Charging and Discharging of Membrane for Lithium Ion Battery Applications

Ashutosh Barua, Pankaj Kumar Mishra, Divya Singh, Arvind Kumar Jain

Abstract: Poly (methyl methacrylate) (PMMA) exhibits excellent electrical as well as mechanical properties. In the present work, pure and nano Zinc oxide (ZnO) doped PMMA membrane films were prepared using process of solution cast. The Characterization of thin film samples of pure and ZnO doped PMMA having 30µm thickness with similar (Al-Al) electrode combination have been studied, detailed graphical representation as a function of current and voltage is carried out for temperature ranging 30°C to 180°C at 300 and 500V. ZnO doped PMMA foil samples exhibits peak maxima around 95±100C and also confirms decrease in activation energy after incorporation of nano ZnO. The TSDC thermograms and its parameters explain the shift of peak towards the lower temperature side. The formation of charge transfer complex (CTC) reveals the tendency of polymer matrix which indicates the effect of glass transition temperature or activation energy, which results in reduction of discharge rate also led to enhance the stability of Lithium-ion batteries (LIBs). The results were analyzed in detail.

Index Terms: ***PMMA, CTC, Lithium-ion batteries, glass transition temperature, activation energy***

I. INTRODUCTION

The poly (methyl methacrylate) (PMMA) is a thermoplastic transparent polymer which is used in synthesizing polymer gel electrolyte. The PMMA is a gelling agent, which act as organic glass as its glass transition temperature (Tg) is below room temperature. Thus, stabilizes polymer gel electrolyte or also called as flexible solid electrolytes. Therefore, it can be applicable in formation of various devices such as rechargeable lithium ion batteries, sensors and display devices etc. The ionic conductivity of such polymer gel electrolyte is generally high [1-3], which can be enhanced by doping with various metal oxides. The good mechanical strength and flexibility for such polymer is due to its high molecular weight.

J. Y. Song et.al studied on the characteristics and of various gel based polymer electrolytes applicable in solid state lithium ion batteries [4]. J. Adebahr et.al studied on the synthesis of nano-TiO2 based PMMA gel electrolyte and characterized by 1H- NMR analysis. The addition of fillers in the gel enhances its ion diffusion via electrolyte membrane [5-6]. Many research based on gel based polymers opens a pathway for studying such electrolytic membranes synthesis and enhanced ionic conductivity of such electrolytic membrane [7-8] can be beneficial in manufacturing field and production of rechargeable devices and storage batteries [8-10].

Thus, here ZnO doped PMMA membranes were synthesized along with pure PMMA membranes and there charging discharging current is compared with pure PMMA electrolytic membrane. It is found that ZnO doped PMMA foil samples exhibits peak maxima around 95±100C and also confirms decrease in activation energy after incorporation of nano ZnO. The Thermally Stimulated Discharge Current (TSDC) thermograms and its parameters explain the shift of peak towards the lower temperature side. The formation of charge transfer complex (CTC) reveals the tendency of polymer matrix which indicates the effect of glass transition temperature or activation energy, which results in reduction of discharge rate also led to enhance the stability of Lithium-ion batteries (LIBs). The results were analyzed in detail. Since formation of gel electrolyte will make system solvent free. Thus, diffusion properties of liquid as well as cohesive properties of solid are both added up and therefore increase ionic conductivity. This explains improved function of ZnO doped PMMA electrolytic membrane compare to PMMA electrolytic membrane.

II. EXPERIMENTAL METHOD

Measurement of charging and discharging currents and electrical conductivity for the above prepared membrane samples.

Measurement were carried out for charging as well as discharging currents on pure as well as doped film samples charged with fields of 300 and 500 volts, at different charging temperatures levels at 40, 50, 60 and 70oC, both the samples have been investigated for the period of 1-100 minutes. Every measurement is done by taking a fresh sample each time. The sample taken for measurement was sandwiched between two parallel plate electrodes carrying high DC Voltage. One time charging circuit is connected and another time the discharging circuit is connected in the circuit as shown in Fig.1 a typical charging and discharging cycle for a polymer film is shown in figure 2.

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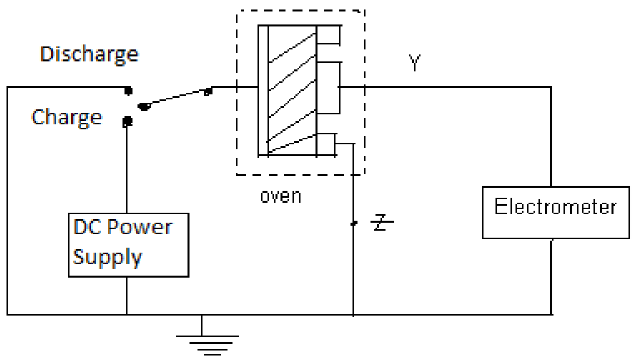

Fig. 1 experimental circuit diagram of measuring system for the DC transient current

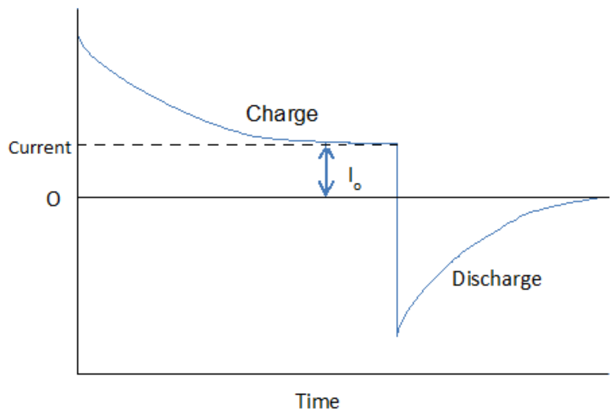

Fig. 2 Typical charging-discharging cycle

The result of currents in charging and discharging modes and steady state electrical conduction are analyzed and interpreted on the basis of existing theories.

III. Results and Discussion

The pure and doped film samples were analyzed for different voltage levels and at different temperatures, i.e. 40, 50, 60, 70. The charging and discharging currents in pure PMMA film and ZnO doped PMMA film samples have been observed for 1-100 minutes. Over a period of time the variation of charging as well as discharging currents are shown.

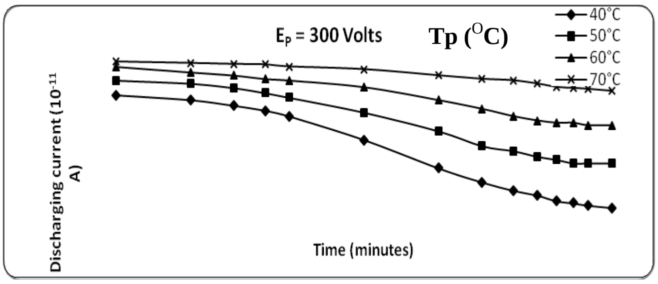

Fig. 3 Discharge current Vs time graphs for pure PMMA films with 300 volts

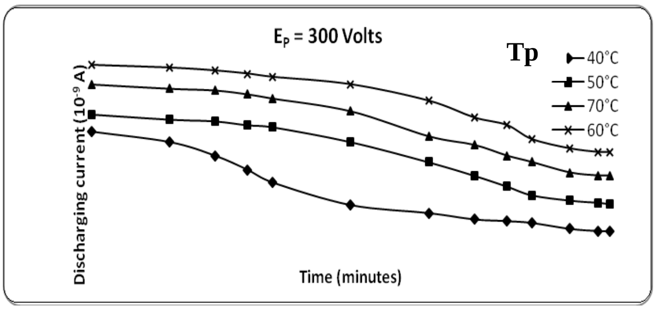

Fig. 4 Discharge current Vs time graphs for ZnO doped PMMA films with 300 volts

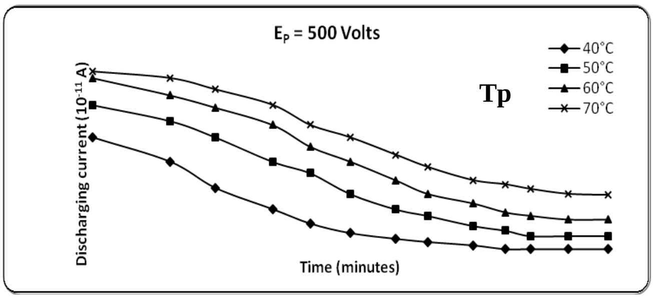

Fig. 5 Discharge current Vs time graphs for PMMA films with 500 volts

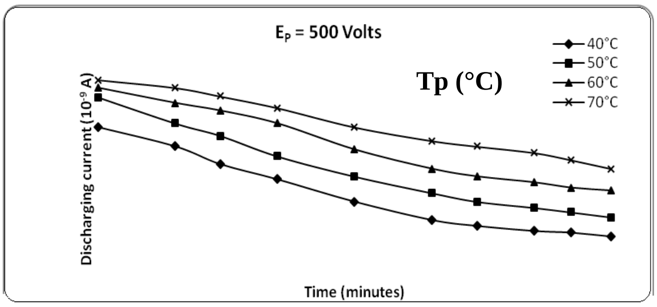

Fig. 6 Discharge current Vs time graphs for ZnO doped PMMA films with 500 volts

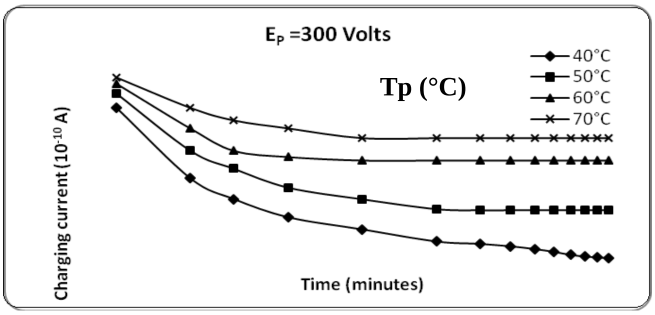

Fig. 7 Charging current Vs time graphs for pure PMMA films with 300 volts.

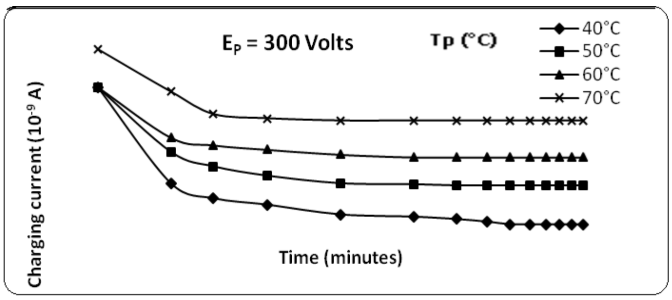

Fig. 8 Charging current Vs time graphs for ZnO doped PMMA films with 300 volts.

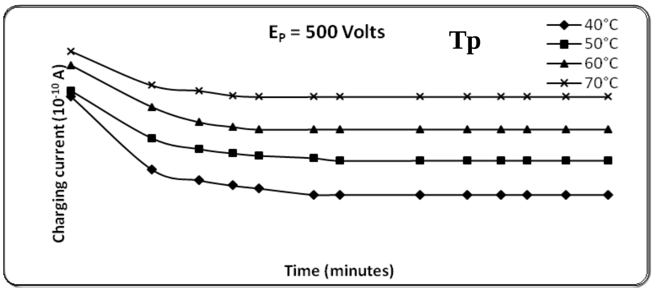

Fig. 9 Charging current Vs time graphs for pure PMMA films with 500 volts

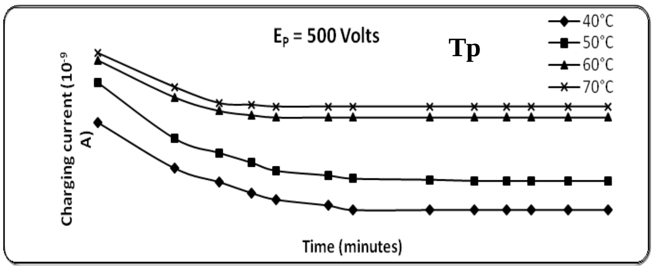

Fig. 10 Charging current Vs time graphs for ZnO doped PMMA films with 500 volts

It has been observed that the Charging current (Fig.7-10) in case of ZnO doped PMMA increases as compared to pure PMMA film. Which is favorable condition for fast charging of Li-ion batteries. However in addition of ZnO to PMMA, discharge rate of thin film also becomes slower as compared to pure PMMA film (Fig.3-6). Therefore, it is also clear that ZnO doped PMMA film, charge remain constant for a longer time in comparison to the pure PMMA film. These properties of doped PMMA thin film is applicable as a material separator in Li-ion batteries.

IV. Conclusion

It is clear from the results, that the addition of dopant has a strong effect on the activation energy (knee voltage) and stabilizes the discharging rate. The molecular motion is assisted with the presence of charge transfer complex which decreases the activation energy, because of the increase in the charge carrier's mobility. Activation energies found to be lower than the pure films. This result indicates that there is a presence of dopant between polar molecules, which reduces the interaction and finally it results in the reduction of activation energy of the material. Due to which discharge rate reduced, which led to enhance the stability. Further, charging rate increases in the doped PMMA Film, these properties performance of ZnO doped PMMA may be useful in future Li-ion batteries. ZnO-PMMA polymeric membrane, which can be used in for Lithium ion battery preparations. As LiBs are commonly used as one of the most modern source of energy storage and its fast charging is still an open research area, As the ZnO doped PMMA polymeric films provides us better results. Further this can be used in LiBs for electrical vehicle, electronic devices and in electrical microgrids. For future study its stability need to be checked and there is scope for further research.

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