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Effect of gamma radiation on dielectric properties of polyacetate polymer

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ABSTRACT

A study on modification of dielectric properties of polyacetate polymer is studied in the dose range of 10^1 –10^6 Gy. It is observed that significant increase in dielectric constant takes place at the higher doses of gamma radiation. This increase is observed mainly in the lower frequency region especially in the range of 42 to 1000 Hz. The increase in dielectric constant is attributed to polarization in the polymer matrix caused due to chain scissioning and subsequent rearrangement of the polymeric chain in the matrix.

Keywords: Gamma Dose, Dielectric constant, Polyacetate

INTRODUCTION

The application of radiation on polymeric materials is of great importance as it allows achievements of some desired modifications in polymer properties. Irradiation of polymeric materials with gamma rays, X-rays, accelerated electrons and ion beams for example leads to the formation of reactive intermediates, free radicals, ions and excited states which then lead to reactions like chain scission, chain aggregation, formation of double bonds and molecular emission. The outcomes of these reactions are formation of oxidized products, grafts, scission of main chain (degradation) or cross-linking. Often the two processes (degradation & cross-linking) occur simultaneously, and the final outcome of the process is determined by a competition between the reactions [1,2]. Oxidation and degradation occur gradually with increasing irradiation dose. Different polymers have different responses to radiation, which are intrinsically related to the chemical structures of the polymers. As a consequence of this, physico-chemical properties like optical, electrical, mechanical, and chemical and track properties of the polymer become modified [3-10].

There are few reports on modifications of electrical properties due to irradiation [11-19]. It is well known that irradiation enhances the electrical conductivity in insulating polymers. This increase in conductivity attributes to the amplifications of conjugated structure, *i.e.* fairly enhanced electron freedom [10]. Irregularities in the polymer chains may also give rise to a hopping mechanism which then enhances the conductivity [18]. In an specific case, it has been observed by Nouh et.al [16] that due to proton irradiation, a decrease in conductivity of the Makrofol polymer takes place. This decrease was explained with the fact that cross-linking reduces crystallinity and induces further lattice defects that may act as scattering centers and energy barriers for the flow of electric current [16]. For Gamma irradiated AAc/MMA films, it has been observed by Fawzy et al. [19] that irradiation reduces the DC conductivity of the samples, which could probably be due to cross linking. It was suggested that the decrease in DC conductivity is due to the formation of some defects in the energy gap as a result of γ- irradiation. These defects (sometimes called traps or clusters) create barriers against the mobility of charge carriers (electrons), and are seen to cause a decrease in DC conductivity from 1.61×10^{-7} for the unirradiated sample to 2.05×10^{-10} for that irradiated with 100 kGy. It has also been observed that under γ-irradiation, dielectric constant decreases with frequency whereas dielectric loss shows random behavior [18].

A survey of the literature indicates that much of the studies have either been on heavy ion effect or lower doses of gamma radiation effect on polymers [13-19]. In an initial study on the effect of very high doses of gamma radiation (between 10^1 to10^6 Gy) in the dielectric properties in PADC detectors, it has been briefly reported [12] that dielectric properties becomes enhanced at doses higher than 10^4 Gy. In this paper now, the modification in dielectric properties due to irradiation of gamma doses are studied in details. The dielectric constant values are reported in the range between 10^1 to 10^6 Gy and compared with values of the pristine one.

MATERIALS AND METHODS

Seven samples of the polyacetate polymeric detector of thickness 770 µm and sizes (2 x 2 cm^2) were prepared. After cleaning and drying the polymer samples, exposure was done from a ^{60}Co gamma source having a dose rate of 3.0 kGy/h. The exposure time varied from 12 s to nearly 14 days in order to deliver the required doses in the range of 10^1 to 10^6 Gy. The errors in doses range from 8% for low dose (10 Gy) to about 1% for high doses. The dielectric constants of these irradiated polymers were evaluated from the Parallel capacitance measurement recorded at different frequencies using a HIOKI 3532- 50, frequency response analyzer.

RESULTS AND DISCUSSION

Figure 1 shows the characteristic plot of dielectric constant with frequency for polyacetate polymer in the frequency range 42 to 7000 Hz. It is understood from the figure that dielectric constant of the polymer is normally higher in the lower frequency region especially below 3000 Hz region. However, the increase is very sharp and prominent in the region below 1000 Hz. At higher frequencies the value slowly decreases. This might be due to the fact that as the frequency increases, the charge carrier migrate through the dielectric and get trapped against a defect site and induce an opposite charge in the vicinity which results in slowing down the motion of charge carriers and value decreases [16]

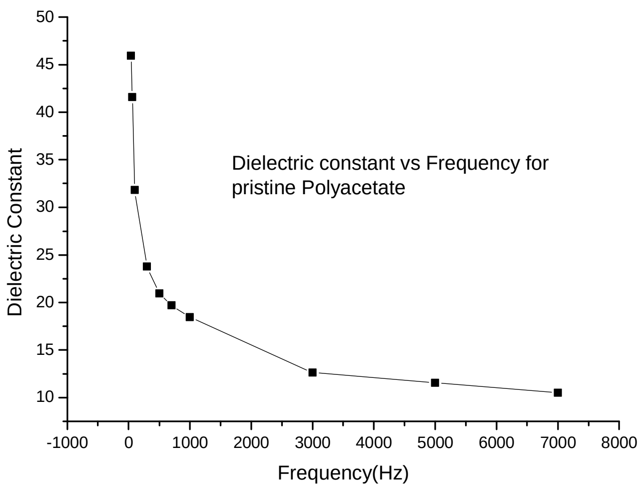

Fig.1. Plot of frequency vs dielectric constant of Polyacetate polymer

When the polymer is irradiated with gamma radiation of different doses, different chemical phenomena like chain scissioning and rearrangement of chain, formation of radicals, ions, polar groups etc. which take place in the polymer matrix, leading to the formation of various oxidized products. All these effects that take place in the polymer matrix are expected to modify the electrical properties of the polymer samples. Thus the dielectric constant of the polymers irradiated at different doses of radiation is listed in Table 1.

Table 1. Dielectric constant value at different frequency for irradiated gamma polyacetate polymer at different doses

Frequency(Hz)	Pristine	10^1Gy	10^2Gy	10^3Gy	10^4Gy	10^5Gy	10^6Gy
42	45.9421	46.8555	57.1065	58.1113	58.6294	73.6656	145.0345
60	41.5746	38.6783	49.0100	45.2821	49.1379	60.4075	117.6889
100	31.8181	28.1460	36.9718	35.3859	39.6700	42.2750	86.6043
300	23.7563	15.4899	29.5521	25.0326	29.3908	30.2211	54.9531
500	20.9316	12.8613	27.1497	21.8471	26.3155	26.5201	47.1786
700	19.7031	11.8539	25.5455	21.2214	24.4948	24.4627	43.1894
1000	18.4459	11.0242	23.9551	19.3319	22.6925	22.6171	39.5373
3000	12.6173	6.4109	17.2312	13.9841	16.2225	16.5465	27.5033
5000	11.5391	5.9398	15.8165	11.7719	14.5409	15.3247	24.7237
7000	10.4897	5.6995	12.2451	11.1134	13.5670	14.2707	23.1954

From table 1 it is obvious that in almost all the cases the value of dielectric constant is higher at lower frequency. Further it is observed that due to gamma exposure there is a gradual increase in dielectric constant till the dose of 10^4Gy, signifying the fact that polarization in the polymer sample increases due to gamma exposure. This polarization enhances significantly at a dose of 10^5 Gy, and finally leading to large enhancement of dielectric constant at the dose of 10^6Gy. The increase in the dielectric constant due to irradiation is probably due to increase in carrier polarization indicating that charge carriers move by discontinuous hopping movements between localized sites. The irregularity in the polymer chains at the radiation doses may give rise to a hoping mechanism which will enhance the polarization in the polymer matrix. Interestingly, it is observed that for the sample irradiated at the dose of 10^6 Gy, there is also an increase in the value of dielectric constant at higher frequency too as compared to other samples, even though the overall pattern of change of dielectric constant with frequency remains same. The change of dielectric constant with irradiation is shown in Figure 2.

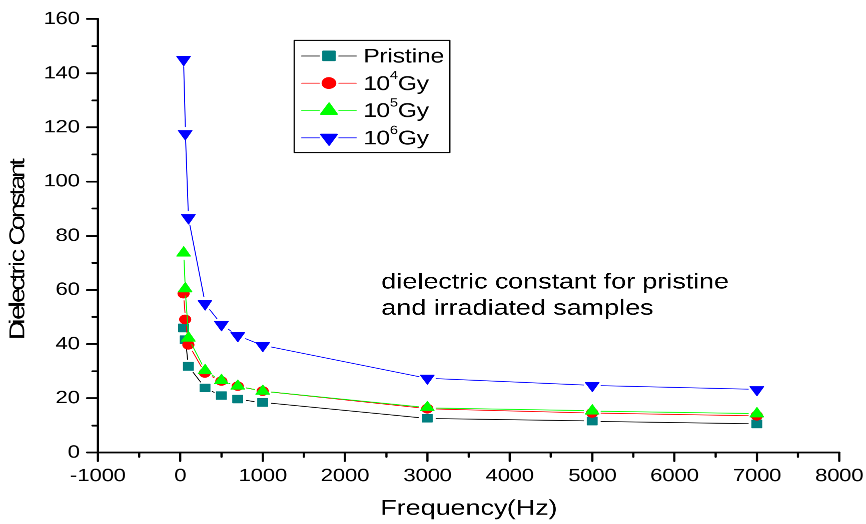

Fig.2. A comparison of dielectric constant value of pristine and Irradiated sample at different frequencies

Even though there is a gradual increase in dielectric constant due to gamma exposure, the increase is prominent at the highest dose of 10^6 Gy (Fig.3). There is almost 310% increase in dielectric values at the dose of 10^6 Gy as compared to only 160% increase at a dose of 10^5 Gy when the frequency is 42 Hz.

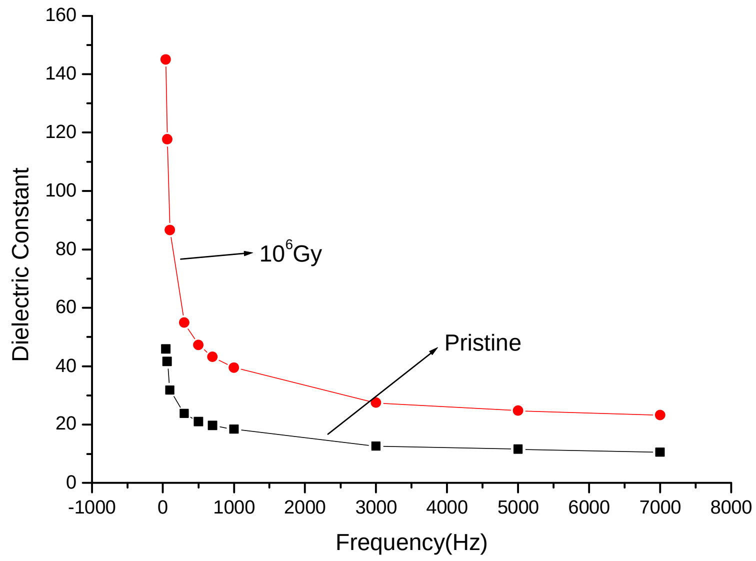

Fig.3. A comparison of dielectric constant between pristine and at a dose of 10^6 Gy

Figure 4 is a plot of dielectric constant against different gamma doses. It is clear from the figure that eventhough there is a gradual increase due to irradiation, but the sharp increase in the dielectric constant value takes place at a dose of higher than 10^4 Gy. Thus it might be possible that at a dose of higher than 10^4 Gy, scissoning of the polymer chain takes place in a significant manner which enhances polarisation of the polymer matrix.

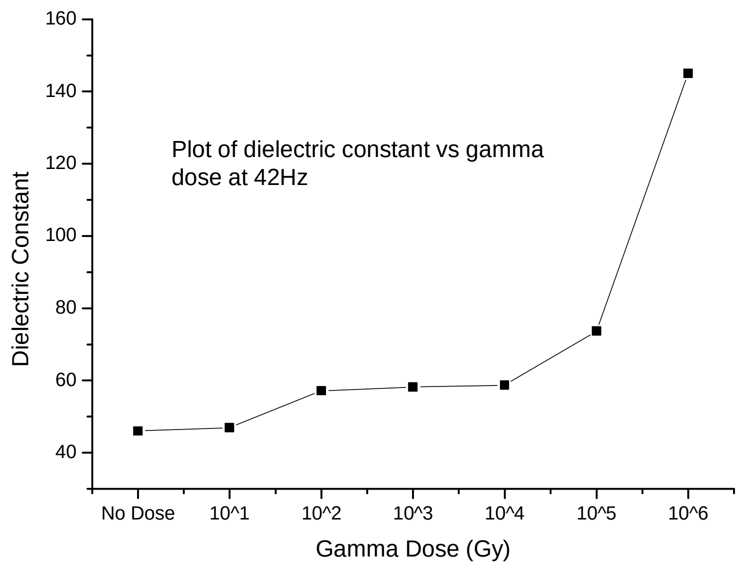

Fig.4 : Plot of dielectric constant at different gamma doses at a frequency of 42 Hz

CONCLUSION

On the basis of the present study the following conclusions have been made

a. Due to gamma exposure the dielectric constant of the polyacetate polymer increases at a dose higher than 10^4 Gy

b. The increase is visible in the lower frequency region i.e. in the range of 42-1000 Hz

c. The increase in dielectric constant value is probably due to irregularity in the polymer chains caused by irradiation. This irregularity give rise to a hopping mechanism which enhances the polarization in the polymer matrix at a dose higher than 10^4 Gy

REFERENCES

[1] A.H. Zahran, E.M. Ibrahim, F.M. Ezz-Eldin, N.B. El-Assy ; *The International Journal of Applied Radiation and Isotopes*, **1981**, 32, 713-717.
[2] R. Kumar, H.S. Virk, K.C. Verma, A. Saha, U.D. Prasad ; *Nuclear Instruments and methods in Physics Research B*, **2006**, 251, 163-166.
[3] D. Fink, W.H. Chung, R. Klett, A. Schmoldt, J. Cardoso, R. Montiel, M.H. Vazquez, L. Wang, F. Hosoi, H. Omichi, P. Goppelt-Langer ; *Radiation Effects and Defects in . Solids*, **1995**, *133*, 193–208.
[4] D. Sinha, K.K. Dwivedi; *Radiation Measurements*. **2003**, 36, 713 –718.
[5] D.Sinha, K.L.Sahoo, U.B.Sinha, T.Swu, A. Chemseddine, D.Fink ; *Radiation Effects and Defects in Solids*, **2004**, 159, 10, 587 –595.
[6] S. A. Nouh, A. Abdel Naby ;*Radiation Effects and Defects in Solids,* **2007**, 162, 109–116.
[7] M. S. Babul , P .V .S. Narayana, T. S. Reddy, D. U. Reddy, *Advances in Applied Science Research*, **2011**, 2 , 226-232.
[8] I. Kaur , V. Kumari, B. Singh, *Der Chemica Sinica*, **2012**, 3, 343-351.
[9] D. Sinha, Tokavi , T. Swu, *Advances in Applied Science Research*, **2012**, 3 , 2128-2133.
[10] D. Sinha ; *Advances in Applied Science Research* **2012**, 3 , 1365-1371.
[11] R. Mishra , S.P. Tripathy, D. Sinha , K.K. Dwivedi , S. Ghosh, D.T. Khathing, M. Muller D. Fink , W.H. Chung ; *Nuclear Instruments and Methods in Physics Research B,* **2000,** 168, 59-64.
[12] D.Sinha, T.Phukan, S.P.Tripathy, R.Mishra , K.K.Dwivedi ; *Radiation Measurements*, **2001**, 34, 109-111.
[13] S. A. Nouh, A. S. Abdel-Naby; *Radiation Effects and Defects in Solids*, **2003**, 158, 8, 553-560
[14] G. M. Nasr, A. F. Mansour, R. M. Ahmed, A. H. Bassyoun*; International Journal of Polymeric Materials*, **2007**, 56, 371-386.
[15] R. Kumar, S. Asad Ali, U. De, D.K. Avasthi, R. Prasad ; *Indian Journal of Physics*, 2009, 83, 963-968.
[16] S.A. Nouh, M.H. Abde-Salem, Y.E. Radwan, S.S. Fouad ; *Radiation Effects and Defects in Solids*, **2011**, *166*, 178-189.
[17] Y.H.A. Fawzy, A.E.H. Ali, E. Maghraby, Radwan R.M.; *World Journal of Condensed Matter Physics* **2011**, 1, 12-18.
[18] S. Fares; *Natural Science*, **2011**, 3, 12, 1034-1039 .
[19] H. A. Fawzy, Amr El-Hag Ali, Ghada F. El-Maghraby, Reda M. Radwan. *World Journal of Condensed Matter Physics,* **2011**, 1,12-18.