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New polymers for solid state nuclear track detection

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Abstract

Two novel polymers have been prepared from a monomer *N*-allyloxycarbonyl diethanolamine-bis(allyl carbonate) i.e., NADAC by cast polymerization and were successfully used as solid state nuclear track detectors for α particles and fission fragments. The homopolymer PNADAC was prepared by IPP catalyzed polymerization of NADAC. A copolymer of NADAC with allyl diglycol carbonate (ADC) called poly-[(NADAC)-co-(ADC)] was also prepared similarly. A preliminary study on the etching conditions and track detection characteristics of the newly developed materials was carried out. It was found that the copolymer is more sensitive to α particles as compared to commercially available PM-250™ track detector.

Keywords: Solid state nuclear track detection; *N*-allyloxycarbonyl diethanolamine-bis(allylcarbonate); Poly-[*N*-allyloxycarbonyl diethanolamine-bis(allylcarbonate)]; Nuclear track detectors; Polymerization; Nuclear tracks; Dosimetry

1. Introduction

Solid state nuclear track detection (SSNTD) is a widely used technique among the various known methods for detection of nuclear radiation (Durrani and Bull, 1987). This method owes its popularity mainly to its simplicity, cost effectiveness and capacity to store permanent records. Although minerals and glasses have been tested as SSNTDs, the higher sensitivity of the plastic materials to many charged particles and ease of track development and evaluation has made plastic materials more popular as SSNTDs. Since the introduction of plastics as SSNTDs in 1965 (Collver et al., 1965), a number of plastic materials, such as cellulosics, polycarbonates, acrylates and polyvinyls, have been extensively studied as track detectors. The introduction of poly allyl diglycol carbonate (PADC) polycarbonate (Cartwright et al., 1978) replaced many of the plastics due to its very high sensitivity to many charged particles, and superior optical properties. It is observed that since 1965, efforts are mainly directed towards testing the commercially available plastics as SSNTDs rather than attempts to design newer plastics as SSNTDs. A few systematic reports on development of some sulphonate resins and some other materials as SSNTDs (Fujii and Yokota, 1988; Fujii et al., 1990; Ogura et al., 1995) are known. This included generalization of some of the structural features of the polymer matrix, which may help in designing materials of higher sensitivity. Other studies have also revealed that the copolymer with ADC has been more sensitive than the homopolymers. Fujii reported the possible relation between structure and track detection characteristics (Fujii et al., 1990) as follows: (1) All polymers containing aromatic rings tend to show lower sensitivity. (2) The highly cross-linked thermosets and the amorphous polymers show better sensitivity. (3) The chain

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bridging the carbonate moieties can be crucial for sensitivity. (4) Materials having one of the functional groups like–$ONO_{2'}$–CO_3–, –SO_2– and –SO_3– have been found to be more sensitive. (5) The density of the cross-links in the polymer matrix was also an important factor. (6) For PADC (CR-39)™, it is known that, the copolymers are more sensitive than homopolymer. Thus, there is ample scope for designing new polymer materials in terms of its constitution and structural features for use as SSNTDs.

We have been working on the preparation of plastic materials as SSNTDs, since 1996 (Nadkarni and Samant, 1996). In continuation with our efforts to indigenously prepare and improve plastic materials for SSNTD applications, we present the preliminary results of casting homo and copolymer films from a novel monomer (Nadkarni et al., 2003,2004) *N*-allyloxycarbonyl diethanolamine-bis(allyl carbonate) (NADAC) monomer with allyl diglycol carbonate (ADC) in this paper. It was thought that a hexafunctional monomer would give a polymer matrix of high-density cross-links, which would lead to high sensitivity of the materials to charge particles. The idea was also to introduce different types of functionalities in a single system. A brief description of the study of some of the etching conditions, the effect of initiator concentration on the sensitivity of the materials and also track detection efficiency studies in comparison with commercially available PADC has been reported.

2. Materials and methods

Indigenously prepared NADAC and ADC monomers, isopropyl peroxydicarbonate (IPP) initiator were used for the preparation of poly-[*N*-allyloxycarbonyl diethanolamine-bis(allyl carbonate)] i.e., (PNADAC) homopolymer and NADAC-ADC copolymer. PADC films from Pershore Molding (UK) of thickness 250 µm was used for comparative studies. Dioctyl phthalate (DOP) plasticizer manufactured by S.D. Fine Chemicals, India was used as such. Glass plates (Schott, Germany), thin Teflon™ sheets, aluminium plates were used for the polymerization molds. The various steps involved in the synthesis and polymerization of monomers are briefly described below. IPP was prepared in our laboratory and polymerization carried out using a polymerization bath controlled using microprocessor-based electronic temperature controller F25 HP, from Julabo, Germany.

2.1. Synthesis of NADAC

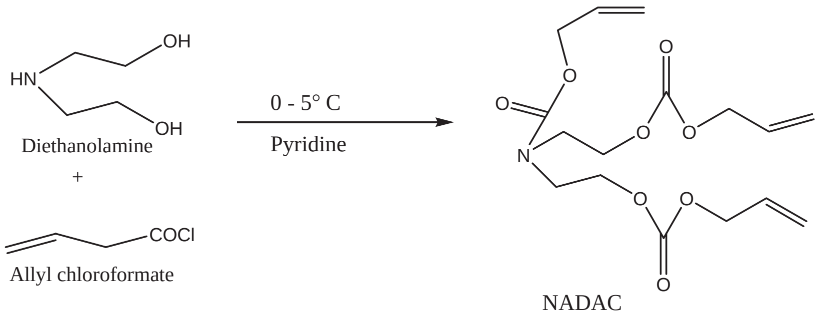
The NADAC monomer was synthesized by reacting diethanol amine and allyl chloroformate (Nadkarni et al., 2004) as indicated in Scheme 1:

2.2. Preparation of the mould

A square-shaped gasket of Teflon with an outer length of 100 mm, inner window of length 80 mm, and a thickness of 500 ± 10 µm was specially prepared for this purpose. It was sandwiched between two clean optical glass plates of size 100 mm $(l) \times 100$ mm $(b) \times 4$ mm (t). A typical mould assembly is shown in Fig. 1.

2.3. Preparation of SSNTD films by cast polymerization

NADAC and ADC monomers were filtered carefully to remove any solid impurities. The monomers were stirred under nitrogen atmosphere to remove any dissolved air and oxygen which hinder the process of polymerization. The mixture containing the monomer, initiator (3% by wt) and platicizer (DOP, 1% by wt) was carefully injected into the mould using a syringe, through a previously prepared tiny hole in the Teflon gasket. Care was taken to avoid any air bubbles in the liquid monomer film during the injection in the mould. The mould was sandwiched between two flat aluminium plates of uniform thickness and pressurized using wing-nut bolts fitted at the four corners of aluminium plates. The entire assembly was then kept in the polymerization bath and heated as per predetermined temperature–time intervals obtained after a careful polymerization kinetics study of NADAC



Scheme 1.