

RADIATION INDUCED MODIFICATION OF SOME DIELECTRIC SOLIDS

BY

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Abstract of the thesis

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ABSTRACT OF THE Ph.D. THESIS

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Chemical modifications observed in irradiated polymeric materials have imparted the initial motivation for studying their impact on track registration properties of a sensitive detector. In polymeric track detectors, only those charged particles with linear energy transfer (LET) above a critical values can create distinct etchable tracks. Atomic radiations such as UV rays and X-rays, nuclear radiations like gamma rays and beta rays are low LET radiations. They mostly affect the physical and chemical properties of the polymeric films. Though they can not create any tracks but can affect etch rate values of detectors depending upon the absorbed dose. For track detectors exposed to high LET charged particles followed or preceded by low LET radiation exposure, both the bulk-etch rate and track-etch rate are found to vary in accordance with the absorbed doses of low LET radiations. Having a thorough knowledge about these effects is,

therefore, necessary specially when track detectors are used for detecting charged particles in an atmosphere of intense low LET background radiation. Besides, it is useful in evaluating the dosimetric properties of track detectors.

Experimental evidence shows that the track registration characteristics of plastic Solid State Nuclear Track Detectors (SSNTDs) are greatly affected when exposed to high doses of gamma rays. The modifications in characteristics originate from the structural alterations produced by irradiation of polymers. Studies have also been carried out on metal alloys and metallic glasses. The action of electromagnetic radiation is known to be one of the major sources of altering the properties of the materials they pass through. The changes are strongly dependent on the internal structure of the absorbing substances and the radiation gamma doses. It may be expected that the interaction of gamma-rays with solids cause electronic ionisation (or excitation) of the orbital electrons and possibly atomic displacements. Since polymeric solid state nuclear track detectors consist of long chain organic molecules, the net effect on the material is the formation of many broken molecular chains and radicals leading to a reduction in the average molecular weight of the substance. Such radiation induced modifications of polymeric materials may influence their etching characteristics, optical properties and some other properties such as thermal stability, morphology and optical band gap which in turn change the track registration properties of these track detectors.

Gamma exposure of the dielectric solids is not an uncommon phenomenon. In nuclear reactors during the process of fission, a high dose of gamma radiation is produced along with the neutrons. This produces different effects on its physical and chemical properties. Since the track detectors are increasingly used in diverse fields such as radiation dosimetry, cosmic-ray study, heavy ion Physics, microanalysis, uranium prospecting etc., so a proper characterisation of these detectors is necessary. Though the passage of lighter particles and gamma rays through these detectors can not be directly recorded, but the modifications that they produce on these detectors can be quantified.

The foremost application of a knowledge of the physico-chemical changes in matter with radiation dose is in the field of radiation dosimetry. Radiation dosimetry provides the basic knowledge required for quantitative measurements of radiation. In addition to that it can also be used to assess the ambient radiations and thus provide a protection against radiation hazards. Keeping these factors in mind we have attempted to study the modifications that take place in seven polymeric solids viz. **PADC (Homalite)**, **PADC (American Acrylics)**, **Lexan**, **Makrofol-E**, **Polycarbonate**, **Triafol-TN** and **Triafol-BN**, by the passage of gamma rays in the dose range from 10^1 Gy to 10^6 Gy.

In order to characterize the irradiated polymers, five different techniques have been used. They are : (1) Nuclear track technique, (2) IR spectroscopy, (3) UV-VIS spectroscopy, (4) ESR spectroscopy and (5) Thermogravimetric analysis. In track technique some of the important properties related to track parameters like, bulk-etch rate, track-etch rate, activation energy, complete etching time, true track length etc. were quantitatively determined with gamma doses for assessing the response of these detector materials towards track registration under intense gamma background region. In order to understand the chemical and structural modifications in these polymers, spectroscopic studies (IR, UV-VIS and ESR) were carried out. For dosimetric applications of these detectors, dose dependent variation in transmittance at different wave lengths in the UV-VIS region were measured. Thermogravimetric studies were also performed to investigate the changes in thermal stability of these polymers caused by gamma radiation of different doses.

The present investigations have revealed that several physico-chemical changes occur in polymers due to gamma exposure. It is found that except some Polycarbonates (Lexan, Makrofol-E, Polycarbonate), all the other detectors gives the higher etch-rate values at the dose of 10^6 Gy. This increase in the etch-rate values is due to the scissioning of the molecular chains of these polymers. Spectroscopic studies have revealed that in the case of PADC (American Acrylics), the linkage of polyallyl chain with diethyleneglycol got ruptured at the

dose of 10^6 Gy, leading to a production of oxygen centered radicals. For Triafol-BN, the increase in the etch-rate values is attributed to the destruction of ether/ester group of the polymer. For Polycarbonates (Lexan, Makrofol-E and Polycarbonate), it is the C-H bond of the benzene ring that breaks, which can not reduce the molecular weight of these polymers to an appreciable extent, and hence no increase in the etch-rate values takes place.

For almost all the detectors, it is found that transmittance starts decreasing with increasing dose ($> 10^3$ Gy) in the UV-VIS region. Moreover, with increasing doses, the transmittance shifts to the higher wave length region. This quantitative change in transmittance is very useful for dosimetric applications.

TGA studies have revealed that thermal resistance has not been modified by different doses of gamma radiation for Lexan, Makrofol-E and PADC (Homalite). However, for PADC (American Acrylics), Triafol-BN and Polycarbonate, thermal stability decreases at higher doses and the materials start losing weight at lower temperatures.

The thesis is laid out in the form of six chapters.

CHAPTER-1 contains the background, nature and importance of the studies related to the modification's induced by radiation in polymeric SSNTD's.

CHAPTER-2 presents a brief review on the interaction of radiation with matter and the subsequent events. Firstly interaction of gamma radiation with matter followed by interaction of radiation with polymers have been discussed. Introduction to nuclear tracks, track registration criteria along with theories used for track formation are also presented briefly. Section 2.5 contains the details about the literature available on radiation induced changes or modifications in polymers. Lastly stabilization against radiation-induced damage are also mentioned in brief.

CHAPTER-3 deals with a detail description of the techniques used to characterize the irradiated polymers. Some important parameters of track studies, like bulk-etch rate, track-etch rate, true track length, activation energy etc. are discussed in details. Several spectroscopic techniques like, IR, UV-VIS, ESR are discussed from section 3.2 to 3.4. Thermogravimetric analysis which has been used to study the thermal behavior of these detectors are also discussed in the end of this chapter.

CHAPTER-4 contains a systematic account of the experimental techniques used to characterize the irradiated polymers. At the very beginning the classification of the detectors and the properties are discussed. There-after, the

preparation of detectors and their irradiations to gamma source and Cf source are described. From section 4.3 to 4.6 contains the details about the experimental procedure of chemical etching, measurement of track parameters, determination of etch rates and determination of activation energies. Section 4.7 to 4.9 deals with the spectroscopic techniques which have been used to characterize the polymers. Lastly a brief experimental procedure about TGA is also mentioned here.

CHAPTER-5 contains results and discussion. It is divided in three parts. Part-1 discusses the details about the modifications in different types of polyallyl diglycol carbonate (PADC). Part-2 consists of the results and discussion on three types of bisphenol-A carbonates viz., Makrofol-E, Lexan and Polycarbonate. Part-3 deals with the work on Triafol-TN and Triafol-BN polymers.

CHAPTER-6 The significant conclusion of the present investigation are highlighted. A brief description on the potentialities and scopes of this work along with some future perspectives is also presented in this chapter.

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