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Full Length Research Paper

Regenerated Polyethylene from Polyethylene Wastes: A Case Study

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Abstract
In this study a sample of highly photo-degraded polyethylene waste is dissolved in toluene. The polymer solution is then treated with 1% HBr by weight of polyethylene waste in toluene using mechanical stirring device. The mixture is the treated 1% ZnO (by weight of polyethylene waste) suspension in toluene and warmed under reflux condition. After cooling the polymer solution thin films are made by solvent casting. The mechanical properties of the cast films are measured and compared with the standard polyethylene sample. The mechanical properties are 70-80% with respect to the standard. The addition of 0.1% of azo-bis-isobutyronitrile (AIBN), a free radical generator, during the chemical treatment further improves the mechanical properties of polyethylene waste.

Keywords: *Photo-degraded Polyethylene, Polyethylene waste (PEW), Azo-bis-isobutyronitrile (AIBN), Regenerated Polyethylene (RPE), Solvent casting, Mechanical Properties.*

Introduction
Different grades of polyethylene (PE) are used in packaging industry, agricultural wastes and several moulded articles. Now a day PE is also used in production of disposable injection syringe. Huge polyethylene wastes may be a potential cheap source of chemicals and energy. Disposing waste to the land fill is becoming undesirable due to legislature pressure, rising costs, the generation of explosive greenhouse gases (such as methane) and the poor biodegradability of commonly used polyethylene.

The two main alternatives for treating municipal and industrial polymer wastes are : energy recycling where waste are incinerated with some energy recovery and mechanical recycling. Mechanical recycling, i.e., conversion of scrap polymers into new products is a popular recovery path for manufacturers and it is carry out single polymer waste as a market for recycled products can only found if the quality is closed to that of the original one.

Lot of efforts has been given by Scientists and Technologists for the recycling and reuses of polyethylene wastes. Hulme et. al., studied the recycling/reprocessing of poly-urethanes (PU) by hot compression moulding as a cost effective method. Helene et. al., studied the degradation mechanism of di-ethylene glycol (DEG) units in a terephthalate polymer. Sharbel et. al., studied accelerated thermal and photo-ageing of four homo-polymers, low-density polyethylene (LDPE), High density polyethylene (HDPE), Polypropylene (PP) and High impact polystyrene (HIPS) were performed and the impact of subsequent reprocessing. Recycling of polyethylene terephthalate (PET) and recycling of polyethylene terephthalate /polycarbonate blend (PET/PC) is studied by Fraiss et. al.,. All these methods involve conversion of scrap polymers into new products called Mechanical recycling. Processibiliy and mechanical properties of extensively recycled high density polyethylene has been studied by Pavel et. al. Dependence of the photo-degradation rate on the crystalline portion of PE films obtained through *in situ* polymerization in the presence of TiO_2 nanospheres, nano- ribbons and microspheres has been studied by Kácris et. al. Degradation and stabilization of low-density polyethylene films used as greenhouse covering materials has been studied by Dilara et. al.,

Now chemical recycling is getting more importance over the mechanical recycling in the cases mixed polymer wastes which are the nature of municipal and commercial wastes. But the fully acceptable method is not still developed to industrialize the process.

Materials and Methods
Experimental
Sample of polyethylene waste (carry bags) is collected from waste land after whether ageing about 4-6 months washed and dried. This sample is designated as PEW.

10 g of the sample (PEW) is dissolved in 200 ml of toluene. The polymer solution is then treated with HBr (1% of the weight of PEW) in toluene with constant mechanical stirring. After stirring the mixture 30 minutes, it is the treated with ZnO (1% of the PEW by weight) suspension in toluene and warmed at 60°C under reflux condenser. After cooling the polymer solution thin films are made by solvent casting. The sample is designated as RPE.

In another sample, HBr (1% by weight of PEW) is added with constant stirring by mechanical device. After 30 minutes a suspension of a mixture of 1% ZnO + 0.1% AIBN by weight of PEW is added and heated at 60-70°C for 30 minutes with stirring. After cooling the polymer solution thin films are made by solvent casting. This sample is called (RPEA).

Ash content of the samples— PEW, RPE, RPEC is measured in a thermo gravimetric instrument (Du Pont Thermal Analyzer, Model 9000). The mechanical properties, hardness and electrical properties of the cast films are measured as per ASTM standard. The experimental results are compared with the standard polyethylene sample.

The chemical changes during the ageing and subsequent chemical treatment of the waste polyethylene (PEW) and regenerated polyethylene (RPE& RPEA) are studied by IR spectroscopic carried out with thin film on KBr disk by casting in FTIR-spectrometer, Simadzu Corporation.

Results and Discussion

From the TGA study ash contents of polyethylene waste (PEW) and regenerated polyethylene (RPE) and standard polyethylene (PE) are shown in the following Table-1. Ash content of the regenerated polyethylene is slightly increases due to addition of zinc oxide suspension. Zinc oxide acts as acid acceptor.

Table 1. Ash content of Polyethylene waste and Regenerated Polyethylene waste.

Sample	Ash content	Sample	Ash content	Sample	Ash content	Sample	Ash content
LDPE	2.0%	PEW	3.2%	RPE	4.3%	RPEA	4.3%

The density and mechanical properties of regenerated polyethylene and virgin LDPE are shown in the Table-2. From the data it is evident that density of the material almost remains almost same compared to the virgin LDPE.

However, tensile strength of regenerated polyethylene RPE is almost half of the virgin LDPE may be due to chain scission during ageing. Tensile strength of the sample RPE is slightly improved may due to improve cohesion forces. In the sample RPEA tensile strength improves very much and becomes closer to 80% -85% of the virgin LDPE. On addition of AIBN some cross linking has been developed consequently its tensile strength improves to higher extent.

Table 2. Mechanical Properties of the treated Samples and virgin polyethylene (LDPE)

Sample	LDPE (virgin)	PEW	RPE	RPEA
Density (g/cc) ASTM D-792	0.92	0.91	0.93	0.93
Tensile Strength (MPa) (ASTM D-638)	13.0-15.0	7.0-8.0	8.0-9.0	11.0-12.0
Hardness (Shore-D)	D41-D50	D40-D45	D40-D45	D40-D50
Dielectric Constant (at 1 kHz) ASTM D-150	2.25-2.30	1.45-1.53	1.70-1.80	2.10-2.22

Dielectric constant of the samples PEW and RPE and RPEA and virgin LDPE are reported in the Table-2. It is evident that ageing increases the dielectric constant of the sample due to increase in polar group in polyethylene waste by areal oxidation; it improves to some extent in RPE and RPEA, which is due to lowering of polar groups by chemical treatment on the polymer chains.

Shore D hardness of the samples PEW and RPE decreases slightly may be due to the chain scission consequently low molecular weight. However, addition of AIBN to the sample increases to the shore D hardness which is closer to LDPE.

The structural changes during ageing of PE films are studied by infrared spectroscopy (IR). The IR spectrum of LDPE is shown in the Figure-1. From the Figure it is evident that PE absorbs near 2872 cm^{-1}& 2853 cm^{-1} for –(CH_2)- group and terminal -CH_3 absorbs at 2962 cm^{-1} and 2853 cm^{-1} due to asymmetric and symmetric stretching absorptions respectively. Bending modes of vibrations absorbs in the region of 1456-722 cm^{-1}.

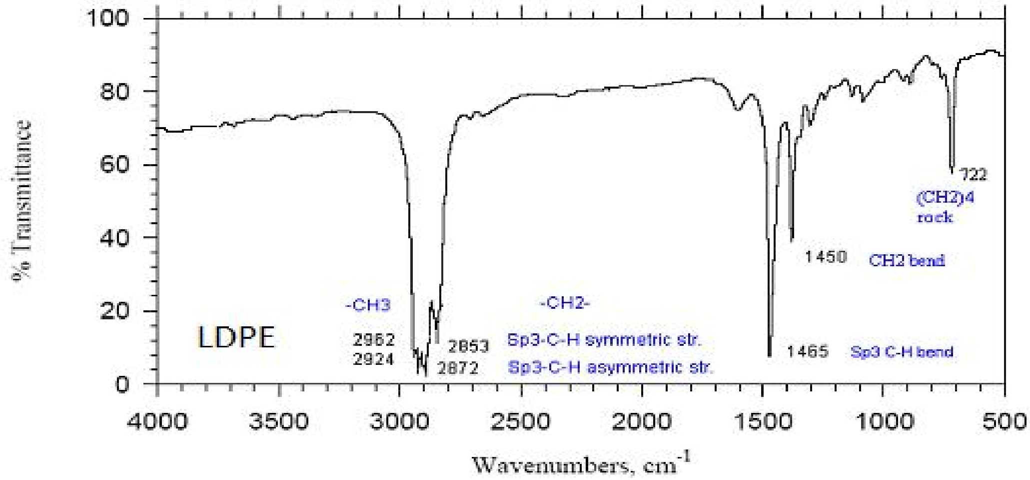

Fig 1. Infrared Spectrum of LDPE.

Figure-2 shows the IR-spectra of Polyethylene waste (PEW). From the Figure-2 it is evident that PEW absorbs strongly in the same region as that of LDPE, in addition to this peaks at 880 cm^{-1} is due to the presence of peroxide linkage C—O—O—C stretching. The other peaks— at 1145 cm^{-1} is due to ether linkage (C—O—C) and 1715 cm^{-1} is due to the presence of keto-group (—CO—). These peaks appeared.

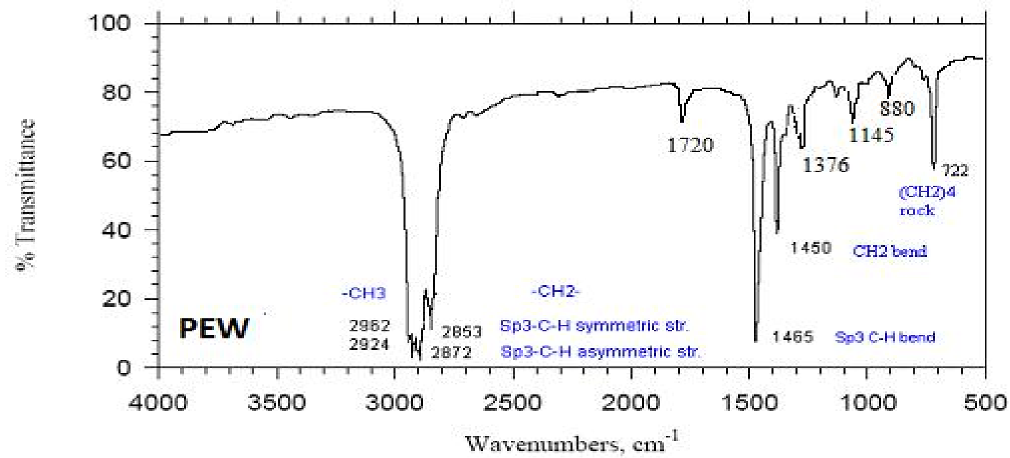

Fig 2. Infrared spectrum of polyethylene waste (PEW).

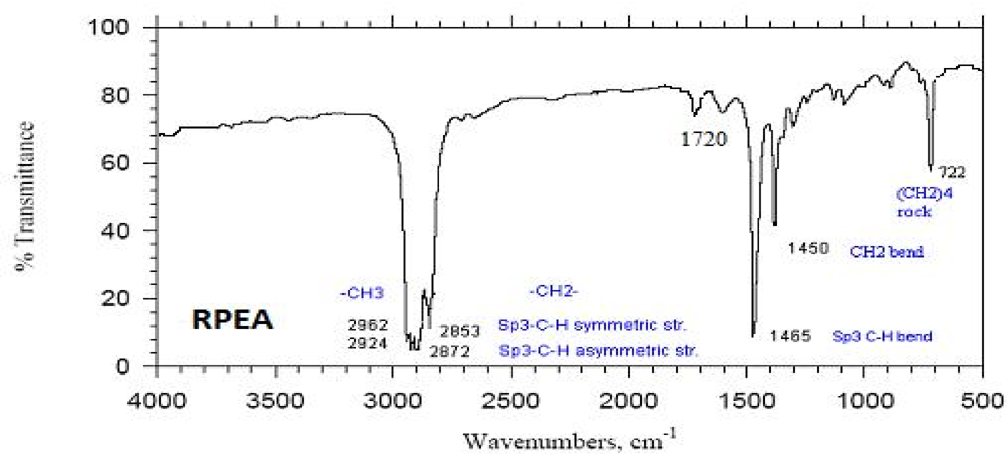

Fig 3. Infrared spectrum of RPEA.

Figure-3 shows the IR-spectra of RPEA. Here the peaks for peroxide and ether linkages disappeared and traces of C—Br bond develops in the region of 1000-1100 cm^{-1}. However, some carbonyl group remains unaffected. The spectrum of RPEA more resembles to the spectra of LDPE. Thus, the probable chemical changes may be shown schematically as follows.

The chemical reactions during ageing and the chemical reactions during regeneration process are shown schematically in the following Figures 4 and 5 respectively.

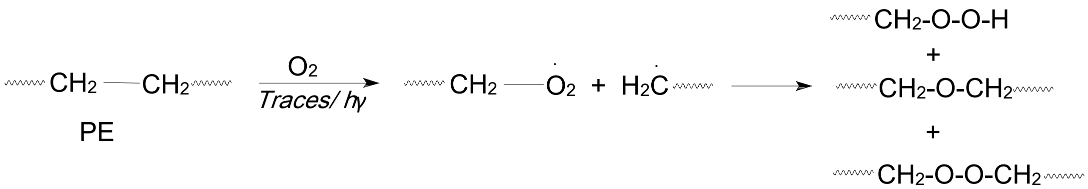

Fig 4. Chemical changes during ageing of LDPE.

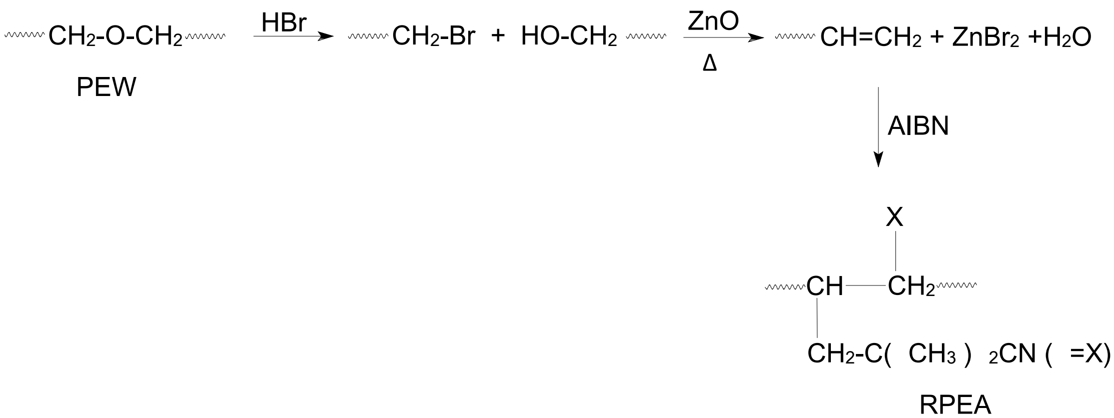

Fig 5. Chemical change during chemical treatment of waste PE.

Conclusion

The mechanical properties of regenerated polyethylene retains near about 80-85% with respect to the standard LDPE sample when treated with HBr followed by ZnO and AIBN. Thus, it can be useful for relatively low performance applications.

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