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FABRICATION OF ELECTROCHEMICAL CELL AND GAS SENSOR BY USING (PEO+$NaClO_3$+PLASTICIZER) POLYMER ELECTROLYTE

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Abstract*—Solid state (PEO+$NaClO_3$+Plasticizer) polymer electrolytes have been prepared by using solution casting technique. In this technique poly (ethylene oxide) (PEO), $NaClO_3$ salt and Dimethyl Formamide (DMF) has been used for the preparation of polymer electrolytes. Using (PEO+$NaClO_3$+Plasticizer) polymer electrolyte, the electrochemical cells have been fabricated for various compositions ratios of (90:10), (80:20) and (70:30) of PEO and $NaClO_3$. The discharge characteristics of the cell were monitored under a constant load of 100kΩ at RT. Using various compositions ratios of theses polymer electrolytes carbon monoxide gas sensor have been fabricated. The sensitivity of theses sensor has been verified at different gas concentrations and also at various temperatures.

***Keywords*— polymer electrolyte, solution casting technique, electrochemical cells, gas sensor, sensitivity.**

I. INTRODUCTION

Polymer electrolytes are key elements in this rapidly moving expansion due their various potential application in electrochemical devices such as batteries, sensor, fuel cells, smart windows, photo electrochemical solar cells, etc.[1–5]. Mainly advantages of polymer electrolytes are their mechanical properties, ease of manufacture of thin films of attractive dimensions and their skill to appearance proper electrode–electrolyte contacts. Poly (ethylene oxide) (PEO) is an excellent polymer which dissolves soaring concentrations of a broad range of salts to form polymeric electrolytes [6]. The PEO was complexed with a number of alkali salts such as $NaYF_4$ [7], NaClO3 [8], $NaNO_3$ [9], $KClO_4$ [10], $KBrO_3$ [11], KIO_3 [12], KNO_3 [5] were reported.

In this present study, (PEO+$NaClO_3$+Plasticizer) polymer electrolyte have been prepared by using solution casting technique. Electrochemical cells and carbon monoxide gas sensor have been fabricated for various compositions ratio of (PEO+$NaClO_3$+Plasticizer) polymer electrolyte. Discharge characteristics of electrochemical cell and sensitivity of carbon monoxide gas sensor have been investigated.

II. EXPERIMENTAL

(i) Fabrication of electrochemical cell using (PEO+$NaClO_3$+Plasticizer) polymer electrolyte:

Solid state (PEO+$NaClO_3$+Plasticizer) polymer electrolyte films (thickness ≈ 100 to 200 μm) have been prepared by solution casting technique. In this technique PEO (Aldrich, M.W. 6×10^5), $NaClO_3$ salt have been taken in various composition ratios of (90:10), (80:20) & (70:30) were dissolved in methanol. Further Dimethyle Formamide (DMF) used as plasticizer and it was doped to dissolved methanol. The solutions were stirred for 15-20 hrs, were cast on polypropylene dishes, moreover it was evaporated slowly at room temperature. At last, the films were dried thoroughly at 10^{-3} Torr [13].

By using above polymer electrolyte films, the solid state electrochemical cell has been fabricated in the configuration of Anode / (Polymer electrolyte + Plasticizer) / cathode was shown in Fig.1. The details about the fabrication of the electrochemical cell were given elsewhere [14]. The discharge characteristics of theses cells were monitored for a constant load resistant of 100kΩ at room temperature were shown in Fig.2.

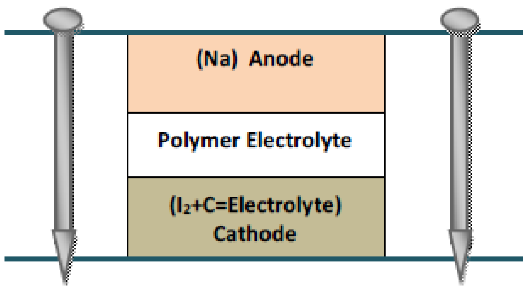

Fig.1. Fabrication diagram of an electrochemical cell.

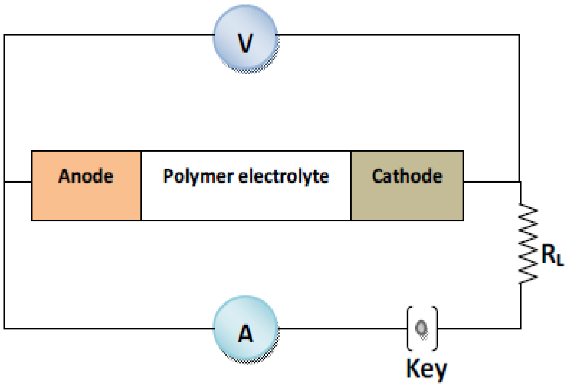

Fig.2. Discharge characteristics circuit diagram of an electrochemical cell.

The choice of choosing the anode in a solid state deepens on the mobile species in the electrolyte [15]. In this present investigation sodium metal was used as the anode material for these polymer electrolytes. For the preparation of cathode material, three types of materials were used namely: [Iodine (I_2) + Graphite (C) + electrolyte] (5:5:1 ratio). The cathode was made in the form of a pellet at ~2 ton/cm^2 after proper mixing of the constituents. Polymer electrolyte was added for the purpose of enhancing the contact properties [16].

(ii) Fabrication of Carbon monoxide gas sensor using (PEO+$NaClO_3$+Plasticizer) polymer electrolyte:

The poly (ethylene oxide) (PEO) (Aldrich, M.W. 6×10^5) and $NaClO_3$ salt were separately dissolved in methanol for few hours, then the dissolved solution were mixed together. Dimethyle Formamide (DMF) used as plasticizer was doped to mixed solution and it was stirred together for about 15-20 hr. (PEO+$NaClO_3$+Plasticizer) polymer electrolytes film was coated on aluminium tube (sample substrate) by dipping a number of times in the solution and each time it was allowed to evaporate at room temperature and schematic diagram of sample substrate was shown in Fig.3. The same process was continued for the preparation of composite polymer electrolytes of various ratios i.e. (90:10), (80:20) & (70:30) [17].

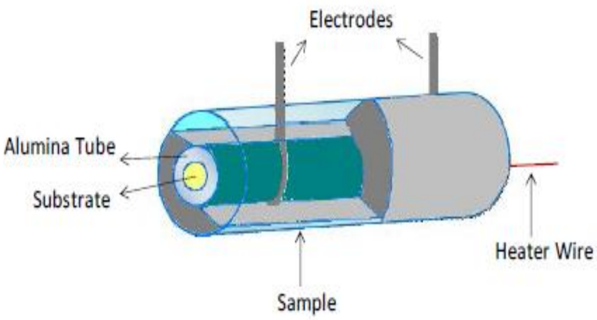

Fig.3. Schematic diagram of sample substrate.

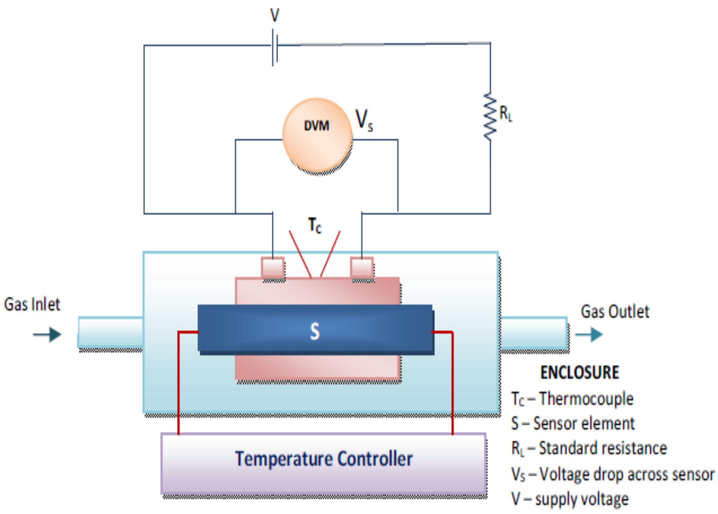

Fig.4. Schematic of measurement setup for the gas sensitivity studies.

To obtain resistance of sensor element, aluminium tube was located on temperature controlled tungsten coil heater in the interior part of a glass attachment. The schematic of the measurement setup was shown in Fig.4. A load resistor R_L was coupled in series through the sensor element R_S. A 10Vof input circuit operating voltage was applied across R_S and R_L. Carbon monoxide gas was allowed to pass through connected inlet. The resistance of the sensor was achieved by monitoring the voltage drop across the sensor element [18-20]. A chromet-alumel thermocouple (T_C) was situated on the device to specify the operating temperature. The accuracy of achieved temperature within ±2°C,

The sensitivity of the sensor is the ratio of the variation in electrical resistance in the presence of air and gas [$(R_a–R_g) = \Delta R$] and resistance in presence of air [R_a].

$$\text{Sensitivity of gas sensor } \mathbf{(S)} = \left(\frac{R_a - R_g}{R_a}\right) = \frac{\Delta R}{R_a} \qquad \text{--- (1)}$$

The sensitivity of the sensor was obtained for various compositions of ($PEO+NaClO_3$+Plasticizer) polymer electrolytes with respect to the temperature and carbon monoxide gas concentration (ppm).

III. RESULTS AND DISCUSSION

(i) Discharge Characteristics of Electrochemical Cells:

Electrochemical cells have been fabricated by using ($PEO+NaClO_3$+Plasticizer) polymer electrolyte's various composition ratios of (90:10) (80:20) (70:30) in the configuration of *Na (anode) / ($PEO+NaClO_3$+Plasticizer) electrolyte / (I_2+C+electrolyte)*. Fig.5. Shows the discharge characteristics of the electrochemical cells of above configuration have been achieved at constant load resistance of 100 kΩ. The open circuit voltage (OCV) and short circuit current (SCC) and other cell parameters were obtained from the discharge characteristics and are tabulated in Table-I. The discharge characteristics, the initial sharp decrease in the voltage for all cells may be because of the polarization and / or formation of a thin layer of sodium salt at the electrode / electrolyte interface [21]. From the Fig.5 and Table-I it was clear that, discharge characteristics and other cell parameter values of ($PEO+NaClO_3$+Plasticizer) polymer electrolytes have been increases with increase of salt concentration in the polymer. Therefore, improved cell parameters were found for ($PEO+NaClO_3$+Plasticizer) (70:30) polymer electrolyte compare to other ratios.

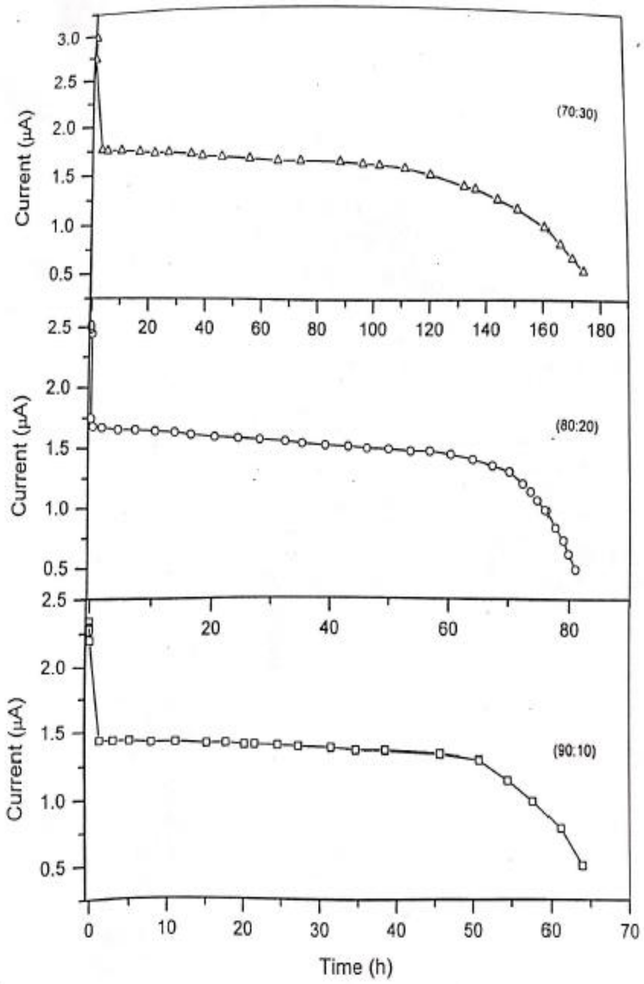

Fig.5. Discharge characteristics of Na / ($PEO+NaClO_3$+Plasticizer) electrolyte / (I_2+C+electrolyte) electrochemical cell for a constant load 100kΩ.

TABLE I
CELL PARAMETERS OF ($PEO+NaClO_3$+Plasticizer) POLYMER ELECTROLYTE ELECTROCHEMICAL SYSTEM.

Cell Parameters	($PEO+NaClO_3$+ Plasticizer) (90:10)	($PEO+NaClO_3$+ Plasticizer) (80:20)	($PEO+NaClO_3$+ Plasticizer) (70:30)
Open Circuit Voltage (OCV) (V)	2.34	2.45	2.99
Short Circuit Current (SCC) (μA)	43.1	46.3	354
Area (Cm^2)	1.34	1.34	1.34
Weight (gm)	1.48	1.27	1.36
Discharge Time (hrs)	56	76	178
Current Density ($\mu A/Cm^2$)	32.16	34.55	264.17
Power Density (mw/kg)	14.20	21.43	22.51
Energy Density (mw-hrs/kg)	795.5	1629.21	4008.27

(ii) Sensitivity Characteristics of Sensor:

Using ($PEO+NaClO_3$+Plasticizer) polymer electrolyte, the gas sensor have been fabricated and their sensor characteristics were studied in presence of carbon monoxide gas. The resistance of the sensor altered when carbon monoxide gas was exposed to the polymer electrolyte film. The sensor returns to its original state as soon as carbon monoxide gas was removed. The output values change to its original value within 8-10 seconds time [10].

Fig.6 shows the variation of the sensitivity with carbon monoxide gas concentration for different operating temperatures. From the Fig.6, it was observed that the gas sensitivity increases with increases in gas concentration and also with increases of operating temperature. The sensitivity as a function of polymer electrolyte composition at various temperatures was shown in Fig.7. From Fig.7 it was clear that the gas sensitivity also increases with an increase in the composition of the polymer electrolytes [22].

The variation of the sensitivity of carbon monoxide gas with temperature for different gas concentration was shown in Fig.8. The value of sensitivity obtained for various compositions were given in Table-II.

TABLE III
CARBON MONOXIDE GAS SENSOR SENSITIVITY VALUES AT VARIOUS TEMPERATURES.

Polymer electrolyte	Sensitivity at 1000ppm		
	50^oC	70^oC	90^oC
($PEO+NaClO_3$+Plasticizer) (90:10)	0.11	0.26	0.33
($PEO+NaClO_3$+Plasticizer) (80:20)	0.13	0.31	0.40
($PEO+NaClO_3$+Plasticizer) (70:30)	0.16	0.33	0.40

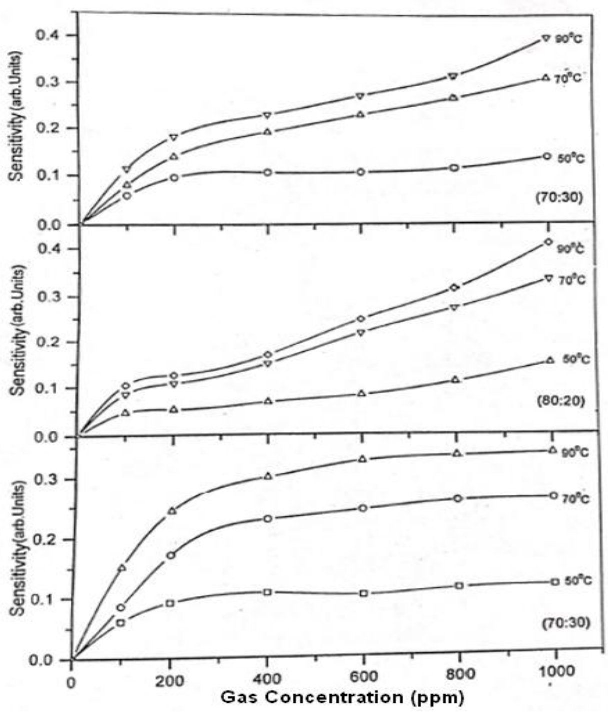

Fig.6. ($PEO+NaClO_3$+Plasticizer) polymer electrolyte gas sensor sensitivity as function gas concentration (ppm) at different temperatures.

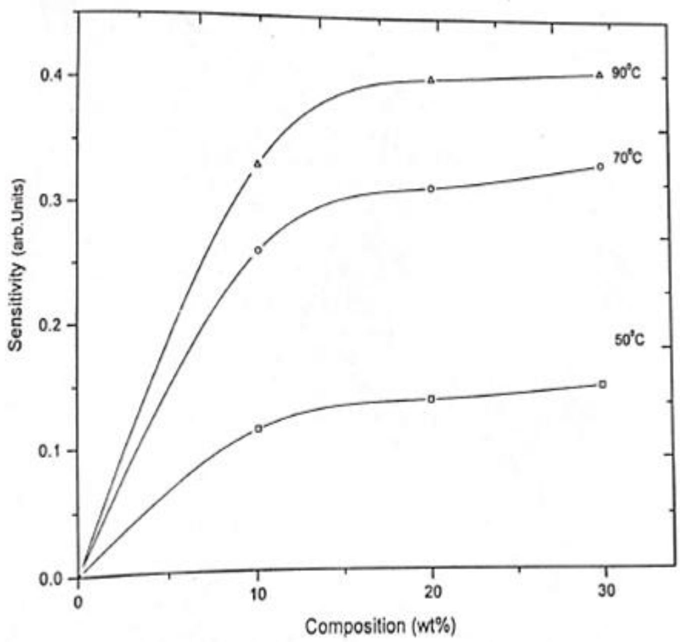

Fig.7. (PEO+NaClO$_3$+Plasticizer) polymer electrolyte gas sensor sensitivity as function of composition (Wt%) of the electrolyte for different temperatures.

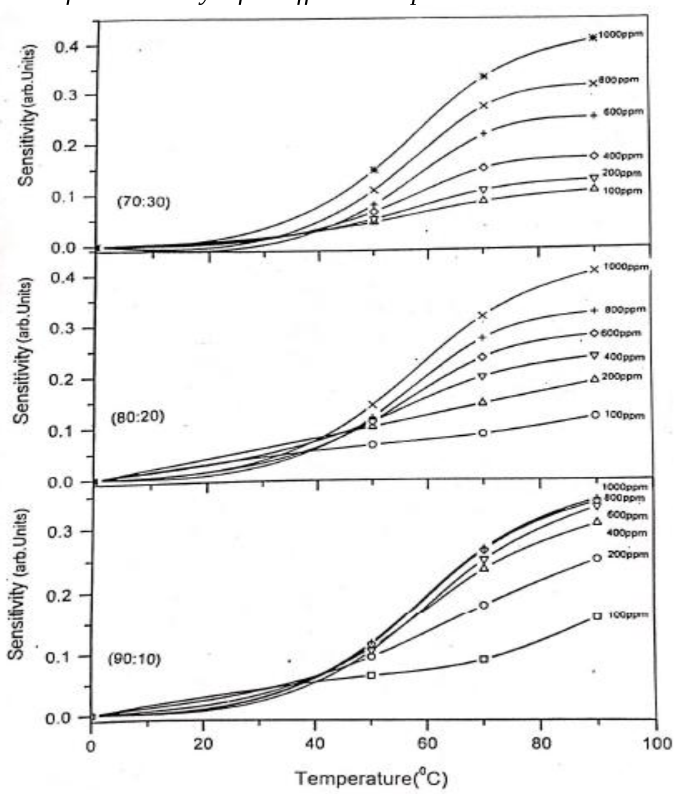

Fig.8. (PEO+NaClO$_3$+Plasticizer) polymer electrolyte gas sensor sensitivity as function of temperature at different gas concentrations (ppm).

From above figures and Table, the following observations have been made [23]:

- The sensitivity of the gas sensor showed an increase with increase in carbon monoxide gas concentration (ppm).
- The sensitivity of the gas sensor was found to increase with an increase in the composition (Wt %) of the salt in the polymer PEO.
- The sensitivity of the gas sensor increases with an increase in the temperature.

IV. CONCLUSIONS

Solid state (PEO+NaClO$_3$+Plasticizer) polymer electrolyte films have been prepared by solution casting technique in various composition ratios i.e. (90:10), (80:20) & (70:30). Electrochemical cells have been fabricated in the configuration of Na / (PEO+NaClO$_3$+Plasticizer) electrolyte / (I$_2$+C+electrolyte). The open circuit voltage was 2.99 V; short circuit current was 354 µA and also obtained other cell parameters. Using (PEO+$NaClO_3$+Plasticizer) polymer electrolyte, the gas sensor have been fabricated and studied its sensor characteristics in the presence of carbon monoxide gas. The sensitivity of the gas sensor augmented with increase of salt concentration, carbon monoxide gas concentration and temperature.

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