Radiation Resistance and Thermal Stability of Nylon 6, Acrylonitrile Copolymer and Polyester Fabrics

S. N. LAWANDY and N. ABD-EL-ZAHER, *National Institute of Standards, Dokki-Cairo, Egypt*

Synopsis

The thermal stability and radiation resistance of three polymers Nylon 6, acrylonitrile copolymer and polyester were investigated. The polymer samples were irradiated by low rate fission neutrons from a ^{252}Cf source. The polyester showed a higher heat and radiation resistance than the two other polymers. It has to be recommended herein that polyester is the most suitable fiber for the manufacture of products in which heat buildup is produced during application, or products where radiation and heat resistance are required.

INTRODUCTION

It is known that when a polymer is exposed to a high radiation energy, physical and chemical changes occur.[1] It is considered that radiation-induced changes in both crystalline and amorphous polymers may occur through four different events: (i) chain scission, (ii) cross-linking, (iii) recombination of broken chain,[1,2] and (iv) formation of mole fractions which may recombine at random forming new mole configurations. The degree to which radiation will affect the polymer depends on the chemical composition, general morphology, free energy state of polymer, type of radiation, and irradiation dose applied.

Several techniques have been used to assess the physical and chemical changes in polymers caused by radiation[3-8] these are, free radical scavaging techniques, intrinsic viscosity determination, cryoscopy, swelling, and mechanical property measurements. Recently other techniques have been investigated by which these changes can be measured. These are the differential scanning colorimetry (DSC) technique,[9,10] X-ray diffraction technique,[11-13] and color detection.[13]

In this article, the radiation effect on three polymeric fibers is investigated. These polymers are: (i) polycaporlactam fibers, produced from polycaprolactam, (ii) polyacrylonitrile fibers manufactured from acrylonitrile polymer or acrylonitrile copolymer with certain other monomers, and (iii) polyester fiber which is a polyethylene tetraphthalate fiber. These fibers are commercially named as Nylon 6 or Perlon, Dralon (FRG) or Orlon, and Dacron or Terylene, respectively.

The thermal analysis techniques were used to detect the radiation effects in these polymers. These techniques measure the change in some physical and chemical properties of the material investigated as a function of temperature.

There are several thermal analysis techniques, but in this paper we shall refer to one useful technique, which is the thermal stability technique (TG),

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which was used before in several polymer studies as following the cure rate and quality control for materials used in polymer manufacture;[14] the thermal stability of polymers is important where there is a fire risk, when used as building construction materials, in clothing manufacture, and in other materials used in the re-entry vehicles in space programs.[15]

In addition, it can be used to study the effect of sequence distribution, relative viscosity, and composition of copolymers on thermal stability.[16]

EXPERIMENTAL PROCEDURE

Materials

The Nylon 6, Dralon, and polyester were supplied by Mylar, Bayer, and Hoechst (West Germany), respectively.

Irradiation Procedure

Samples were irradiated with fission neutrons from a ^{252}Cf source which has a field of 7.8×10^7 n/sec. The neutron fluence from the source was measured simultaneously at position of the sample, using a calibrated fission track detector type LR115 manufactured by Kodac Pathe France. The samples were fixed in position so that fission neutrons were incident approximately normal to the detector.

Thermal Analysis

The thermal behavior of the samples was investigated using A Netzch Geratebau GmbH Selb 348472C thermal analyzer (West Germany). Precise sample weight of 100 mg was used and the heating rate in air was 2°C/min.

RESULTS AND DISCUSSION

Evaluation of Thermal Stability (TG)

When a sample is heated to a certain temperature it may decompose. The decomposition process causes a weight loss in the sample which can be detected by TG technique.

In order to compare results of different materials or materials that are treated by different means, the same experimental conditions are applied to the samples. The TG curves for different samples can be compared starting by the end of thermal stability temperatures of these samples or it may be called the commence decomposition temperature.

In Figure 1 the relative weight loss by heating is plotted against the temperature. From this figure we can notice the instability of Nylon 6 fabric by temperature. This can be attributed to the chain scission at the covalent bond of the amides group in the polymer. This weight loss is relatively high when compared to that of polyester. It is evident that the polyester which has no significant weight loss is thermally stable over a greater range than the two other polymers. This stability may be attributed to the well ordered compact structure and the considerable interaction between macromolecules.[17]

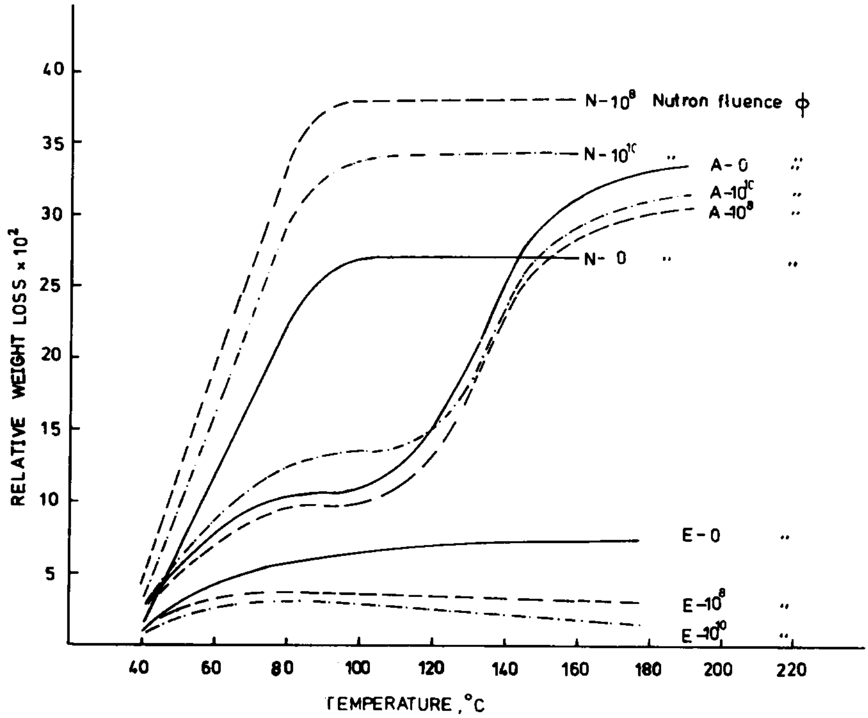

Fig. 1. Relative weight loss vs. temperature variation at different fission neutron rate. (N) nylon 6, (A) acrylonitrile copolymer, and (E) polyester. (The relative weight loss is the weight loss compared with the weight of sample at the commence decomposition temperature.)

The acrylonitrile fiber possesses two stages of weight loss. This is due to its structure which is acrylonitrile/polyethylene copolymer (85/15). The first stage represents the weight loss in the copolymer. At 100°C the polyethylene melts[18] and a second stage starts where the polyethylene degradates and chemical changes occur due to the oxidation beside the weight loss of acrylonitrile polymer.

The third point to be discussed in this figure is the effect of neutron fluence on the thermal stability of these polymers. The polyester possesses a higher stability when it is subjected to radiation fluences. That means the polymer builds up new crosslinks or chain bonds. The same results happen to the acrylonitrile copolymer when a dose power 10^8 neutron is applied, but at a higher fluence of 10^{10} neutron chain scission starts to happen.

The thermal stability of Nylon 6 is highly affected by radiation. This was reported by others.[19] This can be attributed to the simple structure of separate repeating units and the active chain ends which can be easily damaged or separated by radiation fluences.

In Figure 2(a) the fluence rate is plotted against the weight loss at two selected temperatures, 76°C and 160°C. The most significant change in weight loss of Nylon 6 and acrylonitrile copolymer is observed at 10^8 radiation fluence. Nylon 6 at this fluence showed maximum weight loss while the acrylonitrile showed a minimum weight loss at this fluence. The polyester showed no significant change till 10^{10} radiation fluence.

The increase in weight loss by radiation fluence depends on the damage in polymer chain. The decrease in weight loss is due to the recombination of broken chains and the build-up of new physical and chemical cross links. The relative change of weight loss due to heat and radiation vs. the neutron fluence and the relative change due to the neutron fluence only are shown in Fig. 2(a) and 2(b), respectively. Figure 2(b) shows that the damage caused by radiation to Nylon 6 is relatively high especially at higher temperature (160 °C). There is a maximum damage at 10^8 neutron fluence while before and

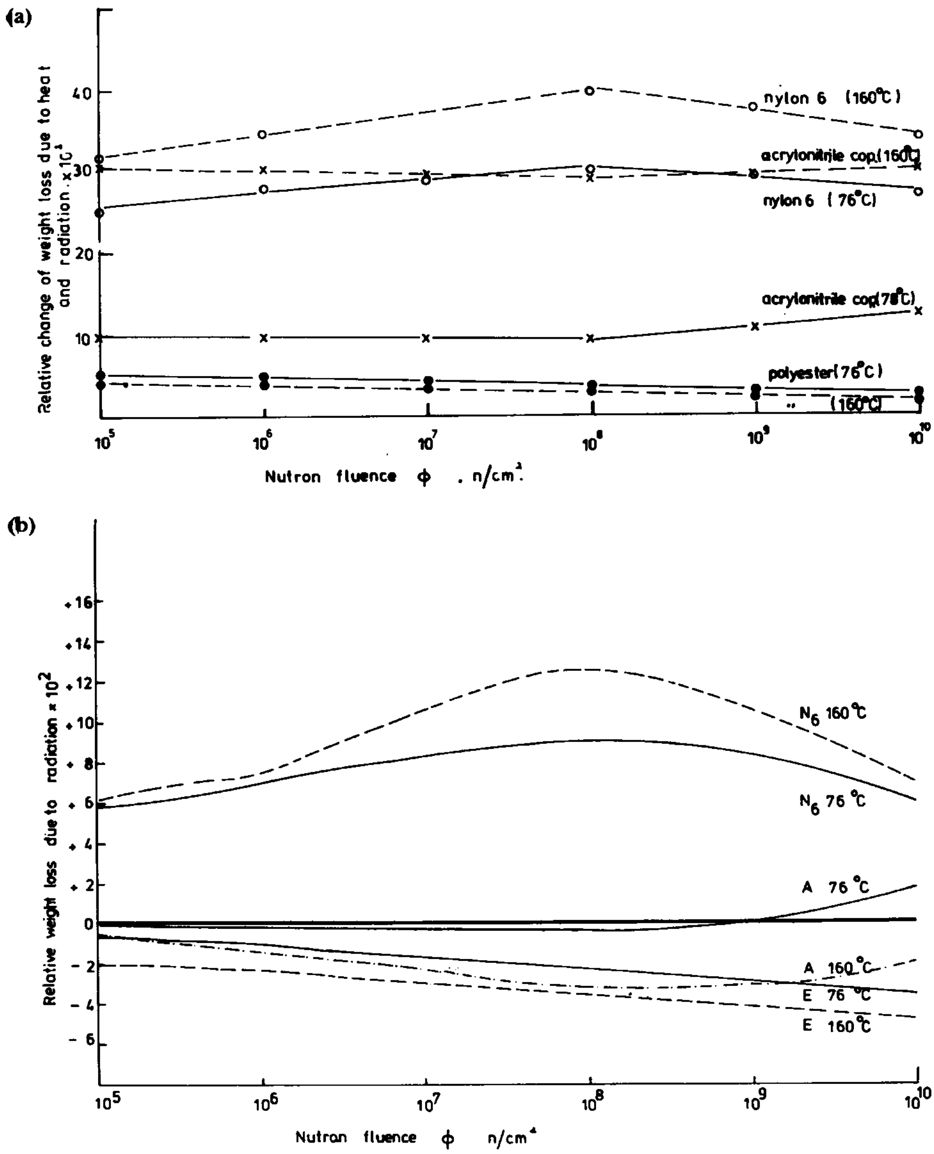

Fig. 2. (a). Relative weight loss due to heat and radiation vs the fission neutron fluence ϕ applied. (b). Relative weight loss due to radiation and heat diminished that caused by heating vs. the neutron fluence ϕ applied.

after this radiation fluence the polymer possesses a lower degree of damage. On the other hand the acrylonitrile copolymer and polyester shows an increase in weight by radiation fluence especially at higher temperature (160°C). It seems that these two polymers will possess weight loss by radiation at radiation fluence greater than 10^{10} n/cm^2.

CONCLUSION

The polyester fabrics showed higher heat and radiation resistance than Nylon 6 and acrylonitrile copolymer. The polyester is a suitable fiber for use in the manufacture of products where heat is built up during applications or when radiation and heat resistance is required.

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