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The comparison of EPDM/clay nanocomposites and conventional composites in exposure of gamma irradiation

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ABSTRACT

The effect of gamma irradiation on the properties of EPDM/clay nanocomposites and its conventional composites with pristine clay is studied. The dispersion of the silicate layers in the EPDM matrix is characterized by XRD (X-ray Diffractometer) and TEM (Transition Electron Microscopy) analyses. XRD and TEM results indicate that the alkylammonium chains are intercalated between the nanolayers silicate after modification. The mechanical behavior of samples is investigated by dynamic mechanical analysis and tensile test. The DMTA results demonstrate that their α-relaxation peaks are shifted to higher temperature, and storage modulus increases with increase of irradiation dose. The experimental data suggest that the exposure of EPDM hybrids to gamma rays improves the tensile strength of samples at lower irradiation doses due to cross-linking effect. The nanocomposites exhibit superior irradiation-resistance properties than that of unfilled EPDM and conventional composites.

1. Introduction

The attention to polymer–clay nanocomposites is of paramount importance due to the intense application of polymers in the industry. The properties of pristine polymers are significantly influenced by the dimension and microstructure of the dispersed phase [1,2]. One of the most promising composite systems would be hybrids based on organic polymers and inorganic clay minerals consisting of layered structure which is belong to the general family of 2:1 layered silicates [3]. Polymer–clay nanocomposites have at least one ultra-fine dimension, typically on the order of 1–10 nm. Polymer–clay nanocomposites possess unique properties concerning the nanoscale structure of particles in the matrices. As reported in the literature, polymer–clay nanocomposites have improved mechanical properties [4,5], thermal stability [6,7], gas permeability resistance [8], and fire retardancy [9,10].

Nanocomposites can be produced by an in situ polymerization or by melt/solution blending [11,12]. As a matter of fact, if the clay were not dispersed, it most likely would represent the role of filler, and a nanocomposite would not be formed [13].

Being interacted by gamma ray, EB, or X-ray source, the polymer and active species such as radicals absorb the energy, thereby initiating various chemical reactions. There are three fundamental processes that are the results of these reactions: (1) cross-linking, where polymer chains are joined and a network is formed; (2) degradation, where the molecular weight of the polymer decreases through chain scissioning; and (3) grafting, where a new monomer is polymerized and grafted onto the base polymer chain. Cross-linking and degradation (through chain scission) are two competing processes that always coexist under irradiation. The overall effect depends on which of these two factors is predominant at a certain time [14–16].

Being very useful in various fields because of excellent properties such as softness, elasticity, and insulation, Ethylene Propylene Diene Methylene linkage rubber (EPDM) is widely considered as a practical material. It is also used in nuclear power plants, and is exposed to ionizing irradiation for a long time. Synthesis and development of irradiation-resistant polymeric materials are strongly desired since the aliphatic polymers are very sensitive to irradiation.

In this research, the exposure of synthesized by melt intercalation method, EPDM/clay conventional composites, and unfilled EPDM to different doses of gamma radiation is carried out. The effect of gamma irradiation on mechanical and dynamic mechanical thermal properties (DMTA) of EPDM/organoclay nanocomposites is also investigated.

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Table 1
Composition of EPDM nanocomposite, EPDM conventional composite, and unfilled EPDM.

Composition	Nanocomposite	Conventional composite	Unfilled EPDM
EPDM (phr)	100	100	100
EPDM–MA (phr)	20	20	20
Organo–clay (phr)	5	–	–
Pure-clay (phr)	–	5	–
Zinc oxide (phr)	5	5	5
Stearic acid (phr)	1	1	1
M (phr)	0.5	0.5	0.5
TMTD (phr)	1.5	1.5	1.5
S (phr)	1.5	1.5	1.5

Table 2
Code of irradiated samples.

Compounds	Samples code						
Nanocomposite	N0	N50	N150	N250	N500	N1000	N1500
Composite	C0	C50	C150	C250	C500	C1000	C1500
Unfilled EPDM	U0	U50	U150	U250	U500	U1000	U1500

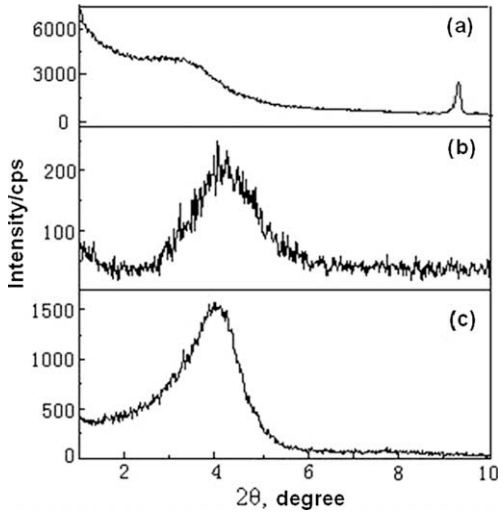

Fig. 1. XRD patterns of (a) EPDM–MA + organoclay, (b) EPDM + organoclay, and (c) organoclay.

2. Experiments

2.1. Materials

Pure sodium montmorillonite (Kunipia-F) with a cation-exchange capacity (CEC) of 119 meq/100 g was supplied by Kunimine Mining Ind. Co. (Tokyo, Japan); octadecylamine purchased from Fluka was used as organic modifier for MMT. Maleic anhydride grafted EPDM oligomer (MAH-g-EPDM) as a compatibilizer (EPDM g002) from Hu zhou Plastic Co., LTD (Hu zhou, China). The EPDM used (J-3062E), ENB type, was obtained from Jilin Chemical Ind. Co., LTD (Jilin, China). All chemicals were used without further purification.

2.2. Preparation of samples for irradiation

To compare the properties of EPDM nanocomposites with EPDM conventional composites and unfilled EPDM after exposing against gamma irradiation, the EPDM–organoclay nanocomposites with organoclay, EPDM–clay conventional composites with pristine clay, and unfilled EPDM without any clay were prepared as follows [5]; 5 phr of clay powder was premixed with 100 phr of EPDM and 20 phr of EPDM–MA by shaking them in a bag. In the case of unfilled EPDM, the EPDM only mixed with EPDM–MA. This mixture was melt blended together in a twin-screw blender at 150 °C. The screw rotational speed was 90 rpm, and mixing time was 15 min for all cases. The products (100 phr) were sequentially mixed with zinc oxide (5 phr), stearic acid (1 phr), vulcanization accelerator [M (2-mercapto benzothiazole, 0.5 phr), TMTD (tetramethyl thiuram disulfide, 1.5 phr)], and sulfur (1.5 phr) by using a roll mill at temperature about 60 °C. The vulcanization was carried out in standard hot press at 150 °C for 30 min to yield rubber sheets (340 1 × 150 w × 2 t mm^3). The compositions of nanocomposite, conventional composite, and unfilled EPDM are shown in Table 1.

2.3. Gamma irradiation

Gamma irradiation was performed at 60 °C industrial equipment (Harbin Guang Ya Irradiation New Technology Company) with an operating dose rate of 3.6 KGy h^{-1} at room temperature in the air. The cross-linked materials of dimensions 11.5 – 7.5 –

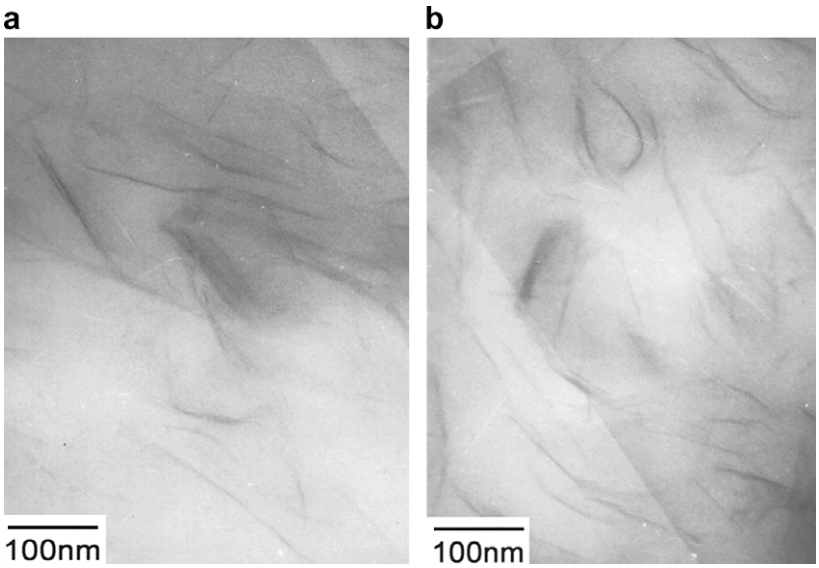

Fig. 2. Transmission electron micrographs of (a) EPDM–organoclay nanocomposites and (b) EPDM–clay conventional composite.