.

....[1]

(iii) Other than the mass and volume, suggest one difference between bulk solid-state battery and thin film solid-state battery.

....

....[1]

(b) Deduce from the units, the meaning of the terms

(i) current density,

.... [1]

(ii) energy density.

.... [1]

(c) For the cell that has an electrode area of 50 cm^2, calculate

(i) the recommended charge-storage capacity of this cell,

charge-storage capacity = ……………………………C [1]

(ii) the recommended maximum value of the discharge current,

maximum current = ……………………………. mA [1]

(iii) the duration this cell can supply the maximum current in **(c)(ii)**,

duration = ……………………………. s [2]

(iv) the energy this cell can supply in this duration, assuming that the e.m.f. has a constant value of 2.5 V.

energy supply = ……………………………. J [2]

(d) **(i)** State the significance of the area under the graph in Fig. 7.3.

……………………………………………………………………………………....................

…………………………………………………………………………….……….... [1]

(ii) Estimate the average charging current over the 5-hour charging time.

average charging current = ……………………………. mA [1]

(e) The energy used in charging the cell is 550 J. Using your answer to **(c)(iv)**, deduce the electrical efficiency of the charge/discharge cycle.

efficiency = ……………………………. % [2]

(f) Suggest a reason for each of the safety considerations,

(i) the cells should not be used in environments with a temperature above 140 °C,

………………………………………………………………………………………………..................

…………………………………………………………………………………………….... [1]

(ii) water or water vapour is kept away from lithium cells.

………………………………………………………………………………………………..................

…………………………………………………………………………………………….... [1]

(g) Draw a diagram, using circuit symbols, to illustrate how you would connect a battery of cells which could produce a current of up to 300 mA at a voltage of approximately 10 V. In your answer, specify the electrode area of the individual cells.

electrode area = …………………………………cm^2 [2]

[Total: 20]

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