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A COMPARATIVE STUDY OF GAS SENSING RESPONSE OF PVC BASED $LICLO_4$ & PVC/PEG MICROPOROUS POLYMER MEMBRANE ELECTROLYTE (MPES)

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ABSTRACT

Gas sensing response of a microporous polymer membrane based on polyvinyl chloride (PVC) was studied. These membranes were obtained by a novel polymer dissolution technique in different compositions of (PVC-PVA). Gas sensing response of the PVC MPEs soaked in 3M molar concentration of Liclo4 was studied for different gases. Highest sensitivity was observed for H_2S gas at an operating temperature of 25 ^{0}c, comparatively for PVC membrane soaked in 1M concentration of PEG, Highest sensitivity was observed for H_2S gas peaking at 0.39 at an operating temperature of 30°C.

KEYWORDS: Microporous polymer electrolytes (MPEs), PVC/PEG MPEs, Gas sensing.

I. INTRODUCTION

Sensors are devices, which convert physical or chemical quantities into electrical signals, which can be processed and counted. The sensor carries out a quantitative conversion of a certain property of the substance. The property, which is registered quantitatively, may be detected in a number of ways and it may have a physical (e.g. mechanical, thermal, electromagnetic etc.) or a chemical nature. In accordance with its principle of operation, the sensor converts the property into an electrically assessable value, which can be transmitted further in the sensor system for assessment or indication [1-2].

Since the gas sensing mechanism is a surface reaction, In comparison with most of the commercially available sensors, based usually on metal oxides which operated at high temperatures, use of microstructured materials is expected to improve gas sensing characteristics. MPEs based gas sensors are commonly used for environmental monitoring and industrial applications due to their advantages such as small dimensions, low cost and convenient operation [3].

The direct transduction of chemical information into an electrical signal associated to existing low power microelectronics and sensing technology make MPEs an attractive material. A drastic change in electrical properties can be observed while MPEs are exposed to different environmental conditions such as chemical, thermal or mechanical. MPEs versatility comes from the wide variety of combinations of conductive fillers, metal salts and insulating polymer matrices drew on for their development [4].

While performing the studies on PVC MPEs and PVC/PEG microporous polymer electrolytes, we find that the mechanisms which are responsible for gas sensing are observed in our MPEs samples. On consideration of the fact that high aspect ratio of PVC and PVC/PEG would provide the MPEs with better electrical and mechanical performances hence an attempt has been made to study PVC MPEs and PVC/PEG samples as a gas sensor. Since still date, a very rare work on such samples is found in literature.

For gas sensing characteristics, MPEs based gas sensors are commonly used for environmental monitoring and industrial applications due to their advantages such as small dimensions, low cost and convenient operation [5-6]. Hence in the present investigation we develop a simple, reliable, time saving and industrially feasible process for the fabrication of micro-porous polymer membrane, PVC based micro-porous membrane was prepared by extracting PVA from PVC-PVA blend film by using simple dissolution of PVA in DMSO. Moreover these membranes can be easily detached from the substrate and could be used for Li battery applications or many other applications depending upon the type of dopant to be used. In this context, we have made an attempt to modify the PVC based microporous polymer electrolytes by addition of PEG in these electrolytes. The aim of this piece of work is_to enhances the performance of MPEs in electrochemical utilities. Gas sensing property of the PVC MPEs and PVC/PEG MPEs are also studied.

II. Experimental descriptions

2.1. MATERIALS AND METHODS

PVC and PVA (Asldrich USA) were used without further purification for the preparation of micro-porous membranes. Reagent grade anhydrous lithium per chlorate was used after drying in vacuum at 110°C for 24 hours. PVC-PVA was prepared by the solvent casting technique by dissolving appropriate amounts of the corresponding constituents in DMF and DMSO respectively.

The films were dried at 80°C in vacuum oven for 3 hours to remove any further traces of DMF and DMSO. Finally the above prepared cast polymer films were immersed in DMSO for the preferential dissolution of PVA to get uniform micro-porous membranes of PVC which is then soaked in different molar concentration of lithium per chlorate with Propylene carbonate (PC) & Diethyl carbonate(DEC) in 1:1 ratio to obtain micro porous polymer membrane electrolyte.

Polyethylene glycol (PEG) is a polyether compound with many applications from industrial manufacturing to medicine. PEG is non-toxic, odorless, colorless, nonirritating and do not evaporate easily. PEG is considered inert (they do not react with other materials). PEG is soluble in many organic solvents. All PEG are readily dissolve in water. PEG and aqueous solutions of PEG have number of recent applications [7].

In order to study the effect of PEG on PVC MPEs, These MPEs of 3M concentrations of $LiClO_4$ were allowed to soak in PEG electrolyte prepared in different molar concentration, for a constant time of soaking (4 hours). For the synthesis of PVC/PEG MPEs, water is used as a solvent for the preparation of molar solution of PEG. The electrolytic solution of PEG was prepared in different concentration as 0.25 M, 0.50 M, 0.75 M and 1 M. The PVC MPEs were immersed and soaked in these molar concentrations for 4 hours to obtain the samples of PVC/PEG MPEs

III. RESULT & DISCUSSION

3.1. Microporous Polymer Electrolytes (MPEs) as a Gas Sensor:

Gas sensing study of the PVC MPEs with 1M, 1.5M, 3M and 3.5M of $LiClO_4$ concentration which has been synthesized by the method as discussed above, was carried out at R. L. College, Parola, Jalgaon. For PVC MPEs 1M, 1.5M and 3.5M of $LiClO_4$ are not found to be effective for gas sensing while better results are obtained for 3M $LiClO_4$ and hence only these results are reported in table.1 & figures 1.

Table 1. Gas sensing response for PVC MPEs sample soaked in 3M$LiClO_4$.

Sample	Temp°C	LPG	CO_2	NH_3	Ethanol	H_2	Cl_2	H_2S
PVC MPEs	40	0.06	0.09	0.12	0.02	0.09	0.10	0.20
	35	0.05	0.10	0.14	0.05	0.07	0.11	0.31
	30	0.03	0.11	0.13	0.07	0.06	0.12	0.31
	25	0.02	0.10	0.10	0.08	0.05	0.10	0.36
	20	0.02	0.10	0.09	0.12	0.05	0.09	0.32

15	0.01	0.06	0.04	0.16	0.02	0.06	0.20
10	0.01	0.01	0.01	0.19	0.01	0.05	0.17

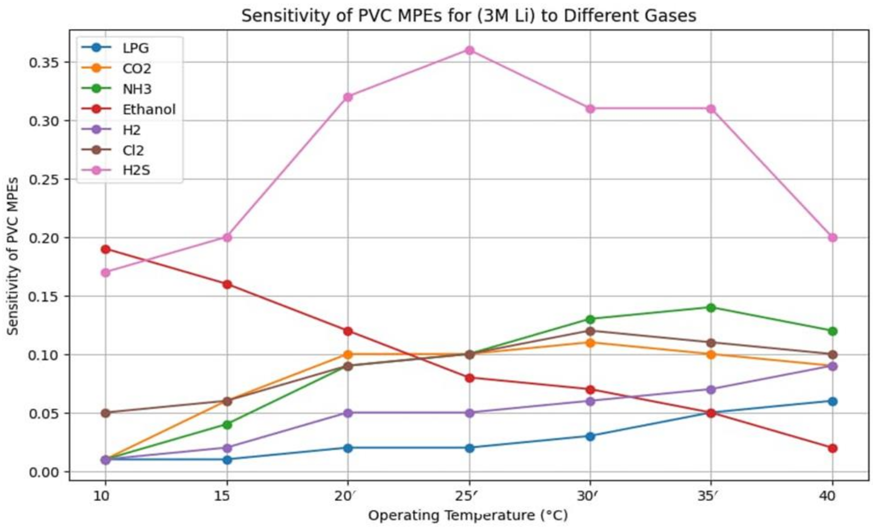

Figure 1. Sensitivity of PVC MPEs for (3M Li) to different gases as a function of operating temperature.

From above table 3 and figures 3, it is clear that 3M $LiClO_4$ sample shows good sensitivity for H_2S at all temperatures (10°C to 40°C) and has highest sensitivity (0.36) at an operating temperature about 25°C. MPEs sample show high sensitivity towards H_2S as compared to other gases. This sensitivity increases with increase in temperature from 10°C to 25°C. From 25°C onwards, sensitivity increases slowly with increase in temperature, while at 10°C highest sensitivity is seen for Ethanol gas. In recent years, several studies are going on to improve the performance of MPEs sensors in order to increase the sensitivity to the lower operating temperature. In the present research work an attempt was made towards the use of Li salt for incorporation into PVC membrane to improve the sensitivity for selective sensing of H_2S, NH_3 and Cl_2 gas [8-10].

3.2. PVC/PEG Microporous Polymer Electrolytes (MPEs) as a Gas Sensor:

Hydrogen sulfide is a highly flammable gas and gas/air mixtures can be explosive. It may travel to sources of ignition and flash back. If ignited, the gas burns to produce toxic vapors and gases, such as Sulpher dioxide. Hydrogen sulfide is both an irritant and a chemical asphyxiate with effects on both oxygen utilization and the central nervous system. Its health effects can vary depending on the level and duration of exposure. Repeated exposure can result in health effects occurring at levels that were previously tolerated without any effect.

Low concentrations irritate the eyes, nose, throat and respiratory system (e.g., burning/ tearing of eyes, cough, shortness of breath). Asthmatics may experience breathing difficulties. The effects can be delayed for several hours, or sometimes several days, when working in low-level concentrations. Repeated or prolonged exposures may cause eye inflammation, headache, fatigue, irritability, insomnia, digestive disturbances and weight loss. Moderate concentrations can cause more severe eye and respiratory irritation (including coughing, difficulty breathing, accumulation of fluid in the lungs), headache, dizziness, nausea, vomiting, staggering and excitability.

Ammonia (NH3) occurs naturally and is produced by human activity.. No health effects have been found in humans exposed to typical environmental concentrations of ammonia. However, exposure to high levels of ammonia can cause irritation and serious burns on the skin and in the mouth, throat, lungs, and eyes. At very high levels, ammonia can even cause death

Hence for work within confined spaces, use of appropriate procedure or sensors like MPEs is necessary for identifying hazards, monitoring and entering confined spaces. Similar results were obtained for PVC/PEG MPEs sample.

Table. 2 Gas sensing response for PVC/PEG MPEs sample. (soaked in 1M PEG)

	Sample Temp°C	LPG	CO_2	NH_3	Ethanol	H_2	Cl_2	H_2S
PVC/PEG MPEs	40	0.01	0.02	0.19	0.13	0.11	0.07	0.24
	35	0.01	0.03	0.21	0.11	0.17	0.06	0.36
	30	0.01	0.05	0.22	0.09	0.13	0.03	0.39
	25	0.02	0.09	0.20	0.08	0.09	0.02	0.38
	20	0.02	0.06	0.20	0.06	0.07	0.02	0.35
	15	0.01	0.04	0.19	0.02	0.06	0.02	0.29
	10	0.01	0.03	0.10	0.01	0.07	0.01	0.18

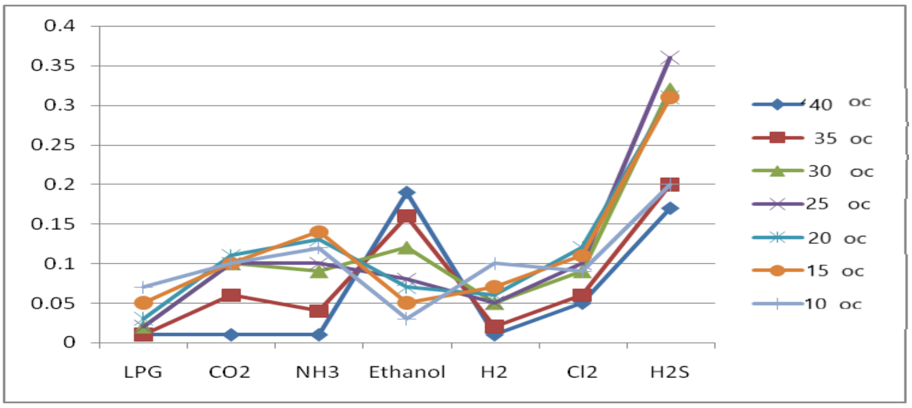

Figure 2. Sensitivity PVC/PEG MPEs sample (soaked in 1M PEG) to different gases as a function of operating temperature.

From above table.2 and figures 2, it is clear that 1M PEG sample shows Highest sensitivity best to H_2S, peaking at 0.39 at 30°C. after H_2S, it also shows good sensitivity towards NH_3,at all temperatures as compared to other gases, with values around 0.19-0.22. H_2S response increases as temp drops from 40°C to 30°C, then falls below 30°C. So 30°C looks like the optimal operating temperature for H_2S detection. LPG and Cl_2 show very low response across all temperatures, mostly 0.01-0.07. This sensor is fairly selective against them. Response to ethanol clearly increases with temperature: 0.01 at 10°C up to 0.13 at 40°C. So our PVC/PEG MPEs sample is most selective toward H_2S and NH_3 with moderate sensitivity to H_2 and ethanol at higher temps.

Various MPEs sensors reported basically works at higher temperature such as 350 °C, but it is inconvenient to work at such high temperature while sensing [9]. It requires extra power consumption for heating and an initial warm-up time, and reduces portability. As a result, it is highly desirable to develop sensors that operate at room temperature, and at the same time, keep the desirable properties of material for gas sensing [11].

CONCLUSION

1. This work successfully establishes a novel polymer resolution technique for fabricating PVC-based microporous polymer electrolyte membranes capable of efficient room-temperature gas sensing.
2. The PVC/ PEG MPEs soaked in 1M PEG demonstrate exceptional performance, achieving peak H_2S sensitivity of 0.39 at 30°C and maintaining strong NH_3 detection across 10-40°C, with minimal cross-sensitivity to LPG and Cl_2. Critically, this sensor overcomes a major limitation of conventional MPEs that demand operating temperatures near 350°C, which increase power consumption, require warm-up time, and hinder portability.
3. By delivering optimal sensitivity at 30°C, the developed membrane enables low-power, real-time detection suitable for field deployment.
4. Comparative analysis confirms that the strategic incorporation of $LiClO_4$ electrolyte with PEG plasticizer in PVC matrices produces a robust, selective sensing platform. Given the severe health hazards of H_2S, highly flammable, explosive, and a chemical asphyxiant and the corrosive risks of NH_3 at high concentrations,
5. this room-temperature sensor addresses a vital safety need. Its use with appropriate monitoring procedures in confined spaces can prevent exposure to toxic vapors and flashback risks. Therefore, PVC/PEG MPEs present a practical, energy-efficient solution

for H_2S and NH_3 detection, advancing safety monitoring in industrial and confined-space environments.

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