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Analysis of TSDC Thermogram of Bio-Magneto electrets of L–Serine

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ABSTRACT

Thermally stimulated Depolarization Current (TSDC) technique is one of the most well known techniques used for the study of molecular motions in a polymer by considering the relaxation processes taking place inside the system. This paper describes the TSDC studies of bio-magneto-electrets of L- Serine. The processes that are taking place during TSDC are similar but opposite to that during magneto electret formation. Therefore the forming parameters will be having a great effect on TSDC spectra. To study the effect of forming parameters, samples were prepared at three different forming temperatures and five different forming magnetic fields and TSDC were performed on the samples. The spectra mainly contain two peaks and the concept of both dipolar orientation and trapping of charges are used to explain the TSDC spectra of bio-magneto-electrets of L-Serine. The peak intensity and peak position is found to vary with the forming parameters.

Keywords: Magneto electrets, TSDC, biopolymers, amino acid, L-serine, dielectric materials

INTRODUCTION

Electrets are the dielectric materials which are having persistent polarization. The electret effect elucidates the mechanism of polarization and absorption well in dielectrics[1]. In addition to this it is found to be having wide variety of applications. The different applications of electrets include their use as transducers, sensors, heat scanners, electret microphones etc[2-5]. The electret effect in biomaterial has an important role in biophysical phenomena and also it found wide range of application in biomedical field. In various biophysical models, electret state is considered as a basis for understanding of membranes, neural signals, biological memory in regeneration, electrical mediation in tissue growth, and other phenomena[6]. Therefore in order to make use of electrets in engineering and bio medical applications, the knowledge about the mechanism behind the polarization and depolarization of the electret is highly

significant. Surface charge decay studies and TSDC are considered as the efficient tools to investigate such electret properties. Even though the surface charge decay studies provides information about the density of surface charge developed and decay time constant, the slow decay time and failure in giving idea about the electret forming mechanism makes it less reliable for electret studies as compared to TSDC. In TSDC, on heating the sample the response time of permanent dipoles and free charges get accelerated and thus the decay can be done within a reasonable time period. It brings idea about the magnitude and type of polarization that is happening in the polymeric system. The various peaks appearing in the TSDC spectrum characterize the operative molecular mechanism through which an electret stores its charge. In this non isothermal relaxation process, mainly the dipoles and free charges of the polymer are expected to get relaxed. The TSDC of the polymer mainly depends on, the property of the polymer, forming conditions of the polymer and the storage conditions of the polymer[7]. Being the building block of proteins, the magnetic field controlled effect of amino acids may expect to have an important role in bio signalling and in various regulating functions. Therefore, in the present case charge storage and its relaxation process in magneto electrets of L-Serine prepared under different forming conditions is analysed using TSDC technique. The variable parameters are polarizing magnetic fields and temperature, which are used to determine the contribution of dipolar and space charge relaxations to the TSDC spectrum of magneto electrets of L-Serine.

EXPERIMENTAL METHOD

Biomagneto electrets of L-Serine were prepared by following the method already described by Khare and Bhatnagar[8, 9]. After preparing magneto electrets, the samples were kept in a custom made TSDC setup for studying the relaxation process. It consists of two silver electrodes one connected to the electrometer and other grounded. Electrets samples were sandwiched between the two electrodes and the assembly was put in an evacuated heating chamber. In order to activate the relaxation process, samples were heated at a rate of 1^0 C/ Min using Lakeshore 330 Auto Tuning Temperature Controller. The relaxation current was recorded using Keithley 610 C Solid State Electrometer. The electrometer was carefully shielded and earthed in order to avoid the effect of ground loop and other electrical noises.

RESULTS AND DISCUSSION

The processes that contribute to the TSDC spectra mainly include

(1) dipolar reorientation
(2) excess charge motion
(3) ohmic conduction

The contribution of each of these processes depends on the conditions under which the bio-magneto-electrets get formed. Therefore the study of TSDC spectra of bio-magneto-electrets prepared under different conditions will help to unravel the various relaxation processes. The important forming parameters include temperature (T_f) and magnetic field (H_f). Therefore the samples were prepared using five different magnetic fields and three different temperatures. The TSDC spectra of the corresponding samples are depicted in *Fig 1*. It can be observed that the spectra mainly contain two peaks. One is having positive polarity in the low temperature region and other one which is having a negative polarity at the high temperature region of the TSDC spectra. In order to analyse this TSDC spectra completely, knowledge

about, the origin of the current peaks, type of polarization happened in the dielectric after magneto electret formation and the reason for the existence of peaks with opposite polarity is necessary.

For getting idea about the origin of the current peaks in the TSDC spectra, the depolarization current studies were done on samples prepared using different forming magnetic fields. It is already reported that if the current peak originates from dipolar relaxation, the current intensity increases linearly with the forming field H_f and if it is a space charge relaxation peak, the intensity changes non linearly with the forming field H_f[10]. Therefore samples were prepared at different magnetic fields keeping the forming temperature constant. *Fig 1(a)* shows the TSDC peak variation with forming magnetic field and for both the peaks an increase in intensity is observed with an increase in forming magnetic field. But there is no significant change in peak position. In the present case the variation in peak intensity with forming magnetic field is linear for the first peak, where as the second peak shows some non linearity. Therefore dipolar relaxation can be considered as one of the reason for the origin of the first peak. According to Turnhout[11] normally the dipolar relaxation happens at low temperatures whereas the motion of excess charges happens at a comparatively high temperature. This is because the dipolar relaxation that arises because of the rotational motion of molecular groups requires less energy as compared to excess charge motion that involves the motion of molecular entities over macroscopic distances. This is another reason for the assumption of first peak as a dipolar relaxation peak.

To understand the polarisation and relaxation process in the bio-magneto-electrets, TSDC studies were performed on samples prepared using different forming temperatures. It mainly gives idea about the kind of polarisation that is happening inside the electret that is, whether it is a distributed polarisation or not[12-14]. *Fig 1(b)* shows the TSDC peak variation with forming temperature. The second peak in the TSDC spectrum may arise because of the motion of excess charges that were trapped during magneto electret formation. During TSDC, reheating of the sample will cause the de trapping and give rise to the current peak at high temperature region. From *fig 1(b)* it is observed that the first peak shows a change in position according to T_f. With an increase in forming temperature the maxima peak position shift towards the low temperature side of the current spectrum. The shift towards low temperature region of the spectrum can be explained as follows. During formation of magneto electret at low forming temperature, the number of molecular species that become mobile and getting oriented under the field will be less. On heating the sample during TSDC, at low temperature the dipoles will get energy to re orient and at the same time because of the dipole moment of the oriented dipoles, the internal field also supports the reorientation in addition to the energy provided by the temperature. But for the samples prepared at low forming temperatures, the oriented dipoles will be less which in turn will reduce the support of internal field for reorientation. The shift also represents the presence of multiple dipole relaxation. But for the second peak there is no shift in position with change in forming temperature. Only increase in intensity of the current peak with temperature is observed.

TSDC process is reverse of that occurring during formation of an electret therefore it gives insight in to the charging

process. During formation, the free charge carriers will get trapped and dipoles will get oriented and contribute to electret properties. The same is expected to get de-trapped and reoriented during thermally stimulated depolarization process and will contribute to the TSDC spectrum. So the net charge, which is released during TSDC, will be the sum of space charge and charges which arises due the re-orientation of the already oriented dipoles. Because of proper short circuiting equilibrium charges will not be having any contribution to the TSDC spectrum. Therefore the final TSDC spectrum will be a result of current due to dipole reorientation and excess charge motion. The total charge released from the TSDC spectra can be calculated by finding out the area under the I Vs Time graph. The comparative study of total charge released from the surface charge decay and TSDC will help to get idea about the type of polarization, that is, whether it is a surface phenomena or volume phenomena. From Table 1 it is observed that the total charge released during TSDC and surface charge decay is of the order of 10^{-8} C and 10^{-9} C respectively. This result indicates that the polarization that is happening during magneto electret formation in L-Serine will be a volume phenomenon. Another important result that confirms the chance for the existence of volume polarization is that the surface charge decay studies shows the presence of iso charge on the surface of the magnetoelectret even though the TSDC gave intense dipolar relaxation current peak[15-17].

Polarity of the current peak mainly depends on the developed surface charge of the electret and the electrode material. Here in the present case the TSDC spectra contain two distinct peaks with opposite polarity. The existence of positive and negative peak can be explained as follows. During TSDC, in order to observe the relaxation phenomena, the electret is keeping between the two electrodes of the TSDC setup. As electrets are the dielectric materials with persistent polarization, on keeping it in between the electrodes, depending on the surface charge of the electret, compensating charges will get developed on the electrode. While doing linear heating in order to observe the relaxation, the already oriented dipoles and trapped charges will get extra energy for re-orientation and detrapping. It will disturb the polarization and hence the surface charges of the magneto electrets. Correspondingly the compensating charges on the electrodes also will get disturbed and make a flow of current in the external circuitary. It is already reported that at low temperature there is more possibility for the orientation of dipoles as compared to excess charge motion. Dipolar orientation will give rise to idio charge in the case of magneto electret. Therefore during TSDC, at low temperature, we can expect the relaxation or re orientation of the dipolar entities. In the present case, the N-Surface of the magneto electret sample, which is having a –ve charge, was kept in contact with the electrode which is connected to the electrometer. Therefore the compensating charge on the electrode will be positive. On heating the sample, the positive compensating charge will get disturbed and will move in the external circuitary, ie the motion of positive charges from one electrode to other through electrometer and gives rise to a positive current. Reverse will be the case with positive surface charge. In *Fig 1* the second peak is having a –ve polarity. In the case of bio-magneto-electret of L-Serine it is already reported that they are having a –ve isocharge after electret formation[9]. In the case of electrets with negative surface charge, the trapped charges will be negative. So compensating

charges will be positive. During TSDC there exist two possibilities

a) When trapped charges get detrapped the compensating charges also will get disturbed and it will move in the external circuitary and constitutes a current having +ve polarity.

b) At high temperature, if the charges get extra energy, it will move from sample to the electrode and the same negative charges will move in the external circuitary in place of compensating charge giving rise to a current with negative polarity. But it mainly depends on the work function of the sample and the electrode. In the present case the second peak shows a –ve polarity which indicates the possibility for the second process ie, the motion of the detrapped –ve charge from the sample to the electrode and then in the external circuitary.

The previous TSDC results confirmed the possibility for orientation of dipoles (I peak) and trapping of charges (II peak). But in order to understand the contribution of magnetic field to the observed properties of magneto electrets, samples were prepared using direct homogeneous and in-homogeneous magnetic field. It is already reported that[18, 19], the observed magneto electret properties such as development of surface charge on the surface perpendicular to the magnetic field may arise due to the inhomogeneity in the magnetic field and magnetically modified contact electrification between dielectric electrode interfaces. Therefore studies were performed in direct homogeneous and in-homogeneous magnetic field. *Fig 2* represents the corresponding TSDC spectra. The current peak that was assumed to be due to the dipolar orientation is completely absent in the TSDC spectra of samples prepared using in-homogeneous magnetic field. During formation unlike the homogeneous field, there is possibility for the random orientation of dipoles. On considering the random orientation, the possibility for the orientation of dipoles in any direction will be the same. On cooling, the oriented dipoles will get frozen in and some will contribute to surface charge. But during TSDC the current due to dipoles in all direction will cancel each other and there will not be any contribution to the TSDC spectrum. Even though the surface charge density of magneto electrets prepared under in-homogeneous magnetic field was high as compared to the ones with homogeneous magnetic field in surface charge decay studies, the intensity of the current peak in the TSDC spectra is found to be low as compared to the ones with homogeneous fields. It may arise because during surface charge decay studies, the dipoles oriented along that direction also will be contributing to the surface charge density, whereas in TSDC only the excess charge motion is having contribution to the second peak.

Table 1: Total Charge Released For the Bio-Magneto-Electret Samples From the TSDC and Surface Charge Decay Studies

Temperature (^{0}C)	Magnetic Field (Tesla)	Total Charge Released From TSDC Studies (X 10^{-8} C)	Total Charge Released From Surface Charge Decay Studies (X 10^{-9} C)
170	1.4	12.09	23
170	1.2	9.5	26.8
170	1.02	3.9	6
170	0.83	2.1	3.5
170	0.65	4.3	1.6

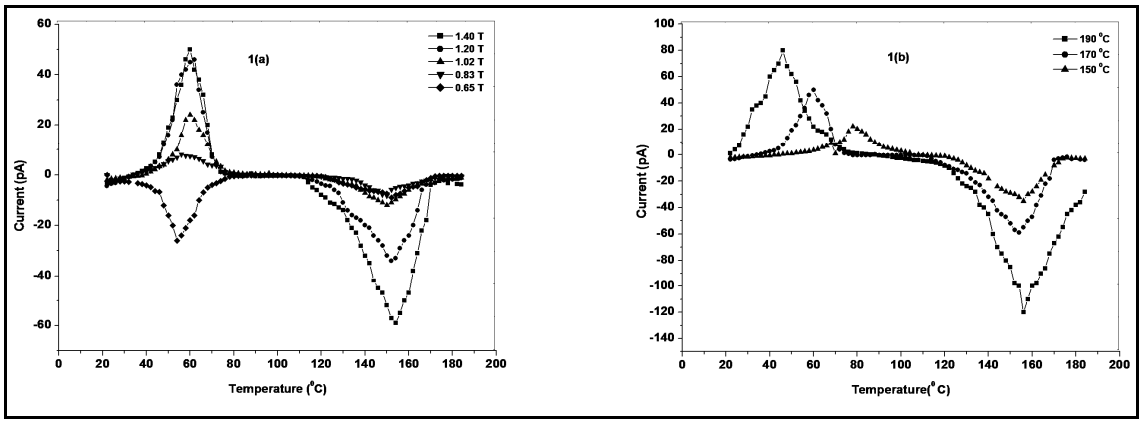

Figure 1: Variation in TSDC spectra with forming parameters
1(a) With Forming Magnetic Field
1(b) With Forming Temperature

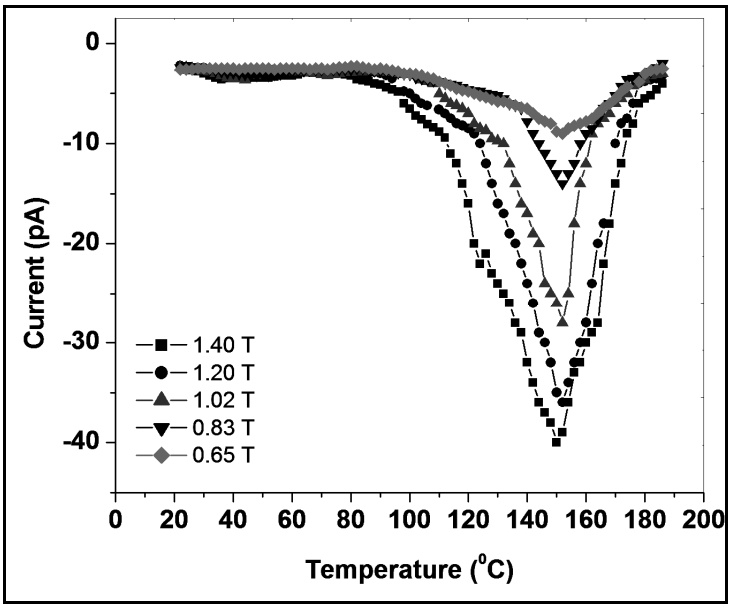

Figure 2: TSDC Spectra of Bio-Magneto-Electrets of L-Serine prepared using different in-homogeneous magnetic fields

CONCLUSIONS

Bio-magneto-electrets of L-Serine were prepared and TSDC studies were performed on the samples. Results show that, both processes, the dipolar relaxation and excess charge motion are contributing to the TSDC spectra. The variation in TSDC spectra with forming parameters is observed by performing TSDC on magneto electrets

prepared under different forming conditions. It is found that the current intensity and peak position is having strong dependence on forming temperature and magnetic field. The occurrence of two current peaks confirms the presence of trapping levels of at least two different depths. Total charge released from the TSDC spectra indicates that the polarization in magneto electrets of L-Serine is a volume phenomenon.

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