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Research Article

PHYSICAL AND CHEMICAL CHARACTERIZATION OF LOW DENSITY POLYETHYLENE AND HIGH DENSITY POLYETHYLENE

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ABSTRACT

Polyethylene is an example for synthetic plastic which has repeating units of carbon and hydrogen atoms in it. Low density polyethylene (LDPE) and High density polyethylene (HDPE) are the two major types of polyethylene which differ in their molecular weight, arrangement, thermal properties and crystalline nature. The physical and chemical characterization of LDPE and HDPE was studied by using Fourier Transform Infrared Spectroscopy (FTIR), Differential Scanning Calorimetry (DSC) and X-Ray Diffraction (XRD). The thermal properties of LDPE and HDPE were analyzed by DSC, functional groups by FTIR and crystalline nature by XRD. There was no much difference observed in LDPE and HDPE except their thermal properties such as their melting temperatures, change in enthalpy and glass transition temperatures.

Keywords: Low-Density Polyethylene, High-Density Polyethylene, FTIR, DSC, XRD

1. INTRODUCTION

Plastic is the most imperative synthetic product which is being manufactured enormously and used for various purposes. The word 'plastic' is derived from the Greek word "*plastikos*" which means it can be molded into many shapes [1]. Plasticity during manufacture, which allows it to be cast, pressed, or extruded into a range of shapes such as films, fibers, plates, tubes, bottles, boxes, and much more. Plastics are mainly derived from petrochemicals and are composed of long chain hydrocarbon polymers with high molecular weights [2]. Through the last five to six decades plastics have been used in a variety of applications and have been replaced with leather materials, wood, traditional metals and many more. The most ideal property of plastic is its toughness which also exerts the foremost environmental problem of degradation. Practically, recycling of plastics has failed to provide a safe solution for disposal of plastic waste. United States of America alone produce 1 trillion plastic bags annually among which, only 5% is being recycled [3].

On the whole, plastics are classified based on their thermal and designing properties. Based on thermal properties, plastics are categorized as *thermoplastics and thermosetting polymers*. Thermoplastics can be molded into any shape upon heating and these include Polyethylene (PE), Polystyrene (PS), Polypropylene (PP), Polyvinyl chloride (PVC), etc. with the molecular weight ranging from 20,000 to 500,000 amu. Thermosetting polymers once set into an exact shape cannot be molded again. These polymers cannot be recycled as their change is irreversible. Polyurethanes, Phenol-formaldehyde, etc are some of the examples of thermosetting polymers [4]. Designing properties of plastics are based upon their significance of manufacturing processes, which include electrical conductivity, tensile strength, thermal stability, degradability and durability [4].

Polyethylene (PE) is a commonly used plastic with many properties based on molecular conformation with applications ranging from film packaging and electrical insulation to containers and piping [5-9]. PE is characterized mostly based on density and the degree of molecule branching. Low density polyethylene (LDPE) is a tough and flexible polymer characterized by long branches that do not place well into crystallites. As the chains become more linear, such as in high density polyethylene (HDPE), the molecules are able to pack more closely [10].

The high rate properties of polymers, including time–temperature superposition in these materials, were recently reviewed by Siviour and Jordan [11]. In semi-crystalline materials, like polyethylene and polytetrafluoroethylene, the retort of the material depends on molecular conformation and volume fraction

of crystallinity, in addition to temperature and strain rate. These materials can be considered as molecular networks consisting of an amorphous phase containing intertwined chains with the randomly oriented crystallite phase acting as physical crosslinks [6-9]. There have been only some studies in the literature which have investigated the high rate mechanical response of unstable PE conformations. Brown et al. studied the effects of conformation on HDPE, Ultra-High Molecular weight Polyethylene (UHMWPE), and PEX across a series of strain rates and temperatures and found that UHMWPE and PEX had very analogous behavior that differed distinctly from HDPE [10, 12-14] The same materials have also been studied under a series of loading circumstances including shock loading and dynamic tensile extrusion [15-19]. Similarly, Omar et al. studied LDPE, HDPE, and linear low density polyethylene (LLDPE), in which HDPE revealed the highest strength in agreement with Brown et al. [10, 20]. Nonetheless, the actual strength values differed significantly between the two sources, possibly due to the almost 20 % difference in crystallinity between the two HDPE materials; the HDPE investigated by Brown et al. with 80.9 % crystallinity exhibited flow stress two to three times higher than reported by Omar et al. for HDPE with 60.99 % crystallinity for a given temperature and strain rate [10, 20].

In the present study, the physical and chemical characterization of LDPE and HDPE was carried out. The chrystallinity of LDPE and HDPE was measured by X-Ray diffractometer (XRD). Fourier Transform Infrared Spectroscopy (FTIR) was used to determine the functional groups and Differential Scanning Calorimetry (DSC) was used to study the thermal properties of LDPE and HDPE.

2. MATERIALS AND METHODS

2.1. Collection of Polyethylene (PE) bags

The Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) bags were collected from the plastic manufacturers Hubli, India. The bags were washed with 1% SDS solution and 70% ethanol to remove the dust particles adhered to plastic bags and used for further analysis.

2.2. Fourier Transform Infrared Spectroscopic analysis (FTIR)

The LDPE and HDPE films were cut in small pieces (1mm size)) separately and crushed with Potassium bromide (KBr) in a mortar and pestle and added to the pan to make pellets. The pan was pressed by hydraulic pump and the pellets formed were analyzed by putting them in a sample holder of the instrument. The samples were measured by NICOLET 6700 Thermo Scientific FTIR instrument with the wave numbers ranging from $400cm^{-1}$ to $4000cm^{-1}$.

2.3. Differential Scanning Calorimetric analysis (DSC)

Thermal analysis of LDPE and HDPE films was measured using Differential Scanning Calorimter Q-20 TA Instrument. LDPE and HDPE films were weighed accurately, added to DSC pan and analyzed by Cell constant calibration method with the temperature ranging from 0°C to 400°C. The weights of LDPE and HDPE films were 1.6mg and 1.2mg respectively.

2.4. X-Ray Diffraction studies (XRD)

The X-ray diffraction patterns of LDPE and HDPE films were measured by X-ray powder Diffractometer (SmartLAb SE, Rigaku Corporation, Japan) which is operated fully automatically using Cu Kβ radiation. The scattered radiation was registered in the angular interval (2θ) from 5° to 100°. A current of 40mA and a voltage of 40kV were used. All diffraction patterns were examined at room temperature and under constant operating conditions.

3. RESULTS AND DISCUSSION

3.1. Fourier Transform Infrared Spectroscopic analysis

The FTIR spectra of LDPE and HDPE are as shown in the Figure 1 and Figure 2 respectively.

Table 1 and Table 2 indicate the functional groups observed for LDPE and HDPE respectively. The peaks at 2920.60 and 2850.61 for LDPE and 2922.52 & 2863.78 for HDPE indicate the presence of alknaes or alkynes of stretching vibrations. There was another peak at 2722.89 for HPDE which corresponds to aldehydes and was lacking in LDPE. The peaks at 1798.20 & 1740.76 indicated the presence of C=O stretching vibrations of esters and were lacking in HDPE. The presence of 1467.01 and 1436.14 in LDPE and 1460.40 and 1377.65 in HDPE indicated the presence of C-H bending vibrations. There was also an additional peak at 1020.00 in LDPE which indicated the presence of alkyl ethers. HDPE had an additional peak at 1166.51 of tertiary alcohols.

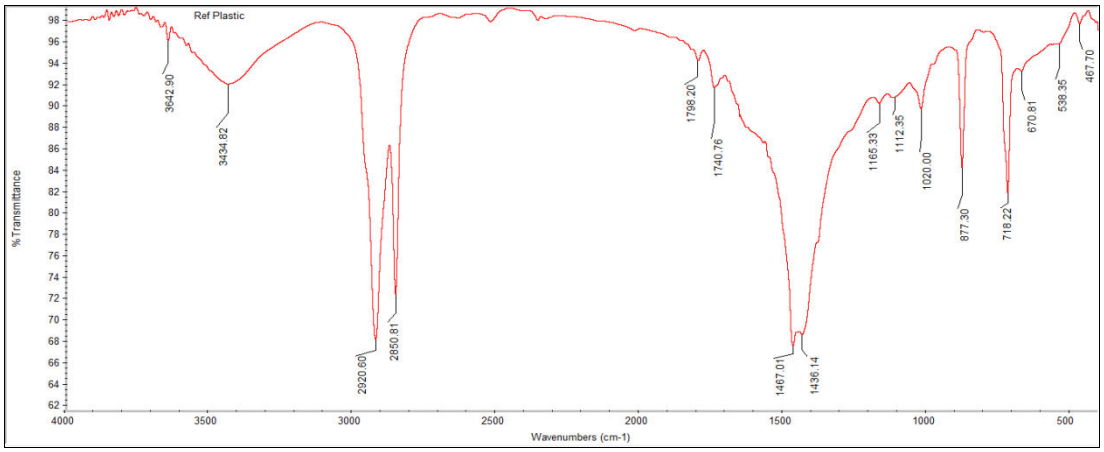

Fig. 1: FTIR Spectrum of LDPE

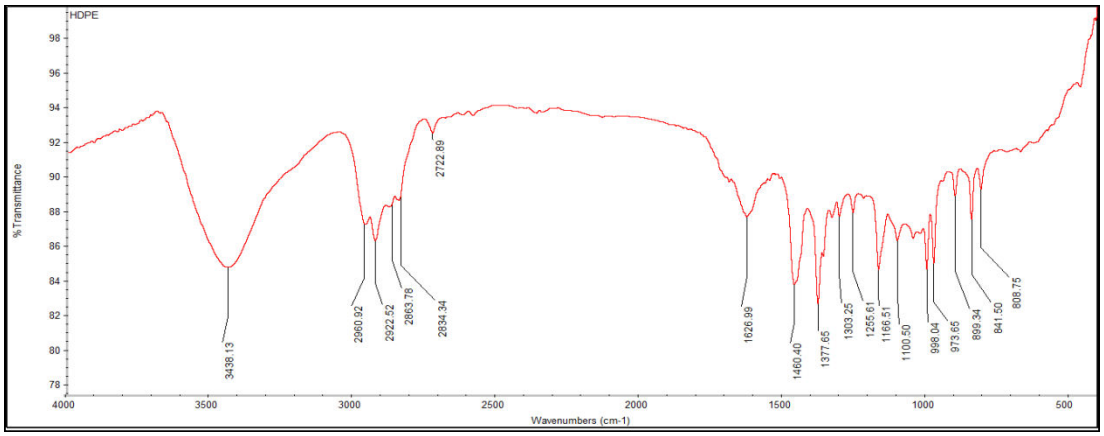

Fig. 2: FTIR Spectrum of HDPE

Table 1. Functional groups and wave numbers (cm^{-1}) of LDPE

Wave number (cm^{-1})	Functional group
3434.62	O-H Stretch Alcohols
2920.60 & 2850.81	C-H Stretch Alkanes/alkynes
1798.20 & 1740.76	C=O Stretch Esters
1467.01	CH_2 symmetrical
1436.14	CH_3 asymmetrical
1020.00	=C-O-C Alkyl Ethers
877.30	C=C-H Bend Alkenes
718.22	C-H Bend Alkanes/Alkenes

Table 2. Functional groups and wave numbers (cm^{-1}) of HDPE

Wave number (cm^{-1})	Functional group
3438.13	O-H Stretch Alcohols
2960.92	C-H Stretch asymmetric
2922.52 & 2863.78	C-H Stretch (as) and (s) respectively
2722.89	H-C=O Stretch Aldehydes
1626.99	C=C Stretch Alkenes
1460.40 & 1377.65	C-H Bend Alkane
1166.51	C-O Stretch 3°alcohols
998.04 & 973.65	C=C-H Bend Alkenes

3.2. Differential Scanning Calorimetric analysis

DSC peaks for LDPE and HDPE are as shown in the figure 3 and figure 4 respectively. The onset melting temperature for LDPE was observed at 109.00°C and peak melt temperature at 121.01°C. Similarly, the onset melting temperature for HDPE was observed at 149.93°C and the melt peak temperature at 162.36°C. There were also Glass transition temperatures at 50.20°C for LDPE and 73.04°C for HDPE. The crystallinity of LDPE and HDPE was calculated by using the formula, $X_c = (\Delta H_f/\Delta H_f^*) \times 100$ where, ΔH_f is change in enthalpy and ΔH_f^* represents enthalpy of fusion for perfect polyethylene sample having 100% crystallinity with value of 293.1 J/g [21].

Table 3. Crystallinity (%) of LDPE and HDPE

	LDPE	HDPE
Melt Onset Temperature ˚C	109.00	149.93
Melt Peak Temperature ˚C	121.01	162.36
Enthalpy (J/g)	182.30	71.49
Crystallinity (%)	62.19	24.39

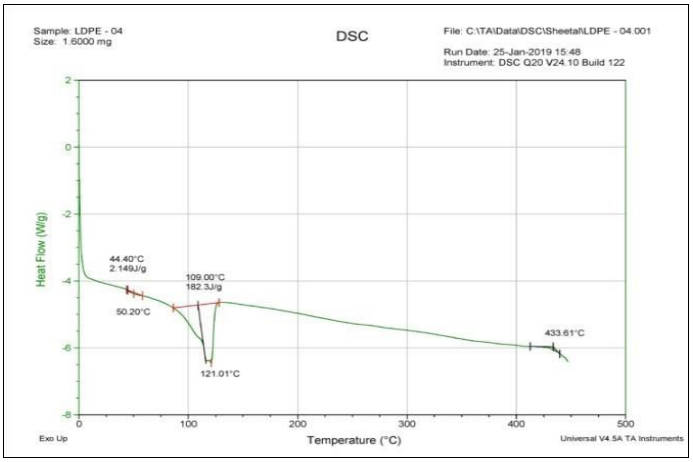

Fig. 3: DSC graph of LDPE

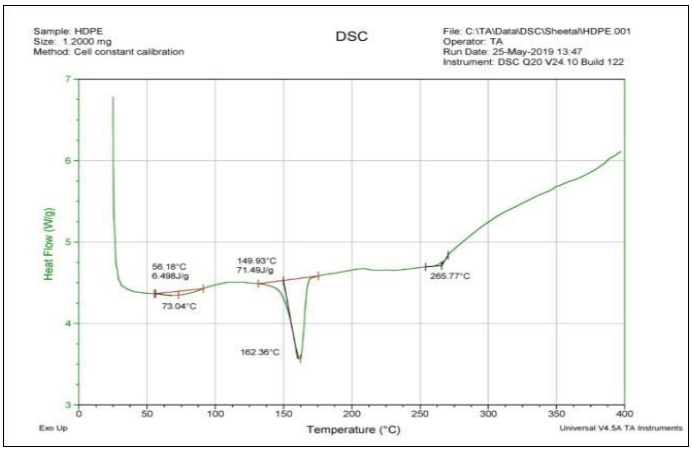

Fig. 4: DSC graph of HDPE

3.3. X-Ray Diffraction analysis

The XRD patterns of LDPE and HDPE are as shown in the figure 5 and 6 respectively. The 2θ angles for LDPE were observed at 21.3˚, 28.43˚ and 36.04˚ where as the 2θ angles for HDPE were observed at 21.6˚, 34.4˚ and 44.1˚. The difference in 2θ angles is mainly due to the change in degree of crystallinity of LDPE and HDPE [22].

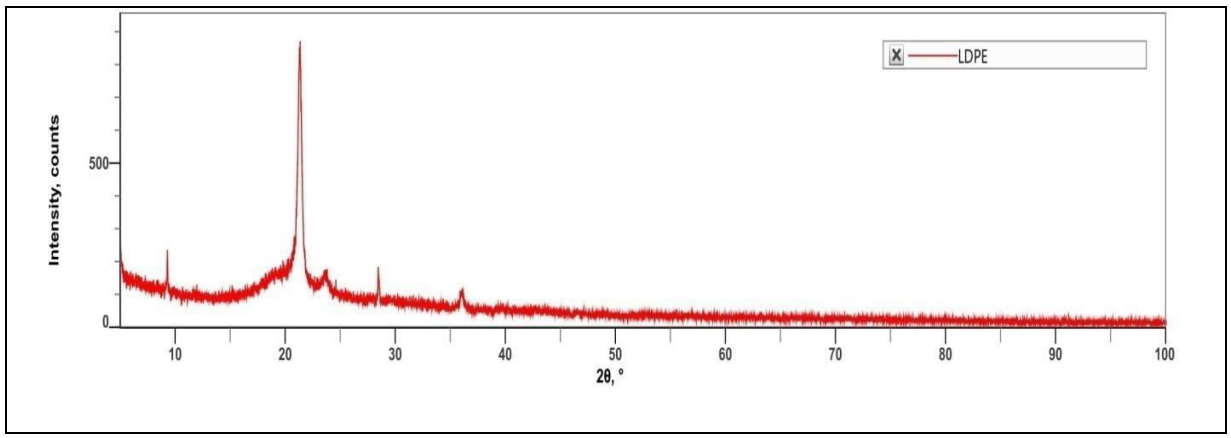

Fig. 5: XRD of LDPE

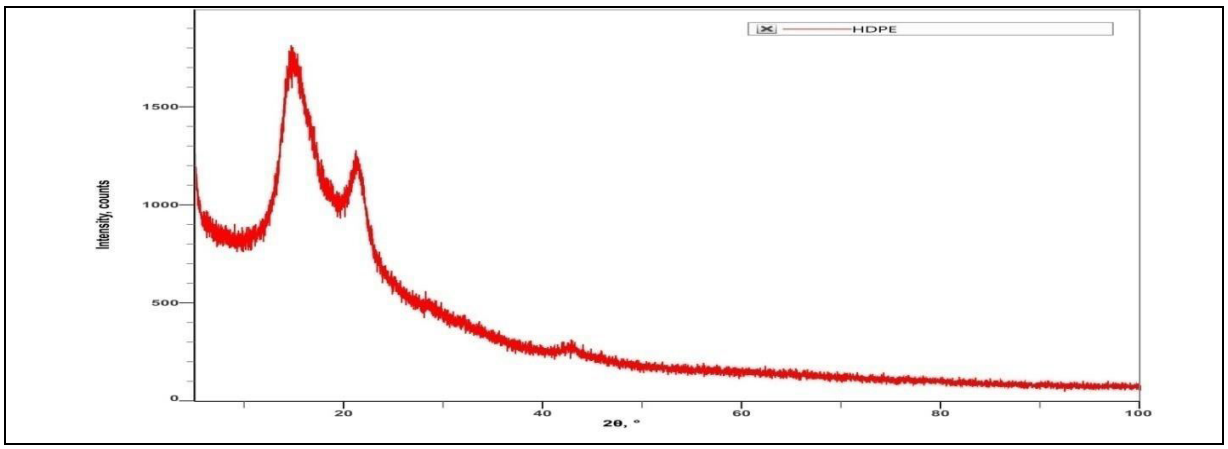

Fig. 6: XRD of HDPE

4. CONCLUSION

Physical and chemical characterization of LDPE and HDPE was carried out to know the basic structural organization, thermal properties, functional groups and crystalline nature. The FTIR and XRD results showed no much difference in chemical and physical characteristics of LDPE and HDPE. The DSC results indicated that the melting temperature and glass transition temperature of HDPE were more than that of LDPE which were due to the HDPE's complex branching and high molecular weight than that of LDPE. The basic characterization of polyethylene films will support us in understanding the mechanism of their synthesis and degradation. This research work aimed to study the basic characteristics of LDPE and HDPE and to inculcate the same in degradation studies. Plastic pollution is the most serious environmental threat at present. The future aspects of this study will be in knowing the efficient methods for degradation by understanding the basic characters of plastics.

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