



COMPARATIVE DEGRADATION OF POLYPROPYLENE USING HEAT AND ULTRAVIOLET LIGHT

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ABSTRACT

Polypropylene is a thermoplastic polymer vastly used by many industries for packaging and are easily discarded to the environment. The aim of this study was to assess the effect of heat and ultraviolet light on polypropylene degradation at various time intervals. Polypropylene was subjected to heat degradation at 50°C, 70°C and 100°C and ultraviolet light at various time intervals of 3, 6 and 10 hours. The level of degradation was determined by the amount of undissolved residue of the treated sample in xylene. These results showed that heat degradation induced reduction in molecular size due to chain scission while UV treatment produced crosslinked molecules with reduced solubility.

KEYWORDS: Polypropylene, heat, ultraviolet, xylene, dissolution.

INTRODUCTION

Polypropylene (polypropene) which is derived from an olefin monomer called propylene^[1] is a thermoplastic material useful for a wide range of applications which include packaging and labeling, textiles, stationeries, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components and polymer bank notes^[2] among others. It is an addition polymer of propene first polymerized in 1951 by Phillips Petroleum chemists^[3] while the isotactic crystalline type was synthesised in 1954 by Giulio Natta and Karl Rehn.^[4] This led to the large scale production of isotactic polypropylene since 1957. Later Natta and his co-workers synthesised the syndiotactic polypropylene.^[5] Polypropylene is rugged and unusually resistant to many chemical solvents and acids.

The most common shaping technique is injection molding. Related techniques like blow molding and injection-stretch molding are also used. The large number of end-use-applications of polypropylene is often possible because of the ability to tailor grades with specific molecular properties and additives during its manufacture. Many physical and surface treatments like surface treatment^[6], atmospheric plasma treatment^[7], and soft plasma treatment^[8] among others can be applied on polypropylene. It can be biaxially oriented to increase the strength and clarity for use as packaging materials.

Most commercial polypropylene is isotactic and has an intermediate level of crystallinity between that of low density polyethylene and high density polyethylene.

Polypropylene is normally tough and flexible, especially when copolymerized with ethylene thus allowing it to be used as an engineering plastic. It has good resistance to fatigue. The melting point is a range, the highest being taken as the melting point. Thus perfectly isotactic type has a melting point of 171°C while commercial polypropylene has lower melting points depending on the degrees of tacticity and crystallinity, the lowest being 130°C. The impact strength at low temperatures is low. In order to increase the impact strength at low temperatures polypropylene is copolymerized with ethylene. This decreases the crystallinity, lowers the melting point and makes the polymer more transparent.

Polymer degradation is a change in the properties of a polymer or polymer-based product which occurs under the influence of one or more environmental factors such as heat, light, microorganisms or chemicals, e.g. tensile strength, colour, shape, etc. These changes are undesirable. However the changes may be desirable as in biodegradation to prevent or reduce environmental pollution or deliberate lowering of molecular weight for recycling purposes. Induced degradation is useful for structure determination.^[9] On the molecular scale, polymer molecules are very large; thus their unique and useful properties are derived from their size. Any loss in chain length or size will reduce their tensile strength and cause premature cracking. This change is to be prevented or delayed in a finished product.^[10]

Ultraviolet degradation occurs in polymers where tertiary carbon bonds exist in their chain structure. UV rays

interact with these bonds to form free radicals which interact further with oxygen in the atmosphere and produce carbonyl groups in the main chain. The exposed surfaces may discolour and crack and in extreme cases complete product disintegration may occur.^[11] Polypropylene is used in many outdoor products where they are exposed to heat and sunlight especially in the tropical weather like in Nigeria. It is therefore necessary to estimate the environmental effects of these factors on the propylene products.

EXPERIMENTALS

Heat Treatment

10g of polypropylene was weighed and placed in different beakers and placed in an oven maintained at a temperature of 50°C, 70°C and 100°C respectively. After different time intervals of three, six and ten hours, the samples of each temperature variation were withdrawn and allowed to cool to room temperature. Then two grams of each sample was placed in a conical flask

containing 100 ml of xylene and covered. They were kept for twenty four hours after which they were shaken vigorously and filtered with previously weighed filter papers. The filter papers containing the residues were weighed again after drying in an oven maintained at 60°C overnight. The procedure for each temperature at expected time intervals was repeated for three times and weights of undissolved samples were taken and their mean recorded in table 1. The percentage of degradation was obtained and recorded in table 3.

Uv Treatment

Polypropylene (10 g) in different beakers was placed in an ultraviolet chamber at time intervals of three hours, six hours and ten hours each. Thereafter they were separately dissolved, filtered and the residues were dried and weighed as in the heat treatment and the results recorded in table 2 while the percentage of degradation was recorded in table 4.

RESULTS AND DISCUSSION

Table 1: Effect of heat degradation at various temperatures and time intervals

Time of degradation (h)	Mass of undissolved (g) at 50°C	Mass of undissolved (g) at 70°C	Mass of undissolved (g) at 100°C
3	0.665	0.365	0.125
6	0.555	0.295	0.085
10	0.495	0.185	0.045

Table 2: Effect of ultraviolet light degradation at various time intervals

Time of degradation (h)	Mass of undissolved (g)
3	0.835
6	0.895
10	0.925

Table 3: Percentage of degradation at various temperatures and time intervals

Time of degradation (h)	Percentage of degradation (%) at 50°C	Percentage of degradation (%) at 70°C	Percentage of degradation (%) at 100°C
3	66.75	81.75	93.75
6	72.25	85.75	95.75
10	75.25	90.75	97.75

Table 4: Percentage of ultraviolet light degradation at various time intervals

Time of degradation (h)	Percentage of degradation (%)
3	58.25
6	55.25
10	53.75

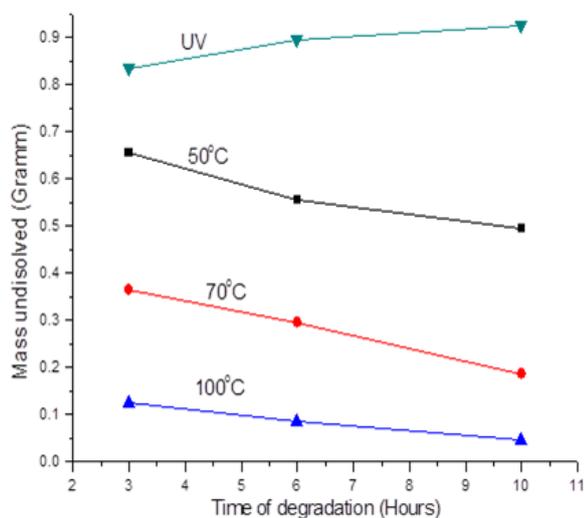


Fig 1: Effect of heat and ultraviolet degradation at various time intervals

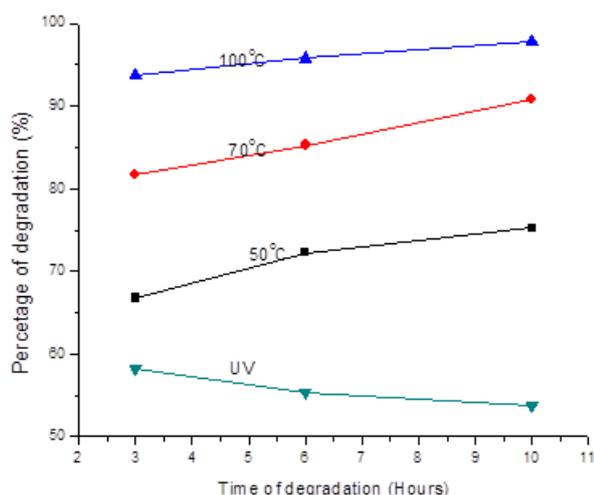


Fig. 2: Percentage of degradation at various time intervals

From the results it was shown that as the polymer is subjected to increased heat and prolonged time, the amount of undissolved polypropylene reduced. This reduction in the mass of undissolved polymer shows that the dissolution was enhanced by heat treatment at a higher temperature and time. The increase in dissolution of the polymer reached a point where at 100°C about 97.75% degradation took place after ten hours exposure. The result showed that dissolution is a function of molecular size, hence the more the prolonged exposure to heat the more chain scission takes place and subsequent reduction in the size of the polymer molecules. This resulted in the increase in dissolution of polypropylene with increase in temperature as well as the length of exposure.

However it was observed that with the UV degradation, there was decrease in the amount dissolved (that is increase in amount of undissolved) as shown on table 2, fig. 1, indicating decrease in the amount of degradation (table 4, fig. 2). This observation probably was as a result of free radical reaction that followed the abstraction of the tertiary hydrogen atom of the polymer backbone¹².

Unlike in the heat process where molecular size reduction progressed as the time of exposure increased, ultraviolet light similar to photo-aging favoured both chain scission and cross-linking reactions¹³. The predominant reaction was crosslinking. These reactions involving cross-linking of the molecules rendered the polymer less soluble in the solvent. It is this cross-linking that causes the hardening and eventual cracking of finished products. Thus undue prolonged exposure of polypropylene products to heat and UV lights has to be avoided to enhance the life span of the materials.

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