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LOW-POWER SOURCES FOR ELECTRONIC GADGETS USING *TRADESCANTIA* LEAF

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The low-power bio-emf-devices (BEDs) have been developed using the *Tradescantia* plant leaf. Different BED-parameters like open circuit voltage (V_{oc}), short circuit current (I_{sc}), internal resistance and the total energy density are obtained. The results suggest that the BEDs provide a new inexpensive and easily available non-conventional power sources for micro-electronic gadgets.

The results of the present investigation depend on the nature of the electrodes used. But the V_{oc} do not show any correlationship with the electrode potential possibly due to the involvement of bio-activities in energy generation and complexity of leaf system. A large variation in V_{oc} and I_{sc} obtained during discharge suggest a dominant role of the bio-chemical reactions in the operation of BED.

Key words: Bio-electropotential, Non-conventional energy sources, Bio-emf-devices.

INTRODUCTION

The electrical and electrochemical properties of plants result from the absorption of various nutrient ions e.g. calcium, potassium, ferric, phosphate, borate, molybdate etc. from the soil alongwith water and also from the easily ionizable organic compounds synthesised by plant cells. The presence of ions in bio-systems apparantly make them physical electrolytic system. But the fact that the ionic movement in them is regulated by the activities of plant cells, make the bio-system different from physical electrolytic system. It is well known that almost every bio-system develops bio-electropotential (BEP) [1-5] for its body organisation and survival. Observations indicate that the BEP has physiological origin [4, 5]. In most of the cases, the bio-electricity generated is very small which do not seem to be of any practical significance in energy area. But the modern technological breakthroughs in electronics have changed the situation. Today, many electronic gadgets are available which consume few micro-watts of power. Thus the exploitation of the electrical properties of bio-system in developing new type of low-power sources seem to be possible. Recent observations of Jain *et al.* suggest that the plant leaves can be used as a new material to develop low-power sources [6]. A detailed investigation on the *Sansevieria trifasciata* leaf has been made [7] which suggest their prospective use in energizing electronic gadgets. In this paper, we present a detailed study on the development of BED using the leaf of *Tradescantia* plant.

EXPERIMENTAL

Thin metallic plates of Zn, A1, C, Cu, Ag and brass are cut into strips of area 15mm x 20mm and 2mm thick supporting plates of teflon having same dimensions with a central hole are affixed on one side of each of them to construct the electrodes. Electrical connections are made through the central hole. The electrodes are washed first using N/10 NaOH, then by a jet of distilled water and finally with acetone. The dried electrodes are then polished prior to construct a unit of BED.

A mature leaf from *Tradescantia* plant is plucked and washed thoroughly with distilled water. Both the surfaces of leaf are uniformly injured using a sharp blade carefully till some bio-fluid oozes out. Now, a portion of this injured leaf is cut to the size of electrodes and is then sandwiched between two electrodes using spring clips which establish good electrical contact. The unit so obtained is a BED.

All electrical measurements are made using HIL digital meters.

RESULTS AND DISCUSSION

BED-parameters. The value of different BED-parameters have been measured several times under normal atmospheric conditions at room temperature 24 ± 2°. The results are presented in Table 1. The reproducibility of results is fairly reasonable in view of the complexity of the system.

The use of homo-electrode pair (C-C) in the BED gives V_{oc} 80 ± 20mV and I_{sc} 50 ± 10 μA. The power from such a BED is very small. In order to tap sufficient energy to energise micro-electronic circuits, the use of hetro-electrode pair is found useful (Table 1). The emf of a complete primary electro-chemical cell is equal to the algebric sum of the oxidation potential of one electrode and the reduction potential of the other. But the results on the BEDs (Table 1) do not show any correlationship of V_{oc} with the standard electrode potentials [8], possibly due to the presence of un-

Table 1. The values of open circuit voltage and spontaneous short circuit current for different BEDs at room temperature (24 ± 2°C).

Electrode pairs	V_{oc} (mV)	I_{sc} (μA)
C – C	80 ± 20	50 ± 10
C – Zn	1000 ± 50	2800 ± 400
Ag – Zn	1000 ± 50	3300 ± 500
Cu – Zn	930 ± 50	1800 ± 300
Brass – Zn	850 ± 20	1100 ± 300
C – A1	750 ± 70	1275 ± 250
Ag – A1	590 ± 20	260 ± 30
Cu – A1	640 ± 80	370 ± 150
Brass – A1	570 ± 40	270 ± 20

known nature of electrolytes, complexity of the bio-system and involvement of bio-activities in energy generation. However, the general behaviour of different electrodes in BEDs is indicative of the presence of voltaic contribution. At present, the bio and voltaic contributions to the energy generation from a BED are not known quantitatively. But one may safely conclude that the mechanism of BED is different than that of primary cells.

The current-voltage and current-power characteristics of different BEDs are studied after waiting for about 15 minutes till the V_{oc} has attained a steady value. The results are plotted in Figures 1 to 4. the observations are made by increasing the current in the circuit by varying load resistance in steps of 100 ohms. The internal resistance of the BED is found to vary from 0.9 to 1.2 kΩ for (C-Zn) BED and from 1.2 to 3.8 kΩ for (C-A1) BED. The maximum power output from C-Zn, Ag-Zn and C-A1 BEDs are 220 μW, 156 μW and 66 μW respectively.

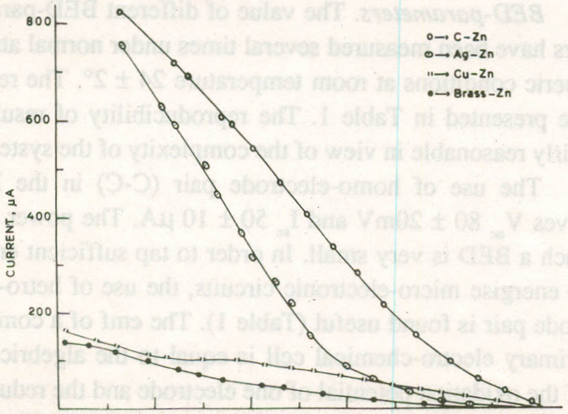

Fig. 1. Current-voltage characteristics of the BEDs (Electrode pairs made using zinc).

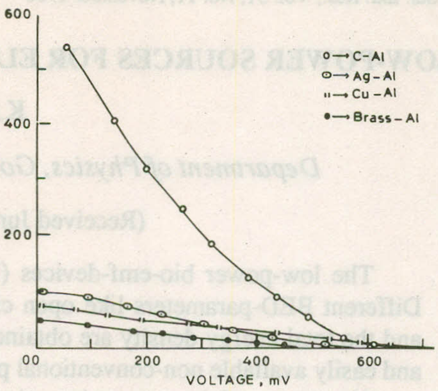

Fig. 2. Current-voltage characteristics of the BEDs (Electrode pairs made using aluminium).

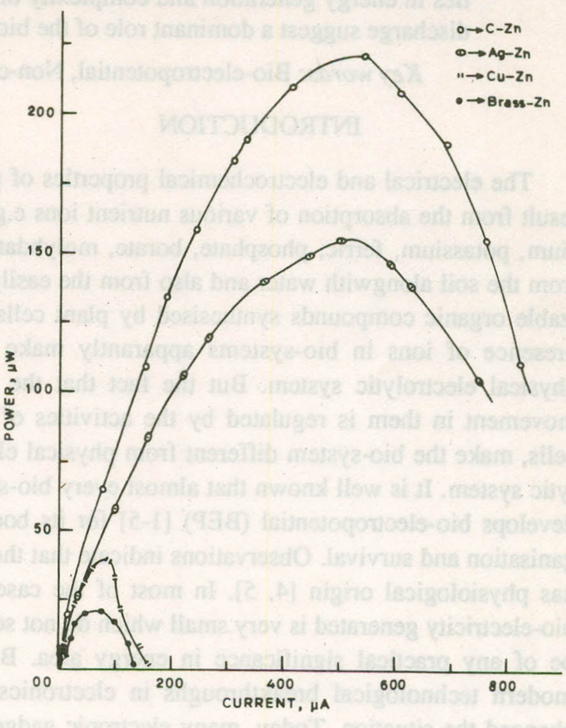

Fig. 3. Power-current characteristics of the BEDs (Electrode pairs made using zinc).

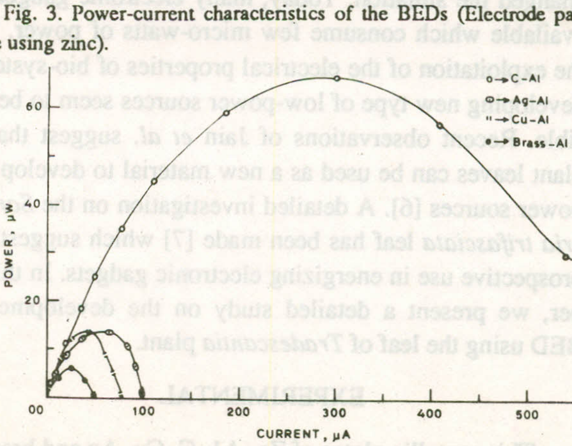

Fig. 4. Power-current characteristics of the BEDs (Electrode pairs made using aluminium).

Discharge characteristics. The self-discharge of (C-Zn) BEDs have been studied (Fig. 5 & 6). Surprisingly, the V_{oc} after decreasing by 100 mV during first five hours regained approximately the same value in about next twenty hours. This indicates that the power generated from a BED may have a large bio-contribution. As the leaf used in BED is injured, a change in the nature of reactants is expected due to the increase in the amount of reducing species, sugar level and the enhanced rate of respiration at the injured site [1, 9], which may initiate several enzyme catalysed bio-electrochemical reactions giving a significant amount of bio-contribution to the power generated. The variation of V_{oc} during self discharge thus suggests that two different types of bio-electrochemical reactions dominate in energy generation. It seems that the initial reaction during first five hours is related to the healing potential [1] developed in the injured bio-system. But as the bio-system in BED is kept under highly stressed condition, healing of injury is difficult. So the second reaction, possibly associated with the struggle for survival, is initiated which continued for next twenty hours. A further fall in V_{oc} seems to be dominated by the variations in physical parameters like water-loss from the bio-system. However, the above proposition is highly conjectural and without additional chemical analysis, it is difficult to know the actual reactants taking part in the reactions.

A large variation (400 to 700 μA) in I_{sc} value has also been observed during self-discharge of BED for the first seven hours followed by a regular fall with some variations superimposed over it. These results, thus, indicate an involvement of bio-activity in the operation of BED.

The BED characteristics have also been studied under constant load discharge (Fig. 7 & 8). When the discharge is carried out under 100 kΩ, the voltage drop remained approximately constant (800 ± 150 mV) for about 17 to 18 hours. The variation in current (8.5 ± 1.5 μA) are also negligible. However, under low load discharge, the time for obtaining useful power reduces significantly (Fig. 7). The graphical integration of the discharge curves for various constant loads have been used to estimate energy densities. Using 50 mg as the weight of leaf employed in BED, a useful energy density of 2.3 to 4.8 W.h/kg is obtained for (C-

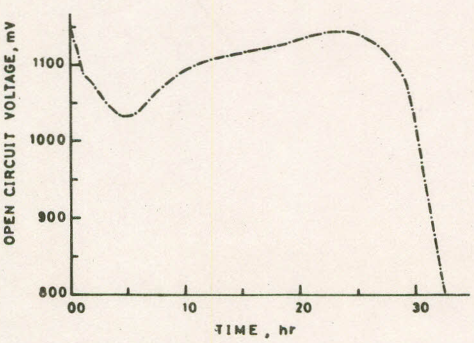

Fig. 5. Self discharge characteristics of (C-Zn) BED.

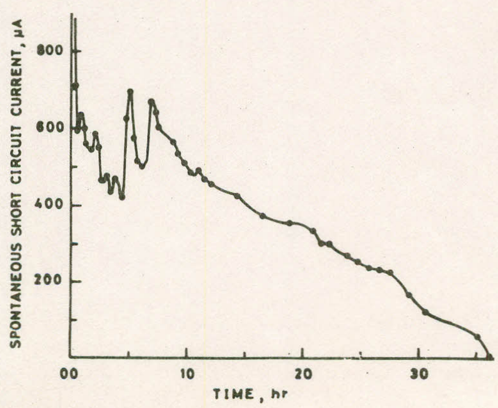

Fig. 6. Time dependence of spontaneous short circuit current of (C-Zn) BED.

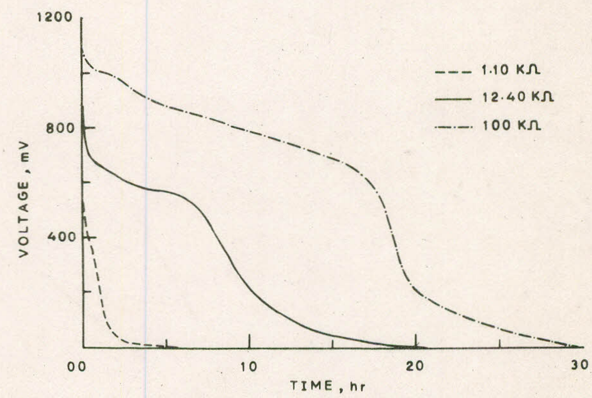

Fig. 7. Discharge characteristics of (C-Zn)BED under different loads.

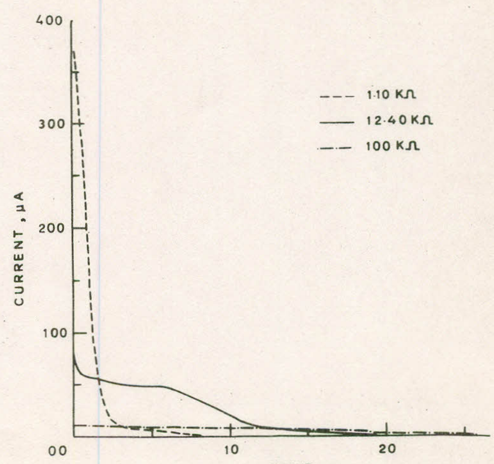

Fig. 8. Time dependence of discharge current from (C-Zn) BED under different loads.

Zn) BED (neglecting the electrode contribution and assuming that the voltage below one third of the open circuit value is not useful). This BED gives steady performance for many hours (6 to 18) under low current (below 50 μA) discharge conditions. Thus, these non-conventional BEDs are new and inexpensive energy sources to run low-power electronic gadgets.

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