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# FABRICATION AND CHARACTERIZATION OF Zn/ PVA+IODINE AQUEOUS SOLUTION/CARBON CELL

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Electrochemical properties of a Zn/ PVA+Iodine aqueous solution/carbon cell have been investigated. In this cell, PVA+Iodine aqueous solution is used as an electrolyte and zinc and carbon rods serve as electrodes. As a cell compartment the cylindrical glass vessels of length 3.0 cm and of diameter 2.0 cm are used. The discharge voltage–current, charge voltage/current–time and discharge voltage/current–time characteristics and open circuit verses time has been examined. The open-circuit voltages and short-circuit currents of cells are observed 1.4 volt and 5.14 mA respectively. The current-voltage characteristics and open circuit voltage-time, charge voltage/current-time and discharge voltage/current-time studies are made. The open circuit voltage has been observed for 100 hours. It is found that the cell is well stable and also rechargeable.

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## 1. Introduction

Organic semiconductors have been studied for more than fifty years and exhibit many properties that still are far from understanding them as well as it has been achieved with inorganic materials [1]. Much work was and is done to study electric and electrochemical properties of organic semiconductors [2] and their use as the active component in optoelectronic and electro-optical devices [3,4]. This is mainly due to low cost, simplicity of device fabrication, interesting electrical, electrochemical and optical properties, and environmentally harmless or friendly technology. An additional motivation stems from the academic point of view due to the molecular properties and the various open scientific questions [5]. The field of organic electronics has reached the point where several applications are routinely available for use; others are close to be commercialized, while others are in a design or testing phase for novel applications including nanoscale technologies.

This enormous progress in applications of organic materials in optoelectronic devices is mainly due to the fact that many aspects of organic device performance are already well understood, and have been thoroughly documented in the scientific literature. But besides the increasing understanding of some physical properties of organic materials, many others are not yet fully understood.

Organic molecules are suitable candidates as building blocks for the future electronics due to their size, easy availability in high purity, tunable optical, electrical [6] and structural properties and moreover due to their ability to self-organize into different nanostructures [7-9]. Many potential applications of organic semiconductors may be realized via investigation and modification of their conductivity [10-13].The wide range of organic molecular species offers different electronic components like diodes [14,15], switches [16-18], storage [19,20], wires [21-23] and insulators, which fueled the hope that electronic devices can be shrunk from the current micrometer-length scale all the way down to the molecular scale [24]. A further advantage is given

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by the possibility to dissolve the organic materials in solvents; thus allowing applying cost-effective, high volume, continuous printing techniques in the production of organic electronics, with great reductions in cost of the final device.

Some organic semiconductors are very sensitive to humidity [10,11], temperature [25-26], infra-red, visible and ultraviolet radiation [27], and different types of gases stick as ammonia [28]. Obviously, investigation of electrochemical behavior and fabrication of electrochemical cells and sensors with liquid and solid electrolytes on the base of organic materials is very promising area [29,30]. For example, Panozzo et al. [31] have described a high-efficiency light-emitting electrochemical cell on the base of organic salt and Arnold [12] has reported an electrochemical glucose sensor. Organic- based transistors that are available to detect charged/uncharged chemical species in aqueous media via the electric field have been developed by Bartic et al. [32]. A number of ions selective electrode devices, semi-conducting oxide sensors and electrochemical ones based on liquid and solid electrolytes have also been described [12,33].

Poly(vinyl alcohol) PVA is a polymer and is a potential candidate for use in electrolytes [34,35]. PVA has solubility in water. Also both iodine and PVA are harmless. Therefore, it would be useful to use this material in electrochemical devices that could be used for storage and conversion of energy. In an earlier study [2], we reported a rechargeable zinc/orange dye aqueous solution/carbon cell. This cell can be used as a source of electric power for low power applications, as an electrochemical sensor of moisture or water precipitation, and for measuring environmental parameters. The voltage and current generated by an electrochemical cell is directly related to the types of materials used in the electrodes and electrolyte. In this work, we investigated electrochemical properties of a Zn/ PVA+Iodine aqueous solution/carbon cell. The open-circuit voltages and short-circuit currents of the cell are observed. The discharge voltage/current–time characteristics exhibit stable and constant behavior.

## 2. Experimental

Poly vinyl alcohol (MERCK), [-CH2CHOH-]$_n$, with density 0.4 - 0.6 gcm$^{-3}$ at room temperature and iodine were used for preparation of the poly vinyl alcohol (PVA)- iodine aqueous solution for Zn/ PVA+Iodine aqueous solution/carbon cell. The wt.% ratio of PVA and iodine in the aqueous solution was 5:1.

In order to make poly vinyl alcohol (PVA)-based polymer electrolyte, 0.6 g of PVA was placed in 20 ml of distilled water in a 100 ml beaker and put it onto hot plate at 75C. When PVA was fully dissolved in distilled water, then filtered it and calculated value of iodine was added to it.

Experimental cell assembly for the polymer electrolyte- based zinc/carbon cell is shown in fig. 1. The cell was sealed in cylindrical glass vessel and cell's length and diameter were 3.0 and 2.0 cm respectively. The separation between two electrodes was 1 cm and the volume of the solution was 3.0 cm$^3$, length of both the electrodes was 3.5 cm. The shape of carbon electrode was cylindrical and zinc electrode was in rectangular shape. The diameter of the carbon rods was 5.0 mm. Width and thickness of the zinc sheets were 0.5 cm and 1.0 mm, respectively.

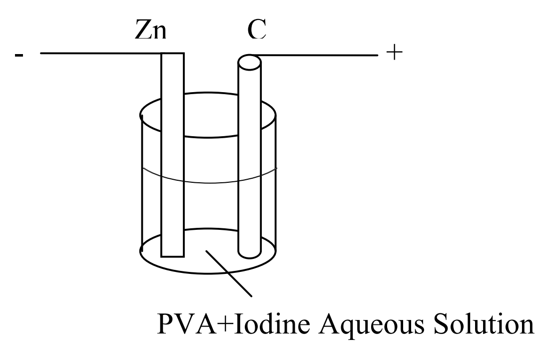


*Fig. 1. Schematic diagram of Zn/ PVA+Iodine aqueous solution/carbon cell.*

The discharge voltage-current, open circuit voltage-time, charge voltage/current-time and discharge voltage/current-time characteristics of cell was measured at room temperature by Keithley 196 Digital Multimeter.

## 3. Results and discussion

The discharge voltage-current (V-I) relationship of the zinc/ PVA+Iodine aqueous solution /carbon electrochemical cell is shown in Fig. 3. The zinc electrode's potential has negative polarity with respect to the carbon electrode [2]. The V-I relationship is typical for electrochemical cells [36].

The charge voltage/current-time and discharge voltage/current-time curves of the cell are presented in fig. 3 and 4 respectively. The cell was discharged at load of 700 Ω. It is found that the cell is rechargeable. The measured values of open-circuit voltage and short-circuit current of the fully charged cell are 1.4 V and 5.14 mA, respectively (fig. 2). The discharge voltage/current-time characteristics exhibit stable and constant behavior (fig. 4).

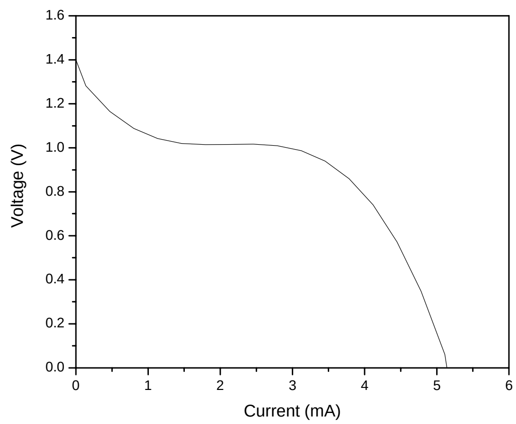


*Fig. 2. Voltage versus current discharge characteristic of Zn/ PVA+Iodine aqueous solution/carbon cell.*

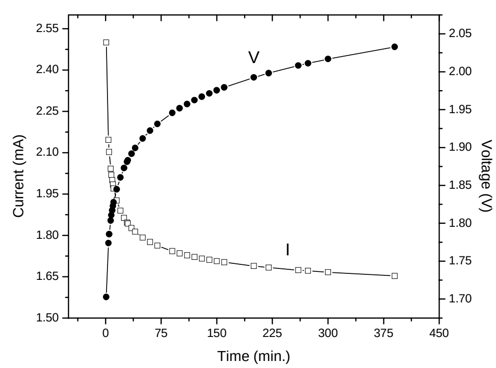


*Fig. 3. Charge voltage/current-time curves for Zn/ PVA+Iodine aqueous solution/carbon cell.*

The current efficiency ($E_i$), i.e., the ratio of the quantity of electricity obtained from the cell and that used to charge it (fig. 3 and 4) for a fixed time ($t$) of 4 hr as calculated by the following formula [37], is 66%.

$$E_i = \frac{\int_0^t I_d dt}{\int_0^t I_c dt} \quad (1)$$

where $I_d$ is discharging current and $I_c$ is charging current.

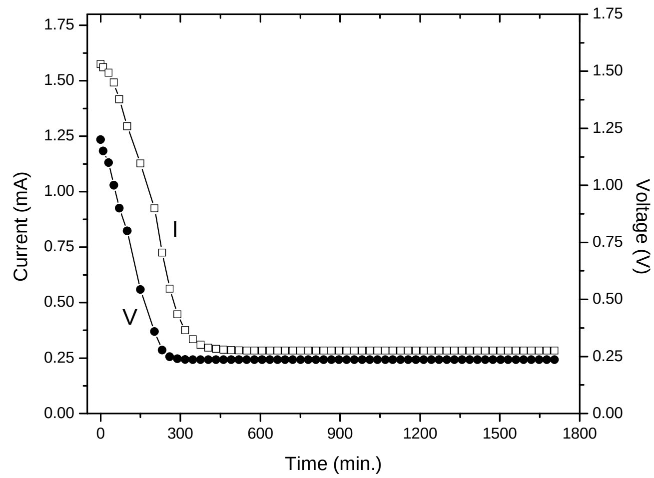


*Fig. 4. Discharge voltage/current-time behavior for Zn/ PVA+Iodine aqueous solution/carbon cell.*

In the zinc/ PVA+Iodine aqueous solution /carbon cell, when the zinc electrode was replaced by carbon and charged the cell, it was found that in the discharge mode the operating voltage dropped from 182.7 to 6.3 mV and current from 0.34 to 0.008 mA, during 12 hours. This indicates that in the zinc/ PVA+Iodine aqueous solution /carbon cell, the zinc electrode is active with respect to that of carbon.

The electrical energy of the cell as a change of free energy ($\Delta G$) was found to be -270 kJmol$^{-1}$ by using following expression [36].

$$\Delta G = -nFE \qquad (2)$$

where $n$ is the number of electrons transferred per mole (it is equal to 2); $F$ is Faraday constant (96487 C); and $E$ is the electromotive force of the cell.

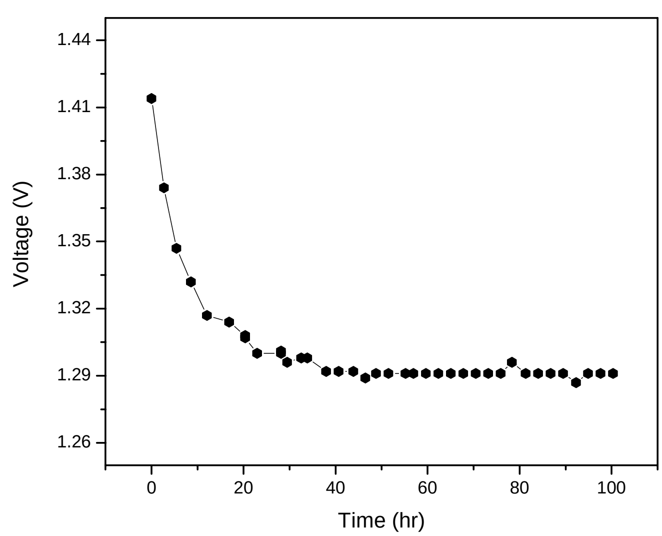


*Fig. 5. Open circuit voltage of Zn/ PVA+Iodine aqueous solution/carbon cell during 100 hrs of storage.*

The capacity of the cell ($C$) was calculated using the expression [36]:

$$C = \frac{nFW}{(MW)} \tag{3}$$

where $W$ is the weight of the active electrode material (zinc in this case): its weight is equal to 2.136 g; $MW$ the molecular weight of the material (for zinc it is equal to 65.37). The calculated value of the $C$ is 6.31 kC = 1.75 Ah.

## 4. Conclusions

An electrochemical zinc/ PVA+Iodine aqueous solution /carbon cell has been fabricated and its electrochemical properties have been investigated. The cell is found to be rechargeable. The value of open circuit voltage and short circuit current of the fresh and fully charged cell are 1.4 V and 5.14 mA, respectively.

The current discharge/charge efficiency is 66%. The stable and constant behavior is observed for discharge voltage/current-time characteristics. The cell may be used as a source of electric power of low power applications, as an electrochemical sensor and for measuring environmental parameters.

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## References

[1] D. G. Wu, J. Ghabboun, J. M. L. Martin and David Cahen. J. Phys. Chem. B. **105,** 12011 (2001).
[2] Khasan S. Karimov, Muhammad H. Sayyad, Mukhtar Ali, Muhammad N. Khan, Syed A.Moiz, Khurram B. Khan, Humera Farah, Zioda M. Karieva, J. Power Sources **155**, 475 (2006).
[3] J. Kanicki, Handbook of Semiconducting Polymers, Skotheim, N.Y., Vol. 1 (1985).
[4] G. Horowitz, Adv. Mater., **2**, 287 (1990).
[5] Y. Zou, A. Scholl, Th. Schmidt, B. Richter, R. Fink and E. Umbach. BESSY Anual Report, 200 (2000).
[6] S. Welter, K. Brunner, J. W. Hofstraat, L. De Cola, Nature **421,** 54 (2003).
[7] S. Stepanow, M. Lingenfelder, A. Dmitriev, H. Spillmann, E. Delvigne, N. Lin, X. Deng, C. Cai, J.V. Barth, K. Kern, Nature. Materials. **3**, 229 (2004).
[8] Y. Wei, K. Kannappan, G. W. Flynn, M. B. Zimmt, J. Ame. Chem. Soc. **126,** 5318 (2004).
[9] X. Yang, Z. Mu, Z. Wang, X. Zhang, J. Wang, Y. Wang, Langmuir. **21**, 7225 (2005).
[10] F. Gutman, L.E. Lyon, Organic Semiconductors, Part A, Krieger Robert E. Publishing Company, Malabar, Florida, USA, p. 125 (1981).
[11] F. Gutman, H. Keyzer, L. E. Lyons, R. B. Smoano, Organic Semiconductors, Part B, Kriger Robert E. Publishing Company, Malabar Florida, USA, 35 (1983).
[12] E. Arnold, in: C. M. Petty, M. R. Bryce, D. Bloor, (Eds.), An Introduction to Molecular Electronics, St. Edmundsbury Press Limited, London, 35 (1995).
[13] T. Makyama, H. Mutsuoka, K. Uehara, A. Sugimoto, K. Mizuno, N. Inoue, Trans. IEEE Jpn. **118**, 1435 (1998).
[14] A. Aviram, M. Ratner, Chem. Phys. Lett., **29**, 277 (1974).
[15] B. Larade, A. M. Bratkovsky, Phys. Rev. B. **68,** 235305 (2003).
[16] C. P. Collier, G. Mattersteig, E. W. Wong, Y. Luo, K. Beverly, J. Sampaio, F. M. Raymo, J. F. Stoddart, J. R. Heath, Science **289**, 1172 (2000).
[17] P. E. Kornilovich, A.M. Bratkovski, Phys. Rev. B. **64**, 195413 (2001).
[18] D. R. Stewart, B. A. A. Ohlberg, P. A. Beck, Y. Chen, R. S. Villiams, J. O. Jeppesen, K. A. Nielsen, J. F. Stoddart, Nano. Lett. **4**, 133 (2004).
[19] J. Chen, M. A. Reed, A. M. Rawlett, J. M. Tour, Science **286,** 1550 (1999).

[20] R. Sessoli, D. Gatteschi, A. Caneschi, M. A. Novak, Nature **365,** 141 (1993).
[21] W. B. Davis, W. A. Svec, M. A. Ratner, M. R. Wasielewski, Nature **396,** 60 (1998).
[22] C. Patoux, J. P. Launay, M. Beley, S. Chodorowski-Kimmes, J. P. Collin, S. James, J. P. Sauvage, J. Am. Chem. Soc. **120**, 3717 (1998).
[23] J. Reichert, R. Ochs, D. Beckmann, H. B. Weber, M. Avor, H. V. Lohneysen, Phys. Rev. Lett. **88,** 176804 (2002).
[24] C. Joachim, J. K. Gimzewski, A. Aviram, Nature 408, 541 (2000).
[25] Kh. S. Karimov, PhD Thesis, A. F. Ioffe Physical Technical Institute, St. Peterburg, Russia, 1982.
[26] Kh. S. Karimov, DSc Thesis, Department of Heat Physics, Academy of Sciences, Tashkent, Uzbekistan, 1994.
[27] Kh. S. Karimov, Kh. M. Akhmedov, A. A. Dzhuraev, M. N. Khan, S. M. Abrarov, M. I. Fiodorov, Eurasian Chem. Technol. J. **2**, 251 (2000).
[28] M. I. Fiodiorov, Patent # 21244719, Moscow Russia 3 (1999).
[29] J. R. Stetter, W. R. Penrose, Sh. Yao, J. Electrochim. Soc. **150**, S11 (2003).
[30] B. Oh, D. R. Vissers, Z. Zhang, R. West, H. Tsukamoto, K. Amine, J. Power Sources, **119-121,** 442 (2003).
[31] S. Pansozzo, M. Armand, O. Stephan, Appl. Phys. Lett. **80**, 679 (2002).
[32] C. Bartic, A. Campitelli, S. Borghs, Appl. Phys. Lett. **82**, 475 (2003).
[33] A. R. Blythe, Electrical Properties of Polymers, Cambridge University Press, USA, p. 91 (1979).
[34] A.A. Mohamad, N.S. Mohamed, M.Z.A. Yahya, R. Othman, S. Ramesh, Y. Alias and A. K. Arof, J. Solid State Ionics **156**, 171 (2003).
[35] Chun-Chen Yang and Sheng-Jen Lin, J. Power Sources **112**, 479 (2002).
[36] D. B. Hibbert, Introduction to Electrochemistry, Macmillan Press Ltd., London, UK, p. 294 (1993).
[37] D. R. Crow, Principles and Applications of Electrochemistry, Third Edit., Chapman and Hall, London, p. 202 (1988).