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Optical and electrical characterization of gamma irradiated low density polyethylene/paraffin wax blend

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ABSTRACT

Blends of LDPE/wax in ratios of 100/0, 98/2, 96/4, 94/6, 92/8, 90/10 and 85/15 (w/w) were prepared by melt-mixing method at the temperature of 150 °C. It was found that increasing the wax content more than 15% leads to phase separation. Optical and electrical properties of pure LDPE, pure paraffin wax and LDPE/paraffin wax blends were studied before and after gamma irradiation. The optical band gap (E_g^{opt}) and Urbacht energy (E_u) in the LDPE/paraffin wax blends were determined. The results show a decrease in E_g^{opt} and increase in E_u by increasing paraffin wax ratio. The transition energy for electrons is an allowed indirect. The electrical properties including dielectric constant (ε'), dielectric loss (ε'') and the ac conductivity (σ_{ac}) in the frequency range (50 KHz–1 MHz) at room temperature were investigated. ε', ε'' and σ_{ac} increase with increasing paraffin wax ratio. ε' and ε'' values are higher at low frequencies, while at high frequencies the trend is reversed. Influence of gamma radiation on the optical and electrical properties for the pure samples and LDPE/paraffin wax blends has been evaluated at different gamma irradiation doses (25 kGy, 50 kGy and 75 kGy). It was found that E_g^{opt} decreases, while E_u increases with increasing irradiation dose. Also, we report an increase in ε', ε'' and σ_{ac} with increasing irradiation dose. The results of the optical and electrical characteristics indicate a relation between the amorphous nature of the samples and electrical conductivity.

1. Introduction

Blending of polymers is an economical technique used to develop new polymeric materials with properties that are excellent or just different from those of specific component polymers [1,2]. A polymer blend is a mixture of two or more polymers that have been blended to produce a new material with different properties. Polymer blending has attracted much care as a simple and cost-effective method for producing polymeric materials that have versatility for industrial applications. This means, the properties of the blends can be evaluated according to the final usage by right selection of the component polymers. To be considered a blend, the compounds should have a concentration of above 2% in mass of the second component. The design, selection, and performance of polymer blends crucially depend on the ability to portend and control the phase behavior and structure properties of the blends Polymer [3,4]. A widely used semi crystalline polymer is

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LDPE. It has been used as an insulating material for electric power cables because of its excellent electrical and mechanical properties [5,6].

Paraffin waxes are straight chain hydrocarbons, which are obtained from petroleum. They which can be used in coating wood to provide a waterproof layer. In addition, paraffin waxes also have dielectric constants, allowing them to be used in making good electrical insulators [7,8].

The study of the optical absorption spectra in solids provides important knowledge about the band structure and the energy gap in both crystalline and amorphous materials. The lower energy part of the absorption spectrum gives knowledge about the atomic vibrations, and higher energy part of the absorption spectrum gives information about electronic status in the materials [9,10]. Study of dielectric behavior and AC conductivity of polymer blends is a fundamental step towards engineering materials for future electrical applications. Dielectric permittivity is one of the parameters that illustrate how a material interacts with an applied electromagnetic field [11]. The dielectric constant of a polymer is mainly influenced by two parameters; first is the molecular polarizability that can be changed by modifying the type and number of polarizable groups, and second is the free volume associated with the polymer [12]. High-energy radiations, such as gamma-rays change the physical and chemical properties of the materials they pass through. In recent years, radiation is used for polymer processing and modification. The irradiation of polymeric materials with ionizing radiation as Gamma rays lead to producing very effective intermediates, free radicals, ions and excited states [13,14]. In our current study, we introduce irradiated blend has a maximum loading of paraffin wax up to at content of 15% results in an obvious decrease in the melting temperature and viscosity of the low density polyethylene, confirmed in our recent work [7], thus it could be used in the applications of papers and carton coating. The materials used in these applications today depend on the use of paraffin wax only, but the addition of LDPE gives superior Properties for the paraffin wax. It's also difficult to use LDPE for papers and carton coating due to its melt flow index, which causing a harmful effect for paper and carton material, therefore there is no applications of LDPE in coating except blending wax with LDPE. In the present work, LDPE/paraffin wax blends were prepared by the melt-mix method, the blends were then exposed to gamma-rays. The present work aims to prepare and study the optical and electrical properties of pure low density polyethylene, pure paraffin wax and LDPE/paraffin wax with different paraffin wax ratios. We also report the effect of gamma radiation on the blends at different gamma irradiation doses for electrical insulator applications.

2. Materials and methods

Low density polyethylene (LDPE), MFI 7 g/10 min at 190 °C/2.16 kg – Density 0.925 g/cm^3 – Melting temperature 130 °C, was supplied by Exxon Mobil Co., Saudi Arabia.

Paraffin wax, of density 0.88 g/cm^3 – Melting temperature 67 °C was supplied by Exxon Mobil Co., Saudi Arabia.

2.1. Method of preparation

Low density polyethylene (LDPE), with MFI of 7 g/10 min at 150 °C, a density of 0.925 g/cm^3 and a melting temperature 130 °C was supplied by Exxon Mobil Co.

Paraffin wax with a density of 0.88 g/cm^3 and a melting temperature of 65 °C was supplied by Exxon Mobil Co.

LDPE was initially melt-mixed with paraffin wax in a Rabender plastograph (screw speed of 30 rpm for 10 min) at a temperature of 150 °C then pressed at 120 °C. Thin sheets of 1.0 mm in thickness of the blends were prepared by compression molding in a hot press.The blends with paraffin wax were prepared in ratios of 100/0, 98/2, 96/4, 94/6, 92/8, 90/10 and 85/15 (w/w). The dispersion of wax in polymer matrix depends greatly on the amount of wax added to the polymer and the molecular structure of polymers. For LDPE blends, the dispersion of the paraffin wax continued up to at content of 15% (w/w). Increasing the amount of wax above this ratio led to phase separation. In other words, the LDPE amorphous areas become saturated with wax, confirmed by differential scanning calorimetry and Thermogravimetric analysis [7].

Determination the absorbance spectra of the samples was carried out using Analytikjena model SPECORDO 210 plus with a scan range of 190–1100 nm. All the spectra were recorded by mounting the samples in the Integrating Sphere Assembly attached with the Spectrophotometer, keeping air as the reference.

The AC measurements were carried out using the Hioki LCR meter of the type 3531 Z Hi-Tester, Japan. The dielectric measurements were performed at room temperature in a frequency range (50 Hz–1 MHz). The sample was situated inside the sample holder, in good contact with two polished and cleaned brass electrodes.

2.2. Irradiation

Square sheets with dimensions of 1 mm × 120 mm × 120 mm were irradiated in the presence of air using a cobalt-60 source of gamma radiation manufactured by the Atomic Energy Authority of India, with a dose rate of 2.8 kGy/h. The unit consists of an annular source permanently enclosed inside a lead shield and cylindrical drawer that can move up and down along the central line. The drawer has a chamber to carry the samples to be irradiated. The dose rate was measured by using the standard Alanine dosimeter.