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# Gamma radiation induced changes in polyoxymethylene

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## ABSTRACT

In the present investigation, a technologically important polymer Polyoxymethylene has been irradiated with gamma radiation in the dose range 0 to 50Mrad and changes induced in several properties of the polymer has been studied as a function of dosage of irradiation. Significant changes have been observed in the crystallinity, electrical conductivity and dielectric constant and dielectric loss of the polymer due to irradiation. The crystallinity of the sample increases with increase in radiation dosage. The conductivity also shows increasing trend as a function of radiation dosage. Results suggest that the C-H bond scission takes place in the polymer due to irradiation. These induced changes will strongly affect the strength of the polymer and hence strength of components made out of this material - in the radiation environment. 

## KEYWORDS

Polyoxymethylene;
Gamma irradiation;
FTIR;
Dielectric constant;
Conductivity.

## INTRODUCTION

Polymer has become an important component in the modern electrical, electronic and mechanical industry. Many modern machines and electronic components have polymers as one of the ingredient. Employing polymers in designing machines and electronic components has resulted in lowering the weight of those items and also the cost of their production.

But it is better to take care while using such machines and electronic components made of polymers in presence of radiations. Because, radiations induce several changes inside the polymer matrix. It can even change the crystallinity of the semi-crystalline polymer and thus strongly affect the physical, chemical, electrical and mechanical properties of the polymer[1].

Thus, study of polymers giving radiation treatment has a greater importance[2-4]. It gives us an idea of the changes happened in the polymer matrix due to irradiation, looking at which one can decide whether to use them in the radiation environment or not and also one gets an idea of the threshold level of radiation up to which the polymer and hence the machines and electronic goods that are made of those polymers will survive[5]. Radiation is found to induce solid state polymerization in several cyclic oligomers of formaldehyde[6,7].

## EXPERIMENTAL

Polyoxymethylene samples were cut into discs of 12 mm diameter & 1mm thickness and were irradiated by Co-60 source with a dose rate of 0.25 Mrad/hr in presence of air at CTRL Laboratory, Mumbai, India.

The samples were irradiated for different doses like 10 Mrad, 20 Mrad, 30 Mrad, 40 Mrad, and 50 Mrad.

X-ray diffraction studies were carried out using MiniFlex II powder diffraction system using Cu kα radiation on the un-irradiated and irradiated samples at different dosages of gamma radiation. The samples for X-Ray diffraction studies were well grounded to 200 mesh size, and mounted over a 3”x1” glass slide by evenly spreading and wetting it by acetone. The percentage of crystallinity has been calculated in each sample.

The electrical conductivity of the Polyoxymethylene samples were carried out using the two probe method with the help of Keithly electrometer model 6514, at room temperature, at the Department of Physics, Indian Institute of Science, Bangalore, India. The pellet surfaces were coated with silver paste while doing the measurements.

The infrared spectra of polymer compounds were recorded in the range of 4000 - 400 cm-1 using FTIR, JASCO 460 Plus spectrophotometer in the Department of Studies in Geology, Manasagangotri, Mysore. The sample holder of the instrument has provision for the measurement of blank KBr as well as for the sample. The sample is prepared by mixing thoroughly KBr with the sample whose FTIR is to be recorded in the ratio of 100: 3. The background measurements were recorded for blank KBr before measuring the sample. The programme of the instrument has provision for automatic correction for background in the sample measurements.

The capacitance and Loss factor of the unirradiated and irradiated PF samples were recorded using the LCR bridge interfaced with computer in the frequency range 10 – 400 kHz with the help of Impedance Analyzer (HP 4192A) at room temperature, at the Department of Physics, Indian Institute of Science, Bangalore, India. At all frequencies, capacitance of both irradiated and unirradiated samples were measured using which the dielectric constant was calculated.

## RESULTS AND DISCUSSION

### Crystallinity and conductivity

The percentage of crystallinity as a function of dosage of irradiation is shown in the Figure 1.

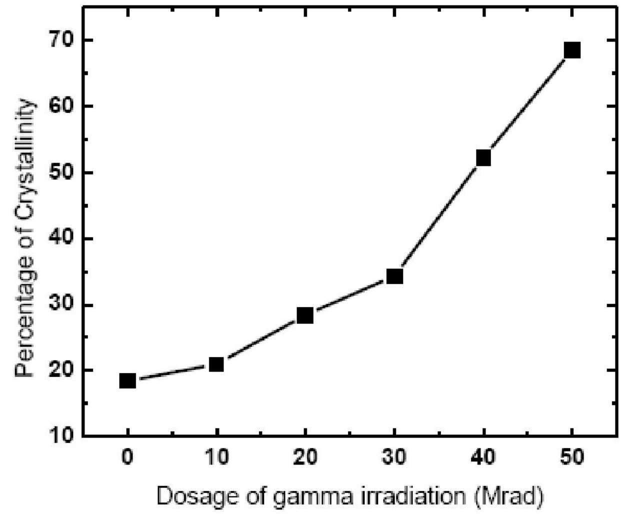


**Figure 1 : Percentage of crystallinity v/s dosage of gamma irradiation.**

It can be clearly seen that the percentage of crystallinity increases from 18 to 68 percent with increase in the dosage of irradiation. This is in good conformation with the observation by S. Okamura et. al.[6] and Y. Chatani et. al.[7]. They have shown that the gamma radiation induces solid state polymerization in several compounds. In the present study also, one can see that, even in case of Polyoxymethylene, the percentage of crystallinity increases with the increase in gamma radiation dosage. The variation in crystallinity with irradiation depends on the nature of radiation and also on the internal structure of the polymer[8-10]. Zhang et. al.[8] have observed increase in amorphicity with increase in irradiation dosage in case of polyethylene oxide.

Study of conductivity and other parameters play

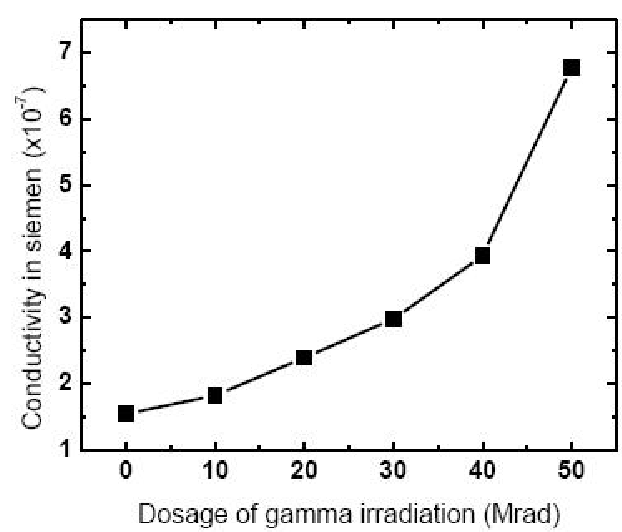


**Figure 2 : Conductivity v/s dosage of gamma irradiation.**

vital role in designing polymer composites for several electrical and electronic applications[11-13]. A plot of variation of conductivity in Polyoxymethylene as a function of radiation dosage is shown in Figure 2. It can be clearly seen from the figure that the conductivity increases with increase in dosage of irradiation.

The increase in percentage of crystallinity of the polymer can be attributed to the scission of side chains and decrease of free volumes in the polymer matrix[14-17]. Increase in electrical conductivity is complementing the same and shows the formation of free radicals due to irradiation. The side chains which sometimes cause for the decrease in electrical conductivity are broken due to irradiation and thus resulting in the increase of electrical conductivity. Cross-linking can also be observed due to gamma irradiation[18].

## FTIR and dielectric constant

IR spectroscopic studies play important role in studying organic systems[19]. In order to study the effect of gamma irradiation on the different streching modes present in the compound the FTIR spectrum was recorded at each irraidiation step. All the observed spectra in the sample so obtained have been grouped together and shown in Figure 3.

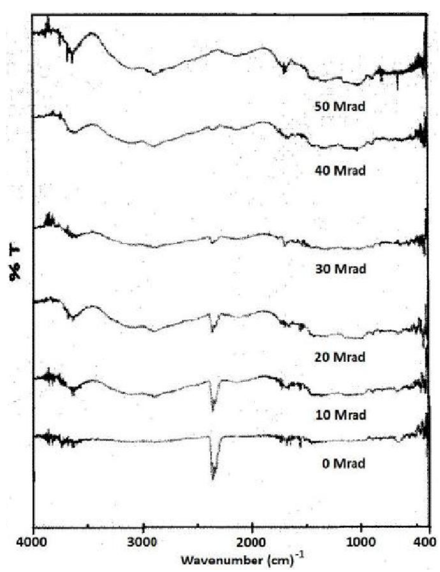


**Figure 3 : FTIR of polyoxymethylene exposed to gamma irradiation from 0 to 50 Mrad.**

Based on the FTIR studies, it can be seen that as the dosage level increases the percent of transmission FTIR of the C-H bond increases, which clearly indicates the formation of free radicals. It has been observed that there is change in the color of the sample after irradiation which might be due to the formation of conjugated double bonds and/or trapped free radicals and ions. The FTIR spectrum shows a decrease in intensity of 2300 $cm^{-1}$ peak, which is associated with stretching vibrations of C–H bond. The presence of many new peaks with the increase of irradiation suggests the formation of alkynes which might be responsible for changing the capacitance and tanδ values.

The variation of dielectric constant and loss factor of the samples at different frequencies as functions of radiation dosage are shown in Figures 4 and 5. These variations clearly indicate that the material can be used as a dielectric.

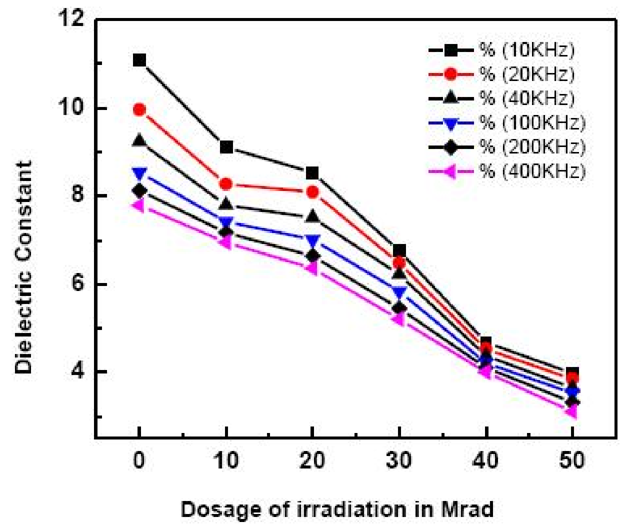


**Figure 4 : Dielectric constant v/s dosage of gamma irradiation at different frequencies.**

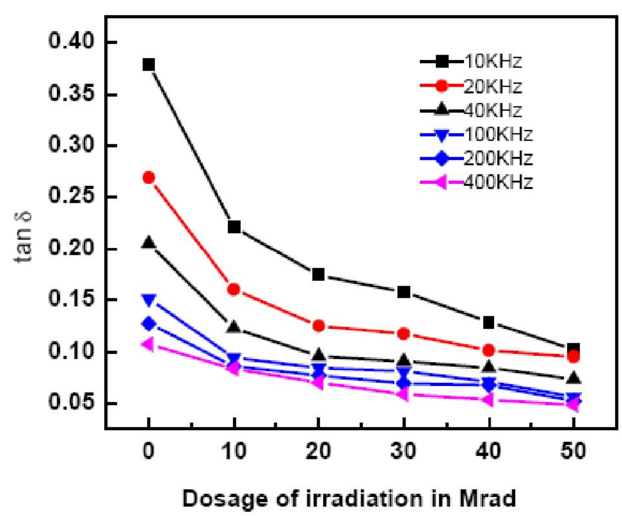


**Figure 5 : Variation of loss factor v/s dosage of gamma irradiation at different frequencies.**

## CONCLUSIONS

Gamma irradiation is increasing the percentage crystallinity in the polymer Polyoxymethylene. Electrical conductivity of the sample is also increasing with increase in irradiation dosage. Gamma irradiation is resulting in the scission of side chains in this polymer. Nature of variations in the dielectric constant and the loss factor as a function of frequency show that the material suits as a dielectric. Though the increase in percentage of crystallinity of the polymer matrix is resulting in the increase in conductivity of the sample, the sample gets more and more brittleness with increase in radiation dosage. Thus, it is better to avoid the usage of machines and electronic items made of components employing this polymer in the radiation environment.

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