ELSEVIER

Journal of Power Sources 55 (1995) 255–257

JOURNAL OF POWER SOURCES

Short Communication

# Study of a new polymer electrolyte ($PVP+KYF_4$) for solid-state electrochemical cells

E. Laxmi Narsaiah, M. Jaipal Reddy, U.V. Subba Rao

*Department of Physics, Osmania University, Hyderabad-500 007, India*

Received 20 December 1994; accepted 6 February 1995

**Abstract**

In search of electrochemical cells based on polymers other than the widely studied conducting polymers, we report the fabrication of a new electrochemical cell based on polyvinylpyrrolidone (PVP) complexed with $KYF_4$ salt. Complexation of $KYF_4$ with PVP is confirmed by infrared (IR) absorption studies. Wagner's polarization studies indicate that the charge transport in this electrolyte is predominantly due to an ionic process ($t_{ion} \approx 0.63$). Using this electrolyte, an electrochemical cell with configuration $K/(PVP+KYF_4)/(I_2+C+\text{electrolyte})$ is fabricated and its discharge characteristics reported. Short-circuit current and open-circuit voltage of this cell are found to be 1 mA and 2.5 V, respectively.

*Keywords:* Polymer electrolytes; Electrochemical cells

## 1. Introduction

Ion-conducting polymers have recently become an area of widespread interest in solid-state ionics because of their potential application in solid-state electrochemical devices [1–4]. Many of the early studies in this field are focused upon poly(ethylene oxide) (PEO), poly(propylene oxide) (PPO) and poly(bis-methoxyethoxy ethoxy phosphazene) (MEEP) complexed with NaI, $NaClO_4$, $NaCF_3SO_3$, $NaPF_6$ [5–8]. Investigations in this field have also been devoted to PEO-based electrolytes using divalent transition metal cations [9–11], alkali salts [12–17] as dopants. Silver ion-conducting polymer electrolytes have also been examined and are based on $PEO+AgClO_4$ [18], $PEO+KAg_4I_5$ [19] and $PEO+AgNO_3$ [20,21]. Several other polymer electrolytes, such as $PEO+NaYF_4$ [22] and $PEO+KYF_4$ [23], have also been explored.

In an attempt to investigate the possibility of fabricating electrochemical cells based on polymers other than conducting polymers, the authors have already reported the results obtained on electrochemical cells that employ polyacrylamide $(PA)+AgNO_3$ [24] and polyvinylpyrrolidone $(PVP)+AgNO_3$ [25] electrolytes The work reported here presents the results of studies on a new polymer electrolyte, namely, $PVP+KYF_4$. Using this electrolyte, an electrochemical cell has been fabricated and its discharge characteristics determined. The data are compared with those for cells based on conducting polymers.

## 2. Experimental

Films of $PVP+KYF_4$ were prepared in a stoichiometric ratio of 80:20 by means of the solution cast technique. An aqueous solution of PVP and methanol with $KYF_4$ was stirred for several hours. The stirred solution was cast on to polypropylene dishes and evaporated slowly at room temperature. The final product was vacuum dried thoroughly at $10^{-3}$ torr.

The IR spectra of the films were recorded, using a Perkin-Elmer FT-IR spectrophotometer (Model 1605), over the range 450 to 4500 $cm^{-1}$. The total ionic transference number ($t_{ion}$) was measured using Wagner's polarization technique [26].

Electrochemical cells were developed with the configuration $K/(PVP+KYF_4)/(I_2+C+\text{electrolyte})$; details on the fabrication of the electrochemical cells have been given elsewhere [21]. The discharge characteristics of the cell were determined for a constant load of 100 kΩ.

0378-7753/95/$09.50 
*SSDI* 0378-7753(95)02198-P

## 3. Results and discussion

The complexation of $KYF_4$ salt with PVP was confirmed by IR studies. The IR spectra of PVP, PVP+$KYF_4$ and $KYF_4$ are shown in Fig. 1. It is clear that the IR spectra of PVP+$KYF_4$ exhibit several changes by comparison with the IR spectra of $KYF_4$ and PVP. These changes are: (i) the appearance of new peaks; (ii) shifts in several of the peaks, and (iii) disappearance of some of the peaks. These observations indicate clearly the complexation of $KYF_4$ salt with the polymer.

The ionic transference number, $t_{ion}$, was measured using the Wagner's polarization technique. In this technique, the PVP+$KYF_4$ film was polarized in the configuration Ag/PVP+$KYF_4$/C. After polarization of the cell with a constant d.c. voltage of 1.5 V, the current was recorded as a function of time; the resulting curve is shown in Fig. 2. The transference numbers $t_{ion}$ and $t_{ele}$ were evaluated from the polarization current versus time plot; the values thus obtained are given in Table 1. The ionic transference number, $t_{ion}$, was found to be 0.63. These results clearly indicate that PVP+$KYF_4$ behaves as a mixed (ionic+electronic) conductor. The charge transport in this electrolyte is predominantly due to an ionic process. Fig. 3 presents the discharge characteristics of an electrochemical cell with configuration K/PVP+$KYF_4$/($I_2$+C+electrolyte) at room temperature and under a constant load of 100 kΩ. The open-circuit voltage (OCV) and short-circuit current (SCC) are found to be 2.5 V and 1 mA, respectively. Several parameters evaluated for this cell are also given in Table 1, along with the parameters of an electrochemical cell with PEO+$KYF_4$.

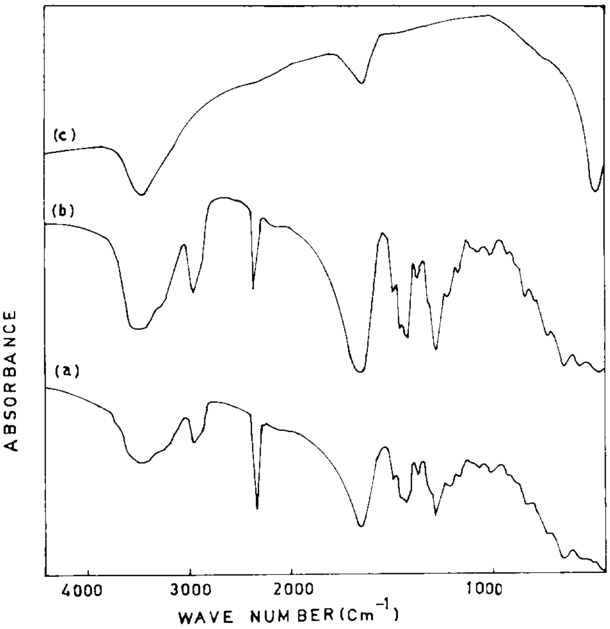


Fig. 1. IR spectra: (a) PVP; (b) PVP+$KYF_4$ and (c) $KYF_4$.

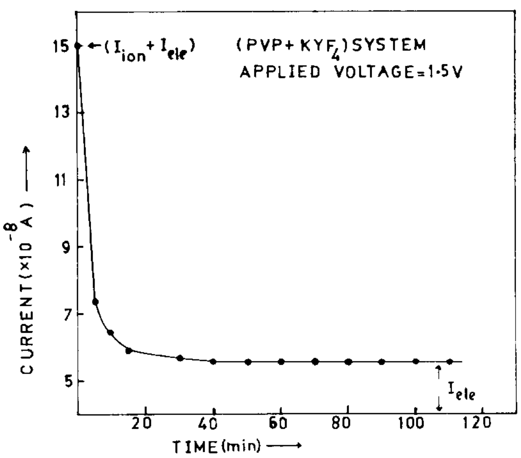


Fig. 2. Polarization current vs. time for PVP+$KYF_4$.

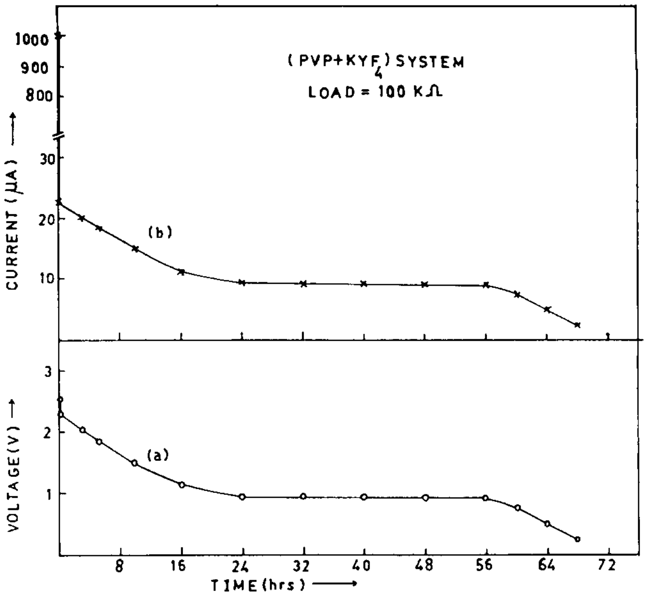


Fig. 3. (a), (b) Discharge characteristics of PVP+$KYF_4$ electrochemical cell.

The data of Table 1 demonstrate that electrochemical cells based on PVP+$KYF_4$ have several improved cell characteristics compared with those of cells with PEO+$KYF_4$. Further, close observation of these cell parameters indicate the possibility of fabricating electrochemical cells based on cheaper polymers such as PVP, rather than using high-cost conducting polymers (such as PEO). Further work is in progress to improve the ionic nature of the present polymer electrolyte and its rechargeable nature.

## 4. Conclusions

A new polymer electrolyte PVP+$KYF_4$ has been utilized to produce an electrochemical cell. The OCV and SCC observed for this cell are 2.5 V and 1 mA,

Table 1
Cell parameters for PVP + $KYF_4$ and PEO + $KYF_4$ systems

| Parameter electrolyte | PEO + $KYF_4$ | PVP + $KYF_4$ [a] |
|---|---|---|
| Open-circuit voltage (V) | 2.4 | 2.5 |
| Short-circuit current (μA) | 240 | 1000 |
| $t_{ion}$ | 0.93 | 0.63 |
| $t_{ele}$ | 0.07 | 0.37 |
| Discharge time for plateau region (h) | 51 | 40 |
| Current density (μA $cm^{-2}$) | 179.1 | 746.2 |
| Discharge capacity (μA $h^{-1}$) | 4.705 | 25 |
| Power density (W $kg^{-1}$) | 1.116 | 2.77 |
| Energy density (Wh $kg^{-1}$) | 56.93 | 111.11 |

[a] Present study.

respectively. A comparison of these results with those for PEO-based cells encourages the development of electrochemical cells based on polymers other than well-studied conducting polymers.

## Acknowledgements

The authors thank the Head, Department of Physics, Osmania University, Hyderabad for encouragement, as well as the UGC, New Delhi, for financial support. One of the authors (ELN) also thanks CSIR New Delhi for the award of a Research Associateship.

## References

[1] M.B. Armand, *Solid State Ionics, 9/10* (1983) 745.
[2] C. Berthier, W. Gorecki, M. Miner, M.B. Armand, J.M. Chabagno and P. Rigaud, *Solid State Ionics, 11* (1983) 91.
[3] B.L. Papke, M.A. Ratner and D.F. Shriver, *J. Electrochem. Soc., 129* (1982) 1694.
[4] M.B. Armand, *Annu. Rev. Mater. Sci., 16* (1986) 245.
[5] D. Fauteux, M.D. Lupien and C.D. Robitaille, *J. Electrochem. Soc., 134* (1987) 2761.
[6] S.G. Greenbaum, Y.S. Pak, M.C. Wintersgill, J.J. Foutanella and J.W. Schultz, *J. Electrochem. Soc., 135* (1988) 235.
[7] S.G. Greenbaum, K.J. Ademic, Y.S. Pak, M.C. Wintersgill and J.J. Foutanella, *Solid State Ionics, 28–30* (1988) 1042.
[8] S.A. Hashmi, A. Chandra and S. Chandra, in B.V.R. Chowdari (ed.), *Solid State Ionics: Materials and Applications,* World Scientific, Singapore, 1992, p. 567.
[9] L.L. Yang, A.R. McGhie and G.C. Farrington, *J. Electrochem. Soc., 133* (1986) 1380.
[10] R. Huq, G. Chiodelly, P. Ferloni, A. Magistris and G.C. Farrington, *J. Electrochem,. Soc., 134* (1987) 364.
[11] L.L. Yang, R. Huq and G.C. Farrington, *Solid State Ionics, 18/19* (1986) 291.
[12] L.S. Yang, Z.Q. Shan and Y.D. Liu, *Solid State Ionics, 40/41* (1990) 1967.
[13] K.M. Abraham, M, Alamgir and R.K. Reynolds, *J. Electrochem. Soc., 136* (1989) 3576.
[14] M. Stainer, L.C. Hardy, D.H. Whitemore and D.F. Shriver, *J. Electrochem. Soc., 131* (1984) 784.
[15] M.F. Daniel, B. Deshat and J.C. Lassengues, *Solid State Ionics, 28–30* (1988) 632.
[16] E.A. Reitman, M.L. Kaplan and R.J. Cava, *Solid State Ionics, 17* (1985) 67.
[17] P.R. Sorensen and T. Jacobsen, *Electrochim. Acta, 27* (1982) 1675.
[18] T.M.A. Abrantes, L.J. Alcacer and C.A.C. Sequeira, *Solid State Ionics, 18/19* (1986) 315.
[19] J.R. Stevens and B.E. Mellander, in L. Alcacer (ed.), *Conducting Polymers,* Reidel, Dordrecht, 1987, p. 95.
[20] S. Chandra, S.A. Hashmi, M. Saleem and R.C. Agrawal, *Solid State Ionics, 66* (1993).
[21] S. Sreepathi Rao, K.V.S. Rao, Md. Shareefuddin, U.V. Suba Rao and S. Chandra, *Solid State Ionics, 67* (1994) 331.
[22] S. Sreepathi Rao, M. Jaipal Reddy, K.N. Reddy and U.V. Subba Rao, *Solid State Ionics, 74* (1994) 225.
[23] M. Jaipal Reddy, S. Sreepathi Rao and U.V. Subba Rao, *J. Polymer Commun.,* submitted for publication.
[24] S. Sreepathi Rao and U.V. Subba Rao, *J. Mater. Sci. Lett., 13* (1994) 1771.
[25] M. Jaipal Reddy, S. Sreepathi Rao, E. Laxmi Narsaiah and U.V. Subba Rao, *Solid State Ionics,* (1994) in press.
[26] J.B Wagner and C. Wagner, *J. Chem. Phys., 26* (1957) 1597.