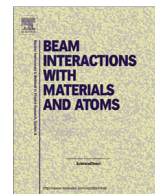




Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

Effects of 1 MeV electrons on the deformation mechanisms of polyethylene/carbon nanotube composites

Jianqun Yang^a, Xiaodong Zhang^a, Chaoming Liu^a, Xingji Li^{a,*}, Hongxia Li^a, Guoliang Ma^a, Feng Tian^b

^a School of Materials Science and Engineering, Harbin Institute of Technology, Harbin 150001, China

^b Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai 201204, China

ARTICLE INFO

Article history:

Received 10 December 2016

Received in revised form 31 March 2017

Accepted 14 April 2017

Available online xxx

Keywords:

Low density polyethylene
Mutiwalled carbon nanotubes
Deformation mechanisms
SAXS
WAXD

ABSTRACT

Polymer nano-composites, especially in polyethylene (PE)/carbon nanotube (CNT) composites can be employed as radiation shielding and structural materials in space. When the PE/CNT composites are used in space, it is easy to suffer from radiation damage caused by charged particles. However, few studies about deformation mechanisms of the composites exposed to electron become available so far. In this paper, mutiwalled carbon nanotubes (MWCNTs) were incorporated into low density polyethylene (LDPE) with MWCNT loadings concentrations of 0.1 wt%. The structural evolution during uniaxial tensile deformation of the LDPE/0.1% MWCNT composites before and after 1 MeV electrons were investigated by means of a small angle X-ray scattering (SAXS) and wide angle X-ray diffraction (WAXD). Experimental results show that 1 MeV electrons obviously increase the ultimate tensile strength of the LDPE/MWCNT composites. From SAXS and WAXD analyses, it is shown that 1 MeV electrons inhibit the disintegration and the rotation of the lamellae, and slow down the formation of the new crystals. It is concluded that the intense interaction between MWCNTs and LDPE matrix and the crosslinking strengthening generated by 1 MeV electrons is the dominant reason for the changes of the deformation behaviors of LDPE.

© 2017 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

Polymer is a versatile material owing to many unique properties like low density, reasonable strength, flexibility and easy processibility, etc. However, the mechanical properties of these materials are inadequate for many engineering applications. Carbon nanotubes (CNTs) have emerged as the most promising nano-fillers for polymer composites due to their remarkable mechanical properties [1,2]. Polymer nano-composites, especially in polyethylene (PE)/carbon nanotube (CNT) composites are regarded as potential materials in space application, which can be employed as radiation shielding and structural materials [3,4]. When polymer nano-composites were used in space, it is easy to suffer from radiation damage caused by charged particles. Many investigations [5,6] have been reported on the effect of charged particles irradiation on the structures and tensile properties of the nano-composites. It is shown that the crosslinking sites produced by ion and electron radiation are located primarily in the amorphous phase and along the lamellar amorphous interphase [7–10]. It's worth noting that previous research mainly involves

the qualitative evaluation of the changes in the mechanical performance index for the nano-composites [11,12]. However, the deformation mechanisms of polymer nano-composites exposed to electron has not been deeply researched so far. The synchrotron radiation technique with a combined small angle X-ray scattering (SAXS) and wide angle X-ray diffraction (WAXD) can provide information on real-time structure of materials during the deformation process [13,14].

In our previous work [15,16], it is found that 1 MeV and 110 keV electrons slow down the strain-induced melting and the strain-induced recrystallization of high density polyethylene (HDPE) and low density polyethylene (LDPE) using by SAXS and WAXD. As we all know, there is a large number of interface in the nano-composites. However, the effect of the interface on the deformation mechanisms of the LDPE/CNT composites is not clear so far. Now, we focus on the deformation mechanisms of the irradiated LDPE/CNT composites by electrons. In this paper, the structural evolution of LDPE/CNT composites with MWCNT loadings concentrations of 0.1 wt% irradiated by 1 MeV electrons is in situ studied by SAXS and WAXD. The effect of electron irradiation on the deformation mechanisms of LDPE/CNT composites is discussed basing on the deformation behaviors and the structural evolution.

* Corresponding author at: 92 West Dazhi Street, Nangang District, Harbin, China.

E-mail address: lxj0218@hit.edu.cn (X. Li).

2. Materials and methods

2.1. Materials preparation and irradiation

The LDPE/MWCNT composites were provided by National Center for Nanoscience and Technology of China. The selected MWCNTs with an average diameter of 15 nm and a purity of about 95% were purchased from CNano Technology Limited Company, USA. The LDPE/MWCNT composites were prepared by a Melt blending technique. The samples blended with 0.1 wt% of MWCNTs were prepared using a screw extruder with a screw speed of 80 rpm at a barrel temperature of 140 °C. Samples with a thickness of 0.25 mm are compressed and moulded under 25 MPa at 150 °C for 5 min warming up and 5 min pressure-keeping, and followed by natural cooling down.

The electron irradiation experiment was performed in vacuum using an accelerator in Technical Physics Institute of Heilongjiang Academy of Science, China. The samples were perpendicularly irradiated by 1 MeV electrons at given flux of $2 \times 10^{11} \text{ cm}^{-2} \text{ s}^{-1}$ with fluence of $3 \times 10^{15} \text{ e/cm}^2$.

2.2. Tensile tests

The length, width and thickness for the dog-bone-shaped samples are 8, 4 and 0.25 mm, respectively. Uniaxial tensile deformation was performed with a home-made tensile apparatus with a speed of 2 $\mu\text{m/s}$ at room temperature in air. The stress and strain mentioned through the article are all engineering stress and engineering strain, respectively.

2.3. SAXS and WAXD measurements

SAXS and WAXD were used to in situ characterize the structure evolution of HDPE samples during tensile deformation. SAXS and WAXD tests were performed on beamline BL16B1 of the Shanghai Synchrotron Radiation Facility (SSRF). The measurements are separate SAXS and WAXD measurements with same detector moved to different positions. The incident X-ray wavelength λ is 0.124 nm. The size of X-ray beam is 0.5 mm $\times$ 0.5 mm. A detector with dimension of 2048 pixel $\times$ 2048 pixel (80 μm /pixel) was used. The distances from sample to detector are 2015 cm (SAXS) and 80 cm (WAXD), respectively. SAXS and WAXD images were taken immediately when the required strain values had been reached during the deformation process. The intensity profiles were recorded with a two-dimensional imaging plate at room temperature. All the X-ray scattering data were corrected for the background and air scattering, the beam fluctuations and sample thickness variations. A camera focusing on the sample side was set up to record the change of sample thickness real-time. Using image processing software, the real-time sample thickness could be calculated from the initial sample thickness. The scattering intensity is proportional to the real-time sample thickness, thus in order to compare signals of different thickness, the scattering intensity must be corrected by real-time sample thickness. In order to characterize the structural evolution during deformation, the SAXS and WAXD integrated intensity curves along the equator and the meridian at different strains are obtained from SAXS and WAXD patterns by the FIT2D software, respectively. The intensities along the equator and the meridian are acquired by the integration in the azimuthal angle range of $-15^\circ \leq \varphi \leq 15^\circ$ and $75^\circ \leq \varphi \leq 105^\circ$, respectively.

3. Results

3.1. Stress–strain curves

Fig. 1 shows tensile curves of the unirradiated and the irradiated LDPE/0.1% MWCNT composites. The tensile curves of all samples show three regions are characterized by strain-hardening, strain-softening and secondary strain-hardening, named with region I, region II and region III, respectively. In the region I, the stress increases with increasing strain from the elastic region up to the ultimate point, showing an obvious strain-hardening effect. In the region II, the stress decreases gradually with increasing the strain, demonstrating a feature of strain-softening. In the region III, the stress tends to increase with strain again, indicating that a secondary strain-hardening occurs, especially in the irradiated samples. The ranges of different regions for the original and the irradiated samples are given in Table 1. Compared with original sample, the transition strains between the regions for the irradiated sample shift to the low strain direction. The result is different from the results in Ref. [16]. Moreover, the irradiation increases the tensile strength of the LDPE/MWCNT composites, while decreases elongation at break, showing a typical characteristic of brittle materials. The above results show that the irradiation obviously affects the tensile behavior of the LDPE/0.1% MWCNT composites. This may be due to the crosslinking network caused by the electron irradiation [17]. The crosslinking sites could block the movement of chains, resulting in higher stress at a given strain, and also leading to an increase in brittleness of LDPE. On the other hand, it is believed that the enhancement of tensile properties of the irradiated LDPE/0.1% MWCNTs may also be attributed to the increase of the aberrance zone between MWCNTs and LDPE matrix caused by the electron irradiation [18].

3.2. SAXS analysis

Fig. 2 shows the in situ SAXS patterns for the original and the irradiated LDPE/0.1% MWCNT composites during uniaxial tensile deformation, respectively. When the strain is zero, the SAXS scattering patterns for original and irradiated samples are elliptical shape, which implies that the molecular structure has preferential orientation. With strains increase, all samples exhibit more obvious anisotropic scattering patterns with an elliptical shape, where the long axis is perpendicular to the stretching direction. It is

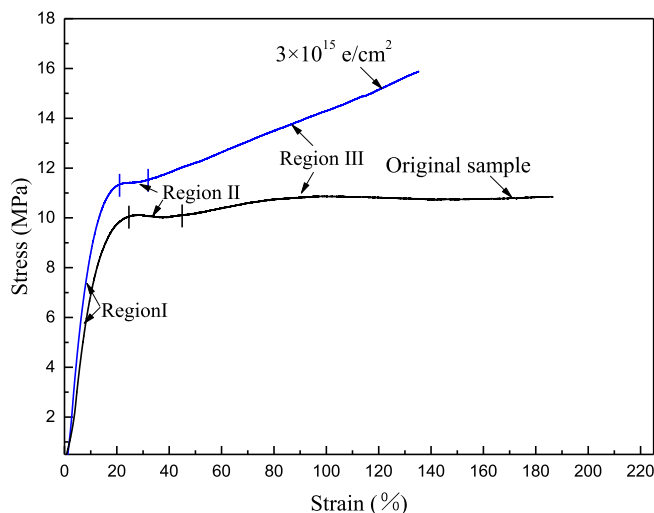


Fig. 1. Engineering uniaxial stress–strain curves for the original and the irradiated LDPE/0.1% MWCNT composites.

Download English Version:

<https://daneshyari.com/en/article/5467211>

Download Persian Version:

<https://daneshyari.com/article/5467211>

[Daneshyari.com](https://daneshyari.com)