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Radiation Measurements

Radiation Measurements 36 (2003) 615–620

[www.elsevier.com/locate/radmeas](http://www.elsevier.com/locate/radmeas)

# Characterization of chemical and optical modifications induced by 22.5 MeV proton beams in CR-39 detectors

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Received 21 October 2002; accepted 7 May 2003

## Abstract

Chemical and optical modifications induced by 22.5 MeV protons slowed down into a 4.4 mm polyallyl diglycol carbonate (CR-39) stack, which was composed of 16 detectors of different thicknesses, are studied. Irradiation was performed perpendicular to the stack surface, in a vacuum chamber, with proton fluences ranging from  $10^{11}$  to  $10^{14}$  particles/cm<sup>2</sup>. These transformations are analyzed using fourier transform infrared (FTIR) absorption spectroscopy in the total attenuation reflection mode and UV–visible spectroscopy by following C=O, C=C and O–H bands evolution and by following the shift in the absorption edge towards the higher wavelengths. The chemical changes occurring in the CR-39 absorption spectra (both FTIR and UV) are analyzed versus the ion beam fluence, the beam penetration depth into the stack and the average deposited energy density. The results show that degradation of CR-39 presents a maximum in the depths ranging between 3500 and 4000  $\mu\text{m}$ . © 2003 Elsevier Ltd. All rights reserved.

**Keywords:** CR-39; Proton irradiation; FTIR and UV spectroscopy; Chain scission; Cross-linking

## 1. Introduction

Four decades have elapsed since the discovery of nuclear track detectors (Young, 1958), but until now there is no general agreement about the mechanism of track formation in these detectors which is known to involve generally atomic displacement, ionization and excitation followed by chemical reaction. Particularly in polymers little is established about the inner structure of the latent tracks (Enge, 1995; Khan and Qureshi, 1999).

Most of the studies relevant to the modifications induced in polymers by the ionizing radiation have been performed in the last years using high-energy projectile (GeV particles) where the energy density transferred to the target can be as high as few eV/Å. It has been pointed out that track

formation is accompanied by changes in chemical, structural, geometrical, optical and electrical parameters (Fink et al., 1996; Steckenreiter et al., 1997; Biswas et al., 1999). The obtained chemical system is characterized by new functional groups, a different backbone with different electronic structure and different physical properties.

For the low-energy heavy particles or light particles, the very few results existing in the literature show that the exact nature of low-energy ion irradiation effects is still ambiguous (Chapiro, 1995). The transferred energy density is small and the induced chemical changes could involve the creation of intermediate species (free radicals) that may recombine themselves or react with the polymeric chains. One could also observe formation of chemical bonds between different molecules (intermolecular cross-linking), irreversible cleavage of bonds (scission) in the main chain, which result in the fragmentation of molecules and the formation of saturated, unsaturated groups with molecular (H<sub>2</sub>, CO, CO<sub>2</sub>, NH<sub>3</sub>, etc.) desorption. The rise of these complex phenomena deeply affects the polymer macromolecular structure and

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