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Enhanced solvent resistance of acrylonitrile–butadiene rubber by electron beam irradiation

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ABSTRACT

In this study, we investigated the effect of electron beam irradiation on NBR (acrylonitrile–butadiene rubber) with TMPTMA (trimethylolpropane trimethacrylate), focusing on the polar and non-polar solvent resistance at different electron beam radiation doses. The electron beam irradiation on NBR containing TMPTMA sheets was performed over a range of absorbed doses from 20 to 200 kGy to make three-dimensional network structures. The solvent resistance was characterized according to ASTM D 471 in benzene and THF solvent. The solvent resistance of NBR was enhanced by the addition of TMPTMA in a dose-dependent manner. In addition, the volume change of immersed NBR in THF solvent was slightly lower than in benzene solvent.

1. Introduction

NBR (acrylonitrile–butadiene rubber) may be concisely described as a special rubber in conventional polymerization technology. This material has been widely used in the automobile and machinery industries because of its moderate cost and, excellent resistance to oils, fuels and greases [1–4]. However, NBR has some disadvantages, such as poor polar and nonpolar solvent resistance. To compensate for these unwanted properties, polymer processing is generally performed to incorporate reinforcement fillers, plasticizers, antioxidants, and cross-linking agents that can enhance the polymer properties. Among them, cross-linking agents, such as trimethylolpropane trimethacrylate (TMPTMA), triallyl cyanurate (TAC), and triallyl isocyanurate (TAIC) are primarily used to improve polymer cross-linking, due to the significant effects of radiation on these materials [5–10].

When a polymer is exposed to high-energy radiation, such as an electron beam, ion beam or γ-ray, its composition and structure inevitably undergo some changes, which in turn lead to changes in the physical and chemical properties of the polymers. The changes caused by high-energy radiation are complex and, so far, have not been fully understood. Moreover, the use of electron beams to initiate polymerization reactions has received a substantial amount of interest. Significant developments in electron beam curing methods have been made in many industries. Electron beam curing improves productivity, increase the rate of production, lowers costs, and improves the properties while using less energy than other methods, and producing fewer polluting emissions and solvents [6–8]. In this study, we investigated the effect of electron beam irradiation on NBR with TMPTMA, focusing on the polar and non-polar solvent resistance at different radiation doses.

2. Experimental

2.1. Preparation of the sample

NBR was purchased from LG Chem., Korea (NBR 6230). The rubber was characterized as having an average acrylonitrile content of 34% by weight. Trimethylolpropane trimethacrylate, as a curing agent, was purchased from TCI Co., Japan. The samples were prepared as a function of the NBR/TMPTMA composition ratio 100:0, 99:1, 97:3, and 95:5 by weight in a lab scale mixer (Brabender Instruments, USA) at 80 °C with a 20 rpm rotor speed for 10 min. After blending, the samples were discharged and compression molded into 3 mm thick plates at 120 °C for 10 min. Electron beam irradiation was carried out on each sample using an electron beam accelerator at a dose rate of 10 kGy/scan with a beam energy of 1.14 MeV in N_2 gas. Different absorbed dose samples were obtained 20, 50, 100, 150, and 200 kGy through multiple passes (Scheme 1).

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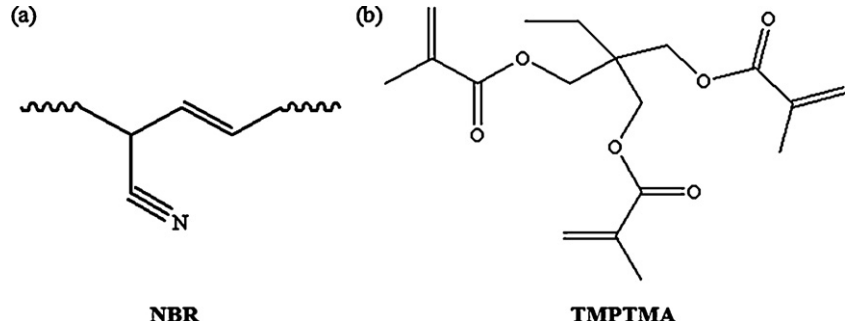

NBR TMPTMA

Scheme 1.

2.2. Analysis methods

The gel contents were measured in a Soxhlet apparatus according to ASTM D 2765-01. The sample was extracted by immersion in xylene at 120 °C for 24 h. After drying at 80 °C for 12 h in a vacuum oven, the gel contents were calculated. The gel contents were calculated using the formula shown below, where W_0 is the initial weight and W is the weight of the insoluble part.

$$\text{Gel contents}(\%) = \left(\frac{W}{W_0}\right) \times 100$$

The FTIR spectra were recorded using a Tensor 37 FTIR spectrometer equipped with an ATR attachment (Bruker, Germany). As indicated by ASTM D 471, the dipping test was performed in the benzene and the THF solvent. And the samples were dipped for a week at room temperature. The volume change was calculated using the following equation:

$$\Delta V = \frac{(W_3 - W_4) - (W_1 - W_2)}{W_1 - W_2} \times 100$$

where ΔV is the volume change, W_1 is the weight of the irradiated NBR in air before the dipping test, W_2 is the weight of the irradiated NBR in distilled water before the dipping test, W_3 is the weight of the irradiated NBR in air after the dipping test, and W_4 is the weight of the irradiated NBR in distilled water after the dipping test. The surface morphology of each sample was determined with the help of FE-SEM (Sirion 200, The Netherlands). The hardness of the samples was measured according to ASTM D 2240-05 using a type Adurometer.

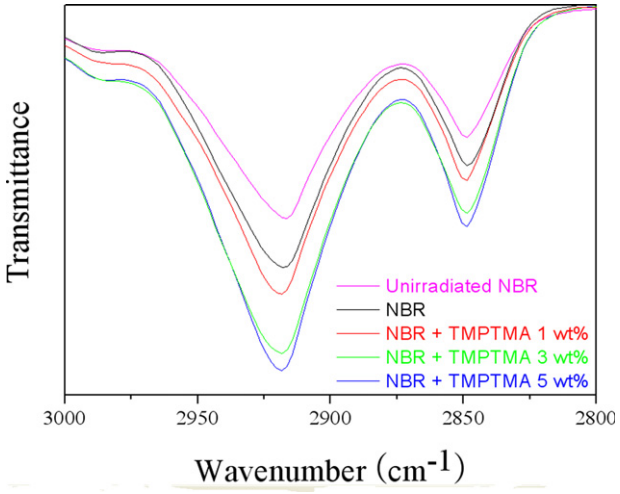

Fig. 2. The FTIR spectra of 200 kGy irradiated NBR containing varying amounts of TMPTMA.

3. Results and discussion

The gel content of NBR as a function of the electron beam irradiation dose is shown in Fig. 1. It is impossible to measure the gel content of NBR before the electron beam irradiation because the NBR was dissolved by a xylene solvent. As the electron beam irradiation increase, the gel content continuously increased due to the increases in the degree of cross-linking between the NBR molecules. The gel content of NBR containing TMPTMA at 3 wt.% and 5 wt.% is dramatically increased. Addition of the TMPTMA

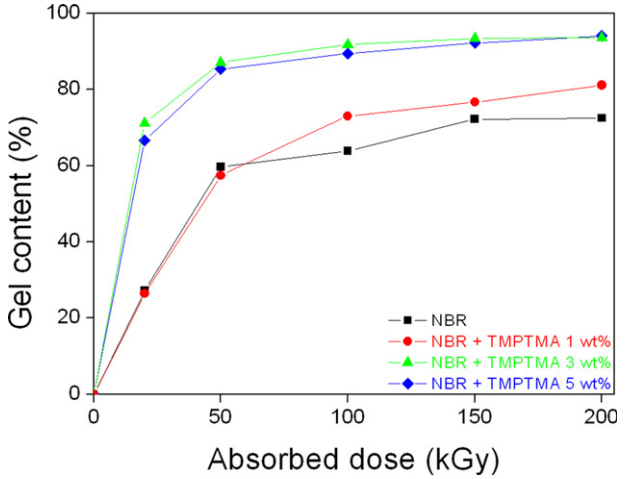

Fig. 1. Gel content curves of NBR containing varying amounts of TMPTMA as a function of the electron beam irradiation.

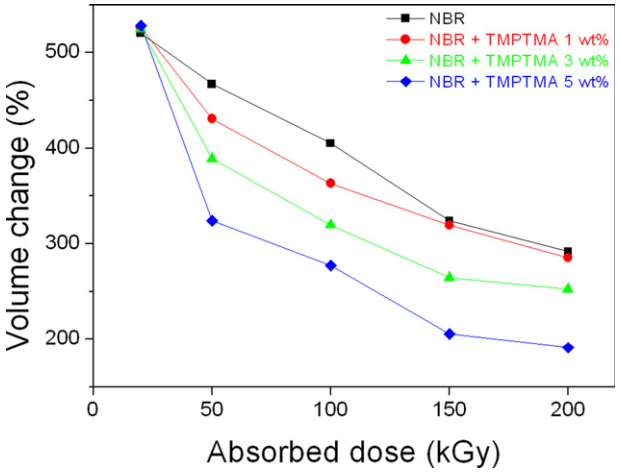

Fig. 3. Volume changes of NBR containing varying amounts of TMPTMA as a function of the electron beam irradiation in benzene.