An Experimental Study on the Coulombic Efficiency of *Bryophyllum pinnatum* Leaf Generated BPL Cell

Mehedi Hasan[1], Sunjida Haque[2], Kamrul Alam Khan[3]

[1]*Lecturer, Department of Electrical and Electronic Engineering, City University, Dhaka, Bangladesh*
[2]*Lecturer, Department of Electrical and Electronic Engineering, City University, Dhaka, Bangladesh*
[3] *Professor, Department of Physics, Jagannath University, Dhaka, Bangladesh*

ABSTRACT

The performance of a primary cell highly depends on the coulombic efficiency of that cell. Being a primary cell, Bryophyllum pinnatum leaf generated BPL cell, where electrodes- pair of zinc and copper dipped in the filtered leaf juice, a good efficiency is required. In this paper, we have tried to show the approximate coulombic efficiency of a unit BPL cell on a certain condition.

Keyword: *-BPL Cell, Electrochemical Cell, Coulombic Efficiency.*

1. INTRODUCTION

The leaf of *Bryophyllum pinnatum* contains several organic acids like amino acid, syringic acid, caffeic acid, ascorbic acid, mallic acid, iso-citric acid etc. which act like acidic electrolyte and also some metals like copper[01][02][03][04][07][08][09]. If we place a pair of zinc and copper at the leaf juice, electrons start to flow through the circuit. In this process, the zinc plates give electrons to the circuit and loose mass also. For a rechargeable battery the fraction of the electrical charge stored during charging that is recoverable during discharge.

Table -1: Coulombic Efficiency for several cells [05].

Cell Type	Coulombic Efficiency in percentage
Lead Acid	70-84
Lithium Ion	85-95
Nickel Cadmium	65-85
Nickel Metal Hydride	65-85
Polysulfide Bromide	60-65
Sodium-Sulphur	75-83
Vanadium Redox	60-80
Zinc Bromide	60-73

The coulombic efficiency is the ratio of the charge obtained to the total charge (the charge obtained plus the charge lost by local action) supplied by the anode [06], i.e.

$$\eta_Q\ \% = \frac{Q_{Output}}{Q_{Input}} \times 100\% = \frac{Q_{Obtained}}{Q_{Supplied}} \times 100\% \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

If the life time of the cell becomes t, with an outer circuit connection, and the current measured by the ammeter is *I*. Then the output charge,

$$Q_{Output} = It \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Again, the source of electron is the anode where electron produces by the oxidation reaction on the metal used as anode. Thus, the weight of the anode reduces with time because of the cell reaction.
If the weight of the anode used is = W_1, and the weight after time *t* is $=W_2$,
The weight lost = $W_1 - W_2 = x\ g$

Again, the molecular weight of the metal used as anode is *M*, and the oxidation number is n.
Then the reaction taking place on the anode can be represented as-

$A \rightarrow A^{n+} + ne^-$
Where, "*A*" represents anode.

Thus, one mole metal will produce *n* mole electron.

So, *M* g metal anode (*A*) will supply *n* mole electron.

x g metal anode will supply = $\frac{n.x}{M}$ mole electron = $\frac{n.x.N_A}{M}$ electron = $\frac{n.x.N_A \times 1.6\times 10^{-19}}{M}$ coulomb charge
= $\frac{n.x.F}{M}$ coulomb charge. [where, 1 F = 1 Faraday.]

That is *x* gm anode by decaying under oxidation process supply $\frac{\text{n.x.F}}{\text{M}}$ coulomb charge.

So, the input charge, $Q_{Input} = \frac{n.x.F}{M}$ coulomb charge………. ……(3)

From Equations-(1), (2) and (3), we get,

$$\eta_Q\ \% = \frac{Q_{Output}}{Q_{Input}} \times 100\%$$
$$= \frac{I.t}{\frac{n.x.F}{M}} \times 100\%$$
$$= \frac{I.t.M}{n.x.F} \times 100\%$$

So,

$$\therefore \eta_Q\ \% = \frac{I.t.M}{n.x.F} \times 100\% \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

By putting the values of the quantities in Equation-(4) we can calculate the coulombic efficiency.

2. METHODOLOGY

To construct *Bryophyllum pinnatum* leaf fuelled BPL cell, we need to collect the plant first which grows anywhere without any nursing. We collected fresh leaf, washed by water and then dried after weighing. The electrodes are collected from local market and then shaped comparing the dimension of the container. The juice was made using

blender with the addition of water and $CuSO_4.5H_2O$ as secondary salt. The whole procedures and the related dimensions are given below-

Collection of Bryophyllum pinnatum Leaf

Fig -1: *Bryophyllum pinnatum* leaf and plant

Sap Preparation

BPL in the sap was 85.308%, water was 14.214% and $CuSO_4.5H_2O$ was 0.4739% approximately.

Fig -2: Juice in the blender.

Electrode Preparation

Copper plates are used as cathode and Zinc plates as anode. The average height, length, thickness and mass of anode were 105.56mm, 53.12mm, 0.71mm and 27.71g respectively and for cathode 105.39mm, 53.26mm, 0.17mm and 6.77g respectively

Fig -3: Electrodes.

Design of BPL Test Cell

A small rectangular box made of glass was used, where the length of the cell was 10cm, width 6cm, height 12cm and inner volume was $720cm^3$.

Fig -4: Glass container.

3. EXPERIMENTAL SET-UP

The total anodic (Zn plates) area was twice the area of cathode (Cu plates). The connections are given in the schematic diagram below.

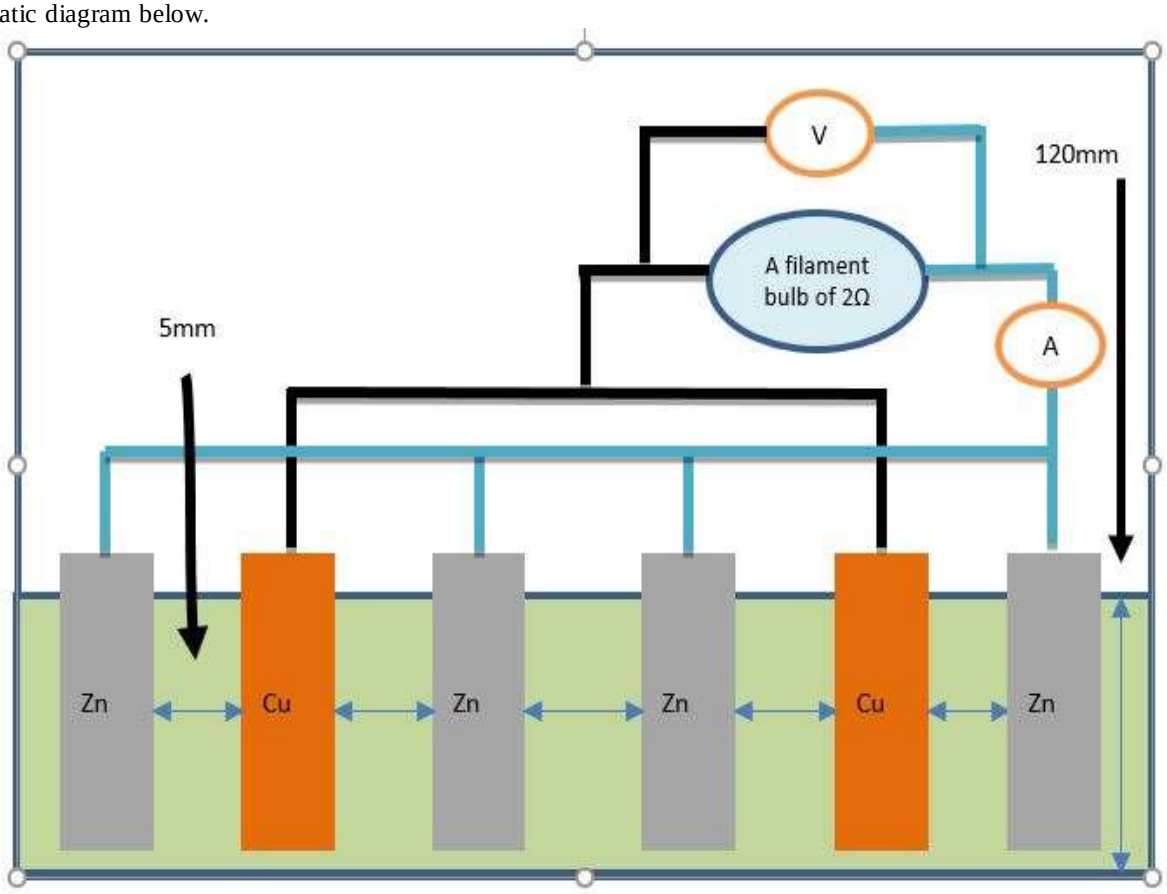

Fig -5: A schematic diagram of the experimental setup.

We have found that the pH of the juice with the malt decrease below 7.0 after shaking well [04] [08]. During the experiment, we have found the Ah rating of this cell was 0.396 [08].
For this, the weight of the anode used was measured (W_1) first. When the cell became dead (assumed), the metal used as anode was separated, cleaned with distilled water and then dried. The weight of the dried metal plate was measured (W_2). We also calculated here the ampere-hour of that unit cell during the study.

4. EXPERIMENTAL DATA

The weight of four unused Zn anodes in the cell was *111.02g*.
The weight of four Zn anodes of that cell was *106.93g* after the study.
So, the reduction of Zn from the anodes = *(111.02 – 106.93)g = 4.09g*.
Approximate ampere-hour of that cell was *0.396Ah*.

5. CALCULATIONS OF COULOMBIC EFFICIENCY (η_Q %)

The reaction taking place on anode (zinc plates)

Zn	–	$2e^-$	→	Zn^{2+}
1mol		2mol		1mol

Thus, 65.4g zinc produces total of charge = *2F = 193000C*
So, 4.09g zinc produces total of charge = $\frac{193000 \times 4.09}{65.4} C = 12069.878C$
Thus, the input charge= *12069.878C*
Again, the output charge = *0.396 Ah = 0.396A×3600s = 1425.6C*
So, the columbic efficiency = $\frac{1425.6C}{12069.878C} = 0.11811 = 11.811\%$.

6. RESULT AND DISCUSSIONS

The columbic efficiency of this BPL cell found *11.811%* which cannot be considered very efficient. However, this can't be exact measurement of this efficiency. Because, addition of copper sulphate affects the cell performance as well as the cell capacity of the BPL cell. Moreover, the impurities of the electrodes, temperature, percentage of water in the filtered juice, juice filtration process found very effective in cell enactment. This means, by adjusting those parameters, we can expect to get a better result. The purpose of this kind of cell is to provide some electrical energy at remote places, so, this value of efficiency is less important in front of the resolutions considering the socio-economic inefficiency of on-grid supply.

7. REFERENCES

[01]. DE Okwu and C Josiah, "Evaluation of the chemical composition of two Nigerian medicinal plants", African Journal of Biotechnology, Vol. 05, Issue. 04, P. 357-361, 2006.
[02]. A Kamboj, AK Saluja "*Bryophyllum pinnatum (Lam.) Kurz.:* Phytochemical and Pharmacological Profile: A Review", Pharmacognosy Reviews, Vol. 03, Issue. 06, P. 364-374, 2009.
[03]. DA Alabi, MZ Onibudo I, NA Amusa, "Chemicals and Nutritional Composition of four Botanicals with Fungitoxic Properties", World Journal of Agricultural Science, Vol. 01, Issue. 01, P. 54-88, 2005.
[04]. M Hasan, L Hassan, S Haque, M Rahman, KA Khan, "A Study to Analyze the Self-Discharge Characteristics of *Bryophyllum Pinnatum* Leaf Fueled BPL Test Cell" International Journal of Research in Engineering and Technology (IJRET), Volume-06 Issue-12, P. 06-11, 2017. DOI: https://doi.org/10.15623/ijret.2017.0612002
[05]. CJ Rydh, BA Sanden, "Energy analysis of batteries in photovoltaic systems. Part I: Performance and energy requirements", Energy Conversion and Management, Vol. 46, Issue. 11-12, P. 1957-1979, 2005.
[06]. AJ Bard,LR Faulkner, "Electrochemical Methods: Fundamentals and Applications" 2nd edition (2000), New York: John Wiley & Sons, ISBN 0-471-04372-9.
[07]. MM Hasan, MKA Khan, MNR Khan and MZ Islam, "Sustainable Electricity Generation at the Coastal Areas and the Islands of Bangladesh Using Biomass Resources", City University Journal, Vol. 02, Issue. 01, P. 09-13, 2016.
[08]. M Hasan, KA Khan, MA Mamun, "An Estimation of the Extractable Electrical Energy from *Bryophyllum pinnatum* Leaf", American International Journal of Research in Science, Technology, Engineering &Mathematics (AIJRSTEM), Vol. 01, Issue. 19, P. 100-106, 2017.
[09]. M Hasan and KA Khan "*Bryophyllum pinnatum* Leaf Fueled Cell: An Alternate Way of Supplying Electricity at the Off-grid Areas in Bangladesh" in Proceedings of 4th International Conference on the Developments in Renewable Energy Technology [ICDRET 2016], P. 01, 2016. DOI: 10.1109/ICDRET.2016.7421522