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Thermal crystallization of polyethylene terephthalate (PET) for recycling and caring for the environment

Cristalización térmica del tereftalato de polietileno (PET) para el reciclaje y el cuidado del medio ambiente

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Abstract

Mexico is one of the main consumers of PET worldwide. In Mexico, urban solid waste has not received adequate attention due to a series of factors of various kinds, among which are: Collection of mixed garbage (in 95% of the national territory) [I, II], public services insufficient and inefficient cleanliness, poor coordination between the different levels of government, incomplete legal framework and legislative work with a particular vision, passivity in ecological matters and little culture of recycling in society [III, IV, V]. Sustainable development, as it is currently disseminated, begins in 1983, when the United Nations (UN) created the Commission on Environment and Development, chaired by Gro Harlem Brundtland, who was Prime Minister of Norway. The Brundtland Commission, carried out studies, analyses, and public consultations [VI], all over the world, for approximately three years, ending in April 1987, with the publication and dissemination of the report called Our Better Common Future known as The Brundtland Report [VII, VIII, IX]. The objective of this study was to determine the temperature at which polyethylene terephthalate (PET) in the form of granules, changes from amorphous to crystalline, since recrystallization improves the properties, which is necessary for the reuse of the material.

Recycling, Polyethylene terephthalate, Thermal crystallization

Resumen

México es uno de los principales consumidores de PET a nivel mundial. En México, los residuos sólidos urbanos no han recibido una atención adecuada debido a una serie de factores de diversa índole, entre los que se encuentran: Recolección de basura mixta (en el 95% del territorio nacional) [I,II], servicios públicos de limpieza insuficiente e ineficiente , mala coordinación entre los diferentes niveles de gobierno, marco legal incompleto y trabajo legislativo con una visión particular, pasividad en materia ecológica y poca cultura del reciclaje en la sociedad [III, IV, V]. El desarrollo sostenible, tal como se difunde actualmente, comienza en 1983, cuando las Naciones Unidas (ONU) crearon la Comisión de Medio Ambiente y Desarrollo, presidida por Gro Harlem Brundtland, quien fue Primera Ministra de Noruega. La Comisión Brundtland llevó a cabo estudios, análisis y consultas públicas [VI] en todo el mundo durante aproximadamente tres años, finalizando en abril de 1987, con la publicación y difusión del informe titulado Our Better Common Future conocido como The Brundtland Report [VII], [VIII, IX]. El objetivo de este estudio fue determinar la temperatura a la que el tereftalato de polietileno (PET) en forma de gránulos, pasa de amorfo a cristalino, ya que la recristalización mejora las propiedades, lo cual es necesario para la reutilización del material.

Reciclado, Polietileno tereftalato, Cristalización térmica

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Introduction

The increase in plastic and medical waste is a reality around the world and existing recycling systems have collapsed in some places. In Singapore, during an eight-week shutdown, an additional 1,470 tons of plastic waste was generated from take-out packaging alone. In Wuhan, China, medical waste rose six times to 240 tons per day during the pandemic, overloading the city's incineration capacity by 49 tons per day.

Mexico is one of the main consumers of PET worldwide. In Mexico, urban solid waste has not received adequate attention due to a series of factors of various kinds, among which are: Collection of mixed garbage (in 95% of the national territory) [I, II], public services insufficient and inefficient cleanliness, poor coordination between the different levels of government, incomplete legal framework and legislative work with a particular vision, passivity in ecological matters and little culture of recycling in society [III, IV, V].

PET is a high-quality plastic (thermoplastic). It is a condensation polymer produced by a continuous melt phase polymerization process.

It is a transparent material and very impervious to air, which makes it widely used for containers of soft drinks, mineral waters, vinegars, edible oils, cosmetics, etc.

It is identified with the number one, or the acronym PET or PETE, surrounded by three arrows at the bottom of the containers made with this material (SPI identification system (Society of Plastic Industries)).

Most PET is recyclable if it is separated from the rest of the garbage. The manufacture of PET consumes a lot of energy, and its incineration produces a lot of heat or electricity thanks to its high calorific value. PET is light, so transporting PET bottles saves 40% of energy cost compared to transporting glass bottles. Chemically stable.

Due to its exceptional chemical resistance, it is not possible to apply adhesives with solvents on it. It acts as a gas barrier.

Excellent fire resistance, does not transmit flame.

Excellent transparency and gloss.

Excellent formability.

Good machinability.

In general recyclable.

Environmentally friendly; its combustion does not generate polluting substances (only in the presence of chlorine it forms dioxins).

It does not generate gases that are harmful to the ozone layer.

Reduces the transmission of noise.

It does not present risks of severe impacts, it is not considered toxic, although in the synthesis of PET, substances that cause irritation of the eyes and respiratory tract are used, its manufacture is also associated with a small increase in the incidence of cancer. Heavy metals can be used as catalysts during the process of production and finally these end up in the environment, being pollutants.

It is suitable for direct food contact applications as it is odorless and tasteless and due to its self-adhering properties. In the case of the film (layer), in the handling process or in the very act of unwinding it, negative charges are induced on the plastic, so when it is brought closer to other bodies, it generates positive charges by induction, and this causes it to attract. The plastic material is insulating and maintains its state of charge for a long time, unless the environment is very humid.

Regarding stability against heat, they are thermoplastic; Articles made with this product should not be exposed to continuous use at temperatures above 65/70 ° C, since they soften by action of the heat. The objective of this study was to recrystallize PET, by means of thermal treatment to improve its properties and be able to reuse it, contributing to the reduction of plastic waste and to the economy.

The subject of this article is addressed in 7 sections. Section 1 presents the introduction. Section 2 describes the method used. In section 3 the results are analyzed and discussed. Section 4 acknowledges the support received. In section 5 the conclusions of the study are presented. In section 6 the references consulted are cited.

1. Description of the method

The methodology used for the thermal treatment of PET was the following:

1. Small pellet-shaped samples of polyethylene terephthalate were photographed before and prior to heat treatment.

2. The density of the PET pellets was measured before heat treatment by means of the pycnometer method.

3. The formula used for the calculation was:

$$\delta PET = \frac{P2-P0}{(P1-P0)-(P3-P2)/\delta H2O} \quad (1)$$

Where: δPET = Density of polyethylene terephthalate in g/cm^3

δH_2O = Density of water in g/cm^3 = 1g/cm^3

P_0 = weight of empty pycnometer in grams

P_1= weight of picnometer with wasser in grams

P_2= weight of picnometer with sample de PET

P_3 = weight of picnometer with sample and water in grams.

The density before heat treatment was of 0.7 to 0.8 g / cm^3.

3. The material was placed in a Memmert brand oven, at 170 ° C, for 1 hour.

4. The samples after heat treatment were allowed to cool for half an hour in a desiccator.

5. The samples were weighed on a balance Brand Ohaus.

4. The density of the samples or pellets was calculated after heat treatment. And the results were of 1.3 to 1.33g/cm^3

5. Photographs were taken of the pellets after the heat treatment.

6. The pellets were characterized by Scanning Electron Microscopy, with a scanning electron microscope (SEM), JEOL brand, as well as by Infrared transmission spectroscopy with a Nicolet brand spectrometer before and after heat treatment.

4. Results

1. The variation of the density in the Poliethylene terephthalate (PET) before the heat treatment was of 0.70 to 0.80 g/cm^3. Table 1.

No. of Sample	Density in g/cm^3
1	0.72
2	0.70
3	0.75
4	0.80
5	0.78

Table 1 Density of pellets of PET before the Heat Treatment

The samples of the pellets before heat treatment showed a transparent appearance, characteristic of amorphous material. Figure 1.

Figure 1 Pellets of PET, without Heat Treatment

2. The sample changed color after being subjected to 170 ° C for 1 hour. The transparent color showed in Figure 1, turned out to be milky white. Figure 2.

Figure 2. Pellets with Heat Treatment (170°C 1 hour)

4. The result of the density, after the treatment, turned out to be 1.3 to 1.33 g / cm^3. Table 2.

Number of Sample	Density in g/cm^3
1	1.31
2	1.30
3	1.32
4	1.33
5	1.32

Table 2 Density of material PET after Heat Treatment

Wavelength (cm^{-1})	% of Transmittance
723	96.08
873	97.93
1079	97.25
1091	97.05
1237	96.19
1409	98.53
1719	96.96
2961	99.7
2966	99.73

Table 3. Transmittance values in percentage and Wavelengths in (cm^{-1}) of the PET without Heat Treatment

Longitud de onda (cm^{-1})	% de Transmitancia
721	94.72
872	97.49
1082	96.3
1240	95.55
1341	98.36
1409	98.40
1712	96.44
2849	98.55
2918	98.37

Table 4. PET with Heat Treatment 1 hour at 170°C

5. Both the color and the change in density after heat treatment are characteristics of a crystallized material.

6. With respect to the results obtained by Infrared Spectrometry, a change in transmittance was observed in the material after heat treatment, which shows that the material transformed from amorphous to crystalline. Tables 3 and Table 4. Figure 3 and Figure 4.

About the Morphology the samples before heat treatment showed an amorphous appearance, and after heat treatment show a crystalline structure. Figures 5 and 6, respectively.

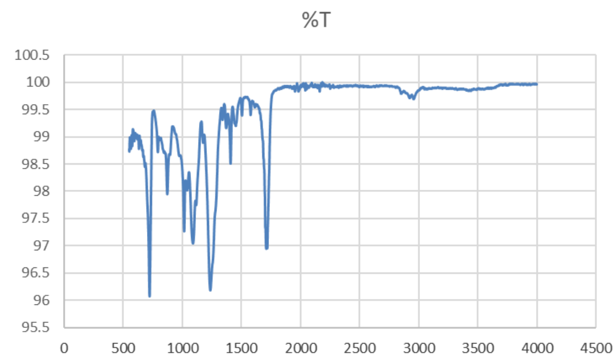

Figure 3 FTR de Pellets of PET without Heat Treatment

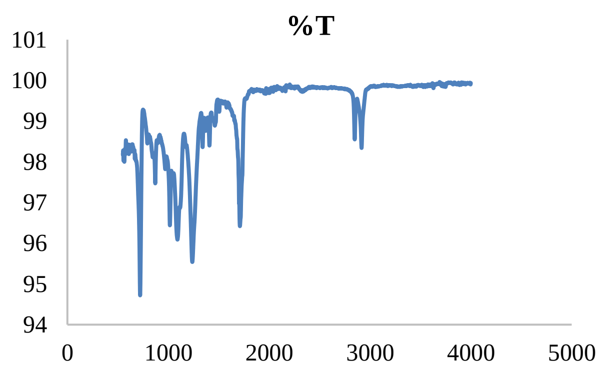

Figure 4 Pellets of PET with Heat Treatment 1hour to 170°C

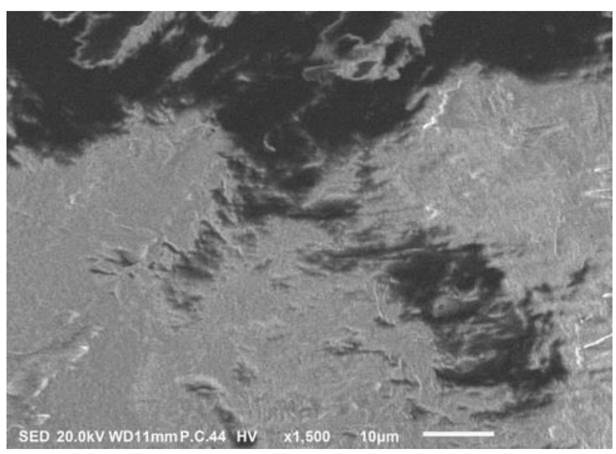

Figure 5 PET without heat treatment to 1500X

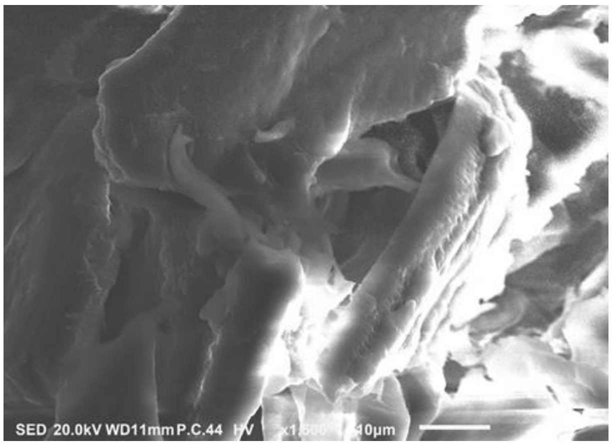

Figure 6 PET with heat treatment. 1500X

4. Thanks

I. I thank the Tecnológico de Estudios Superiores de Jocotitlán for the trust placed in me to carry out hours of research at the institution.

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5. Conclusions

This study shows that the heat treatment applied to the pellets, for 1 hour at 170ºC, was sufficient to transform the PET from amorphous to crystalline, which was also verified with the change in density, change in color of the material, change in the morphology of material as well as in the change in the percentage of transmittance obtained in the corresponding infrared spectrum, whose procedure can be applied specifically to PET and give greater value in its use and efficiency to the use of solid urban waste, thus contributing to Sustainable development.

Besides, the heat treatment used is accessible and cheap, since it does not need sophisticated instruments, only a furnace with the necessary capacity according to the amount of material to be crystallized.

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