Pak. j. sci. ind. res., vol. 32, no. 1, January 1989

A CT-BASED SOLID STATE ELECTROCHEMICAL CELL USING PLANT-LEAVES

K. M. Jain

Department of Physics, Govt. Science College, Rewa (M.P.)-486 001, India

(Received November 10, 1988)

The CT-complex forming capability of plant leaves has been used to develop a new type of light, small and economically-viable solid state electrochemical cells with configuration Mg/leafcathod/graphite. The open circuit voltage of 1.7 ± 0.1 volts and short circuit current density of 2.75 ± 0.25 mA/sq.cm. were observed. The Gibbs-Helmholtz equation is used to estimate potential value theoretically. The cell performance indices have also been obtained.

Key words: Solid state batteries, Superionic conductors, Charge-transfer complexes, Power and energy densities.

INTRODUCTION

Advent of micro-electronic circuits has generated heightened interest in developing small, light and economically-viable power sources of low wattage. The solid state batteries using superionic conductors [1-3] and organic charge-transfer (CT) complexes [4,5] have attracted the attention. But the potential advantages of optimum operational conditions, higher energy densities and lower cost are yet to be achieved.

Recently Jain *et al.* [6] have developed a CT-based bio-solid state battery using vitamin-A acetate – iodine complex. In this battery, CT-complex acts as cathode. The battery is developed by sandwiching the cathode between anode and an inert electrode. Unlike the conventional battery-systems, no any salt is physically included in the cell-assembly but is allowed to form at the anode surface during operation. The formation of salt layer *in situ* makes the battery operation feasible. Inspite of many attractive features including ease of fabrication, this bio-battery is not really economic. But the use of biological material make this battery unique and interesting.

It is known that a plant leaf contains various biochemicals e.g., proteins, carotenoids etc. As these chemicals are capable of forming CT-complexes with electron acceptors [7-11], one can consider a plant leaf as a new type of electron donor. Based on this idea, I propose a new method of developing economically-viable bio-solid state electrochemical cell (BSC) using plant leaves *in vivo*. The BSC developed using *Calotropis* leaf is studied in detail.

EXPERIMENTAL

Fresh and mature plant leaves of *Calotropis, Bryophyllem pinnatum,* Rose and *Vinka rosea* are used. The disc shaped electrodes of magnesium and graphite have been constructed. The diameter of the electrodes is 1 cm.

The leaf is thoroughly washed with distilled water and then its epidermis is carefully removed. Now a small portion of the size of electrodes from this leaf is taken and placed over magnesium electrode. A requisite quantity of iodine powder is uniformly spread over the upper leaf surface with the help of a glass rod. After this, the graphite disc is placed over it under some positive pressure. Now the complete unit is kept at 35° in an oven for 24 hours. The dried unit so obtained is a new type of BSC.

All electrical measurements are made using HIL-digital panel meters.

RESULTS AND DISCUSSION

The plant leaves owing to their electron donating property form CT-complexes with electron acceptors like iodine. The cells developed are thus CT-based BSC.

The values of open circuit voltage (OCV) is found to be equal to 1.7 ± 0.1 volts for all the leaf systems. But the short circuit current (SCC) values have been found to vary significantly (1-3 mA/sq.cm.) possibly due to varying chemical composition of leaves. In a single leaf-system, SCC-value of BSC is observed to depend upon the quantity of iodine. For a typical 1 mm. thick (weighing approximately 90 mg) *Calotropis* leaf portion of 0.785 sq.cm. surface area, 20 mg of iodine gave best results. The BSC developed using *Calotropis* leaf gave the SCC density of 2.75 ± 0.25 mA/sq.cm. The change of OCV with temperature is negligible in the vicinity of room temperature (30°) and so the simplified Gibbs-Helmholtz equation can be used to estimate OCV. The heat of formation of MgI_2 is -86 K-cal/mole. This gives a theoretical value of 1.86 volts which is in close agreement with experimental value (1.7 ± 0.1 volts). This suggests that the energy producing reaction in BSC is possibly the salt formation. This computation of potential from free energy indicates that the OCV-value depends only on electron accepting component (iodine) of the complex. In other words, the consideration of general electron donating property is important and not the varying chemical composition of leaf. This inference also helps in justifying the use of plant leaves *in vivo* in developing BSC. However a detailed investigation on the effect of structure, varying active and non-active components of leaf on the cell performance is desirable.

The current-voltage characteristics have also been obtained (Fig. 1). A linear dependence of voltage on the drain current is obtained in the begining followed by a rapid fall of voltage at large current values (greater than 200 μA). A linear region is due to internal resistance of the cell. At large current, the electrode polarization effect may dominate. Assuming the cell-weight, including the complex and electrode contribution, 0.25 g, the maximum power density of 2W/kg is obtained.

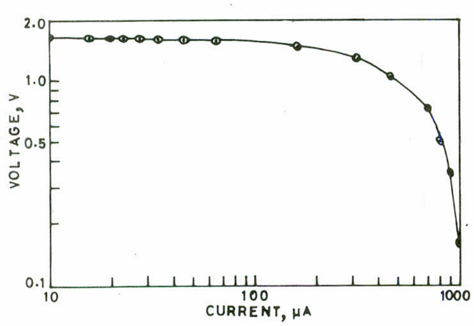

Fig. 1. The current-voltage characteristics of BSC developed from *Calotropis* leaf.

A complete discharge data under constant load of 100 KΩ (discharge current 15.5 μA) is plotted in Fig. 2. The graphical integration of this discharge curve gave a useful energy density of 24 W.h/kg.

The voltage drop rate is observed to be negligible when the cell is discharged under high loads (> 100 KΩ) but under lower loads (1-10 KΩ), it is found to vary from 1.0 to 0.1 mV/minute. The recovery of voltage has always been fast.

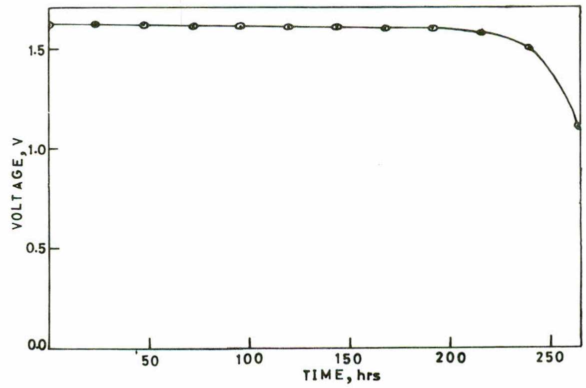

Fig. 2. Constant load (100 KΩ) discharge characteristics of BSC developed from *Calotropis* leaf at room temperature (30°).

The results presented here suggest that this new BSC may be quite useful in energizing various micro-electronic circuits. Detailed investigations are underway in our laboratory.

Acknowledgements. Author is thankful to the Head of Physics Department and Principal of the college for providing facilities.

REFERENCES

1. S. Chandra, *Super Ionic Solids* (North Holland, 1981).
2. R.H. Dahm, S. Hackwood, R.G. Linford and J.M. Pollock, Nature, **272**, 522 (1978).
3. M.D. Ingram and C.A. Vincent, Annual Reports (A), The Chem. Soc., **74**, 23 (1977).
4. F. Gutmann, A.M. Hermann and A. Rembaum, J. Electrochem. Soc., **114**, 323 (1967), J. Electrochem. Soc., **115**, 359 (1968).
5. F. Gutmann and L.E. Lyons, *Organic Semiconductors* (John Wiley, New York, 1967).
6. K.M. Jain, S. Abraham and A. Hundet, Jpn. J. Appl. Phys., **27**, 867 (1988).
7. K.M.C. Davis, D.D. Eley and R.S. Smart, Nature, **188**, 724 (1960).
8. B. Mallik, K.M. Jain and T.N. Misra, Biochem. J., **189**, 547 (1980).
9. A. Szent-Gyorgy, *Introduction to a Submolecular Biology* (A.P., London, 1960).
10. J.R. Platt, Science, **129**, 372 (1959).
11. B. Roserberg, T.N. Misra and R. Switzer, Nature, **217**, 423 (1968).